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The Virtual Mirror

Reflecting on Your Social and Psychological Self to Increase Organizational Creativity

Abstract: *This article offers a novel approach for managers to increase creativity in their teams by measuring individual personality characteristics crucial for creative people. We assess inter-personal interaction with sensor-equipped badges worn on the body. In a research project with 22 study subjects, who wore the badges during work for one month, we were able to predict 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). As opposed to conventional personality tests, where people have to fill out lengthy questionnaires and surveys, our method offers an automated, and potentially more reliable way to assess these personality characteristics. Once these characteristics are considered, teams can be reshuffled and their membership changed for higher creativity.*

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Introduction

We are in the age of creativity – creative individuals, teams, and organizations are at a premium. There is much research about what makes organizations more creative (Woodmann et al. 1993, Bharadwaj and Menon 2000, Guimera et Al. 2005, Amabile 1988, Leenders et al. 2007). Creative organizations are better than non-creative organizations in creating valuable new products, services, or processes. Creativity for organizations and individuals – doing things in a new way or for the first time – also provides a key to understanding phenomena of change and of organizational effectiveness and performance. To understand what makes organizations more creative, we need to understand the creative process, the creative product, the creative person, the creative situation, and the interaction among them (Woodman et al. 1993). For the creative person, both cognitive and non-cognitive aspects of the mind influence creative behavior. This behavior is based on complex interactions among the individuals involved, which are repeated on each level of social organization. In this sense, organizational creativity is a function of the creative outputs of its component individuals, groups and organizations (Bharadwaj and Menon 2000).

There is a tightly woven interplay between individual creativity, group creativity, and organizational creativity. Past work on idea creation and organizational success has focused on user innovation and the quality of the idea generated (Goldenberg et al. 1999; 2001; Goldenberg and Mazursky 2002). Most of the early research in creativity has been characterized by the study of famously creative people such as Leonardo da Vinci, Isaac Newton and many others (Simonton 1986, Csíkszentmihályi 1996). Researchers subsequently identified personality traits that are reasonably stable among different creative people such as “high valuation of esthetic qualities in experience, broad interests, attraction to complexity, high energy, independence of

judgment, autonomy, intuition, self-confidence, ability to resolve antinomies or to accommodate apparently opposite or conflicting traits in one's self-concept, and a firm sense of self as creative" (Barron and Harrington 1981; Csíkszentmihályi 1996). In other research, characteristics consistently identified by R&D scientists as being important for creativity were persistence, curiosity, energy, and intellectual honesty (Amabile 1981). Researchers also identified cognitive abilities that correlated with idea creation such as fluency of expression, figural fluency, ideational fluency, speech fluency, word fluency, practical ideational fluency, and originality (Carrol 1985). Intrinsic motivation was identified as a further key for individual creativity (Amabile 1990).

On the group level, researchers found that factors most supportive of creative groups were democratic leadership, organic and self-organizing group structure, and group members drawn from diverse backgrounds and domains (King and Anderson 1990). Obviously group creativity is not just the cumulative aggregate of the individual group members' creativity. Rather, factors such as group composition (e.g., diversity), group characteristics, (e.g., cohesiveness, group size), and group processes (problem solving strategies and social information processes) fundamentally influence the group's creativity (Woodman et al. 1993, Guimera et al. 2005).

On the organizational level research about creativity is frequently confounded with the capability of an organization to innovate (Bharadwaj and Menon, 2000). Research by Paolillo and Brown (1978) found positive correlations for organizational innovation with autonomy, information flow, creativity, rewards, and training, by asking employees to rate the innovative capabilities of their R&D labs. They also found that the numbers of formal supervisory levels were negatively correlated with innovation. The pioneering work of Allen et al. (1980) identified

the crucial influence of inter- and intra-organizational communication on organizational creativity. Lenders et al. (2007) found an inverse u-shaped relationship between frequency of communication of team members and creative performance.

Recently, the relationship between social network structure and organizational and individual performance as a proxy for organizational creativity has emerged as an important focus of this research (Katz et al. 2004). The increasing availability of electronic communication archives such as e-mail, blogs, and online forums fostered works that examined the relationship between social network structure and organizational creativity (Barabasi 2005).

Consequently, much recent work has examined the relationship between quantitative measures and group performance. The two most common measures employed in this kind of analysis are *centrality* (e.g. Baldwin et al. 1997; Balkundi and Harrison 2006; Brass 1981; Tsai 2001; Wasserman and Faust 2005), and *density* (e.g. Balkundi and Harrison 2006; 2005; Reagans and Zuckerman 2001; Reagans et al. 2004). 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 and teams that are central in the inter-group network perform better than other teams. At the same time some authors obtained opposite results. For example, Boyd and 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.

Hypotheses

In our work we look at contribution index and fluctuation in centrality of individuals in

social networks, measured at a microscopic level as a predictor of individual and organizational creativity. By applying social network analysis to ego and social group networks and by using social badges that automatically collect data on interactions, this study contributes novel insights on individual, group, and organizational creativity.

Our main hypothesis is that individual social networking structure and fluctuations thereof are predictors of personality characteristics supportive for individual and group creativity. Using social badges – body-worn sensors described in detail in the next section – permits us to measure these social network metrics on a much more granular and individual level than before. In particular, our hypotheses speculate about extroversion, neuroticism, openness, and agreeability of individuals. The first hypothesis reasons that extroverted people might contribute more to discussions, i.e. they have a lot of interactions, and are active initiators of discussions where they are much more of a sender than a receiver of creative ideas, hence:

H1: *Extroversion is positively correlated to direct interpersonal communication, measured through contribution index (Gloor et al. 2003) when facing the communication partner.*

The second hypothesis makes use of the fact that neurotic people tend to not look their discussion partners into the face (Costa and McCrae 1983), but rather look sideways when talking to somebody else, hence:

H2: *Neuroticism is negatively correlated to direct interpersonal communication, measured through the contribution index when facing the communication partner.*

The third hypothesis builds the motivation for hypotheses four and five, looking at networking positions of extrovert people. It posits that extroverts are feeling more productive in activities at the center of social networks, while introverts are more productive doing work in peripheral positions, therefore:

H3: *Social network position in combination with subjective job satisfaction predicts the level of extroversion.*

In prior work, based on e-mail analysis (Kidane and Gloor 2007), we found that oscillating social network structures of teams predicted highly creative teams, while steady communication structures predicted high productivity. Transferring these insights to individual actors, we

speculate that individuals who frequently switch between peripheral and central positions are more open to new things, while actors in steady network positions are more agreeable, thus:

H4: *Fluctuation in actor betweenness centrality and individual openness are positively correlated*.

And,

H5: *Fluctuation in actor betweenness centrality and individual agreeability are negatively correlated*.

Methodology

"Mirror mirror on the wall, who is the most hip of them all?"

In this article we introduce a modern-day version of the magical mirror of the stepmother of Snow White. Using a body-worn sensor network we measure physical interaction of co-located people. Our "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 better understand who they are. People's repositioning, based on their social and psychological strengths, while respecting individual privacy, permits an organization to increase its creativity by making much better use of its talent pool.

We analyzed social interaction among 22 bank employees who work as a team in a bank in Germany. For the period of one month they were wearing social badges developed at the MIT Media Laboratory (Pentland et al. 2005; Pentland 2005), which allowed us to measure their relative location and behavioral characteristics, such as gestures and tone of voice. 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 2004) or, as in this case, social badge logs. Using Condor, we conducted a longitudinal microscopic dynamic social network analysis by collecting social badge interaction information at the individual actor level over a period of one month. Besides the microscopic sensor data we also gathered bank employees' e-mails directly from the bank's mail server.

In our analysis we approximate creativity with productivity in creative tasks. In previous studies we have measured creativity as new services development in a strategy consulting firm (Gloor 2006) and new features implemented in open source software (Kidane and Gloor 2007). Similar to Guimera et al. (2005), who analyzed success and social network structure in Broadway's musical industry, we compare success of a creative task with social networking structure. However, instead of comparing success at the macro level we do it at the interpersonal micro level. In this project we compared longitudinal microscopic networking structure of creative group tasks, for example online marketing campaigns, with outcome such as personal productivity and number of new customers recruited per marketing campaign.

The accumulated social network data were complemented by self-administered surveys of study subjects. They reported their daily assessment of their productivity and satisfaction with their own work by answering the following four questions:

1. How productive have you been today? (extremely, very, average, little, not at all).

2. How satisfied have you been with today's work? (extremely, very, average, little, not at all).

3. How stressed did you feel today? (extremely, very, average, little, not at all).

4. How was the quality of the interaction in your team today? (extremely good, good, ok, not so good, bad).

In addition, we assessed the subjects' personality characteristics. To obtain an objective measure of personality traits we used the Revised NEO Personality Inventory, or NEO PI-R. 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 and 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 criterion of *conscientiousness* includes assessment of 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 on 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, are more composed, at ease, secure, and even-tempered.

As has been mentioned in the introduction, researchers have associated characteristics of individuals such as high agreeableness, high extroversion, high openness, and low neuroticism with people who are particularly creative (Barron and Harrington 1981; Amabile 1981; Carrol 1985). The same individual characteristics are also supportive of creative groups (Woodman et al. 1993; Guimera et Al. 2005).

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

The NEO-FFI test has been calibrated with a mixed gender sample of 2,112 people in Germany. It has been found that measurements obtained by the NEO-FFI are stable over time, illustrating that these characteristics are part of personality. Results are dependent on gender and age. Figure 1 displays a radar chart that compares the aggregated results of the NEO-FFI completed by our study subjects with the representative reference values of the 2,112 people sample. The grey line depicts the reference values and the black line presents the combined results of our study subjects (N=18). Four team members did not complete the NEO-FFI survey.

[INSERT FIGURE 1 ABOUT HERE]

Conscientiousness and agreeability of our sample of 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 as measured by the German reference sample, while their extraversion level corresponded to the reference values. In the next section we look at how these dimensions can be predicted based on how well balanced and fluctuating face-to-face interactions and e-mail interactions among the 22 employees are.

Results

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 less than one 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 a colleague in an office generally will not cause an infrared reading since computer monitors block the direct eye contact. Bluetooth readings revealed physical proximity. Exclusive Bluetooth measurements might have captured imaginary communication between two people when in fact a cubicle wall separated them. We addressed this problem by combining readings from a Bluetooth sensor, which captured physical distance, and the IR sensor, which only captured visible interaction between two people at a distance of at most one to two meters

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). The index is calculated for each actor by deducting the number of messages received from the number of messages sent and dividing the result by the total number of messages sent and received. – In this case it is defined as total number of infrared readings picked up by an actor, that is CI = (IR out - IR in)/(IR out + IR in). 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 squarely into the face of another actor. 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.

[INSERT FIGURE 2 ABOUT HERE]

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. At the same time, 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.

[INSERT TABLE 1 ABOUT HERE]

As table 1 illustrates, there is *indeed positive correlation between the contribution index and extroversion* (hypothesis H1), as well as strong *negative correlation between neuroticism and contribution index* (hypothesis H2). Controlling for gender and age did not increase R^2(Adj). Note that while the 2112 people sample NEO-FFI benchmark (Borkenau and Ostendorf 1993) shows negative correlation (-0.33) between NEO-FFI assessed neuroticism and extroversion, we found even stronger negative correlation (-0.39), although it was not significant (p=0.13). As expected, we did not get further correlations between the other three NEO-FFI dimensions openness, agreeability, and conscientiousness and the contribution index.

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

Based on the NEO-FFI definition of extroverts and introverts in the previous section, we introduce a new extroversion coefficient E_S, using the self-reported[1] 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

[1] While our proposed method to measure creativity metrics extroversion, neuroticism, openness and agreeability does not use questionnaires, we used the questionnaires introduced in previous "methods" section to verify our results.

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

$$E_S = \textit{Pearson coefficient (daily self productivity\&satisfaction ratings/betweenness)}$$

We found confirmation of hypothesis H3: E_S is indeed strongly correlated with the extroversion dimension of NEO-FFI (Corr=0.64, R^2(Adj) = 0.36, p=0.02), i.e. *the social network position in combination with the subjective satisfaction rating predicts the level of extroversion*. Not too surprisingly, E_S is also somewhat correlated with the contribution index of an actor, although the correlation is weaker (Corr=0.44, R^2(Adj)=0.12, p=0.13).

Measuring Openness and Agreeability

In prior work (Kidane and Gloor 2006) we 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. 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 "creative people" 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 NEO-FFI properties.

[INSERT FIGURE 3 ABOUT HERE]

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 (corr=0.59, R^2(Adj)=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

hypothesis H4 holds true: *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 (corr=-0.54, R^2(Adj)=0.24, p=0.03). What this means is that hypothesis H5 holds true also: *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 NEO-FFI between agreeability and openness is given as almost non-existent (0.07) (Borkenau and Ostendorf 1993), we obtained for our sample a stronger negative correlation of –0.26, which was not significant however (p=0.33).

Discussion and Conclusions

Comparing Social Network Position and Extroversion

In this section we rely on a visual analysis of the social networks using the social network analysis software tool Condor. 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 NEO-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 (large white and small black nodes) are more central than strong extroverts, which are very peripheral (large black nodes). Small grey 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.

[INSERT FIGURE 4 ABOUT HERE]

[INSERT FIGURE 5 ABOUT HERE]

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 in figure 4, in that introverts (large white nodes) and neutrals (small black nodes) occupy more central network positions than extroverts (large black nodes).

Figure 6 illustrates individual communication collected by infrared sensors among actors as an adjacency matrix sorted by three levels of extroversion. All actors are listed on both the X and the Y axis. If actor A interacts with actor B, there is a dark square in the intersection of row A and column B. The darker is the square (A,B) the more intensive is the interaction between A and B. Note that while the adjacency matrix is mostly symmetric, this is not always the case. If A looks at B while talking to her, while B never looks at A, square (A,B) will be solid blue, while square (B,A) will be empty. Actors have been sorted by extroversion as measured by the NEO-FFI test, with actors with extroversion 1 being the least, and extroversion 3 being the most extrovert. There is a fourth category (unknown) consisting of the actors who did not take the

NEO-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.

[INSERT FIGURE 6 ABOUT HERE]

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 (extroversion=1) and moderate extroverts (extroversion=2) on the other hand are surprisingly popular, both in being spoken to, and in communicating with others.

Comparing Social Network Position and Openness

Figure 7 displays the adjacency matrix of the 16 actors who completed this part of the NEO-FFI test, sorted by their NEO-FFI openness, with the openness scale ranging from one to three, three being the most open.

[INSERT FIGURE 7 ABOUT HERE]

As the adjacency matrix of the combined e-mail and infrared social network in figure 7 illustrates, the more open-minded is an actor 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 two rectangles at right in figure 7). Less open minded people, on the other hand, communicate very little, or even not at all, among themselves.

Comparing Face-to-Face and e-Mail Interactions

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.

[INSERT FIGURE 8 ABOUT HERE]

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 seven to nine, 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. At the same time 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. R^2(Adj)= 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.

Potential Deficiencies of This Study

One open question is how the knowledge of being measured might change the results. Does an employee who knows that she is being measured for agreeability behave more agreeable? We think this is not the case because of two reasons. First, the employees did not know that they were being measured for these characteristics; they only knew that the experimenters would construct their social network based on personal interaction. Secondly, and more importantly, we measured their communication patterns for the duration of four weeks. While it might be possible to play a role for a short period of time, researchers agree that it is impossible to play a role for extended periods of time (Costa and McCrae1992). Another concern we had was the accuracy of the sensors, in particular if they might capture imaginary communication between two people when in fact a cubicle wall separated them. We addressed this problem by combining readings from a Bluetooth sensor, which captured physical distance, and an IR sensor, which only captured visible interaction between two people at a distance of at most 1 to 2 meters. In fact, experiments showed that the IR sensor was sufficient to capture the physical interaction. Yet, two people might be talking with each other over a visual obstacle such as a computer monitor in the same office, this way prohibiting the two IR sensors from measuring physical interaction. Because our sensors also have microphones built in we were able to check for this condition by capturing the respondents' voice while they were in proximity to each other and we found that in practice communication blockage happened very rarely, so we could safely excluded this problem.

Applications

Microscopic social network analysis can be used to complement proven psychological tests such as the NEO-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 wearing social badges, a user might be able to get some answers to questions 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?” While it might be possible to obtain first conclusions about the personality of a person this is most likely too simplistic. Further research with larger samples and in other environments is needed to obtain more solid insights into the relationship between physical interaction behavior and personality characteristics. However our first results are quite encouraging. We therefore describe some scenarios about what the implications of these insights for managers might be. We portray three straightforward applications how our microscopic social network approach can be used to increase organizational creativity on the individual and group level.

First it might help individual employees to become more efficient and productive members of creative teams. If they get immediate feedback, mirroring their communication behavior back to them through readings of the social sensors, it might assist them to choose roles and activities well-suited to their personality traits.

Second, managers will be able to compose teams for creative tasks based on a better knowledge of individual characteristics. They will be able to make sure that teams have members who are high on agreeability or others who are open to new ideas, while making sure that they are low on neuroticism.

In meeting settings, interaction patterns could be immediately mirrored back to meeting participants. By immediately mirroring their communication behavior to meeting participants, meetings can be made more productive, efficient, and creative. We have anecdotal evidence of this effect, in that in meetings where everybody was wearing social badges, it became immediately apparent to speakers if what they were saying was of interest to the other meeting participants.

A final application area might be predicting political leanings. In an exciting stream of research by John Joost and other (Giles 2008; Thorisdottir et al. 2007), NEO-FFI measurements and political opinion have been correlated. One of their results was that Democrats have substantially higher openness and extroversion and lower contentiousness than Republicans. Imagine equipping voters with social badges for a short period of time to understand the political landscape of a country!

Future Research

While these scenarios are still lying in the future and will need much further research, we have similar experiments currently underway with teams in two high tech companies, and with nurses in a hospital, aiming to identify highly creative and high-performing interaction patterns of knowledge workers by measuring social interaction at the microscopic level. As already mentioned in the introduction, identification and support of open, agreeable, non-neurotic and extrovert members of teams, are key building blocks of supporting organizational creativity. 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 NEO-FFI test, is quite small. We

therefore would like 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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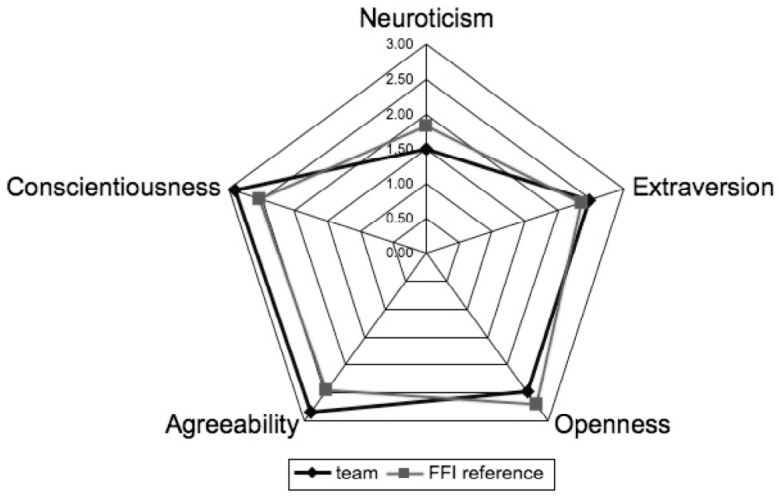

Figure 1. Experimental and reference NEO-FFI values (N=18)

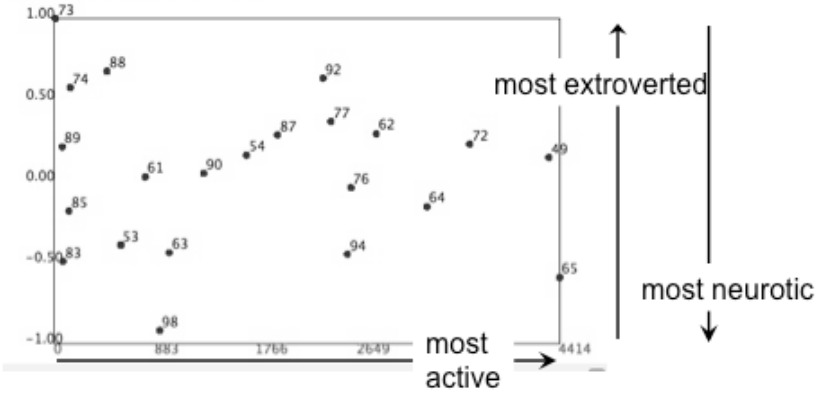

Figure 2. Contribution index (y-axis) predicts extroversion and neuroticism, numbers are coded ID's of actors (N= 22)

Table 1

Correlation of 5 FFI values with contribution index (CI) (N= 16)

	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

+p<0.1; *p<0.05; ** p<0.01

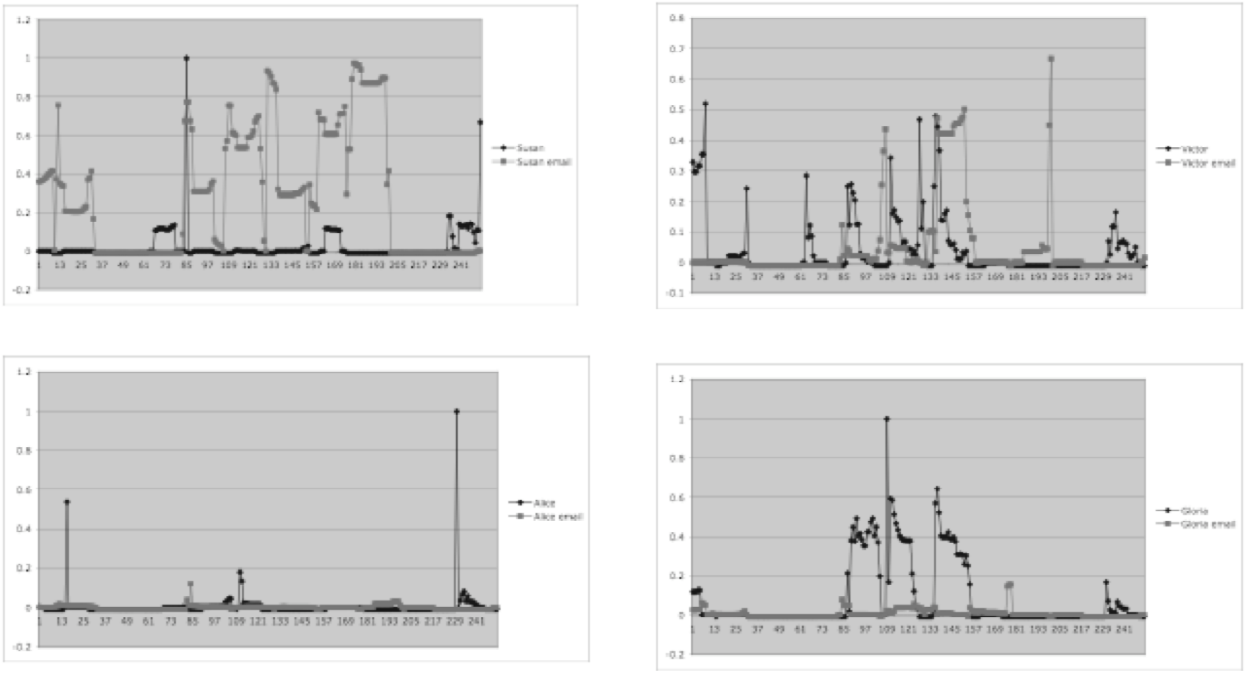

Figure 3. E-mail (grey) and IR/face-to-face (black) temporal betweenness values of different actors (N= 4)

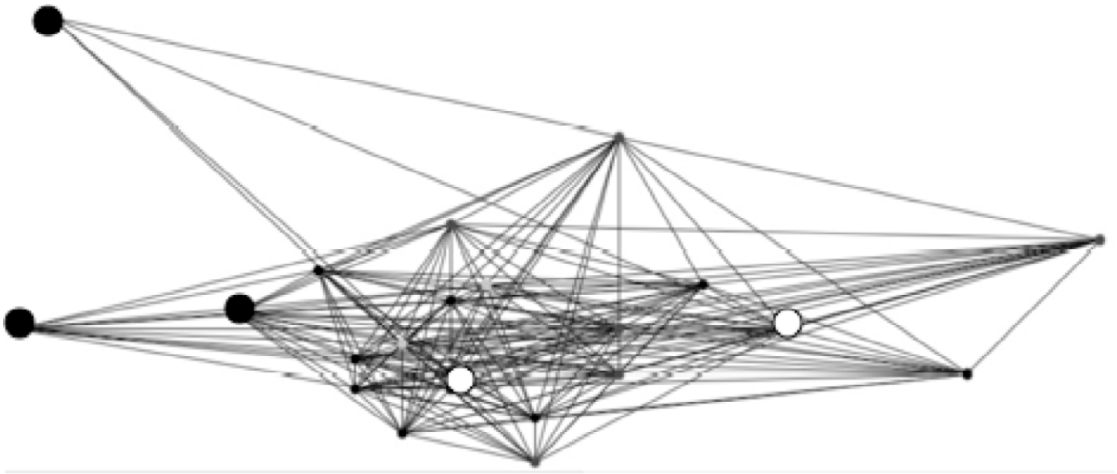

Figure 4. Social infrared network of one month, small nodes are “neutral”, large black nodes are “extroverts”, large white are strong “introverts” by FFI-Extroversion (N= 22)

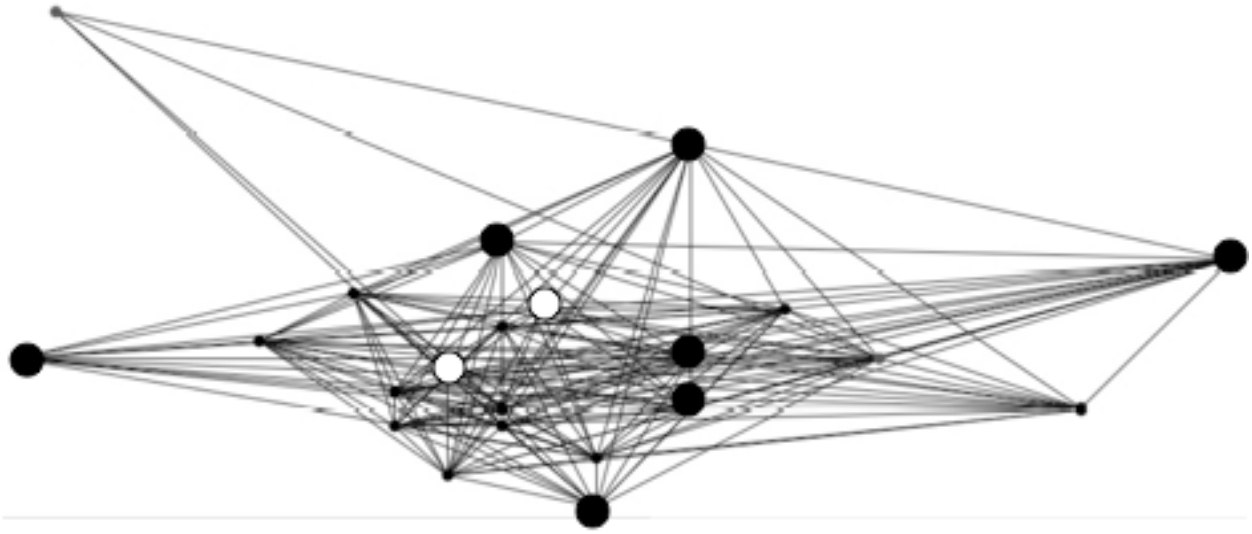

Figure 5. Social IR network of one month, small nodes are “neutral”, large black nodes are “extroverts”, large white nodes are strong “introverts” by E_S (N=22)

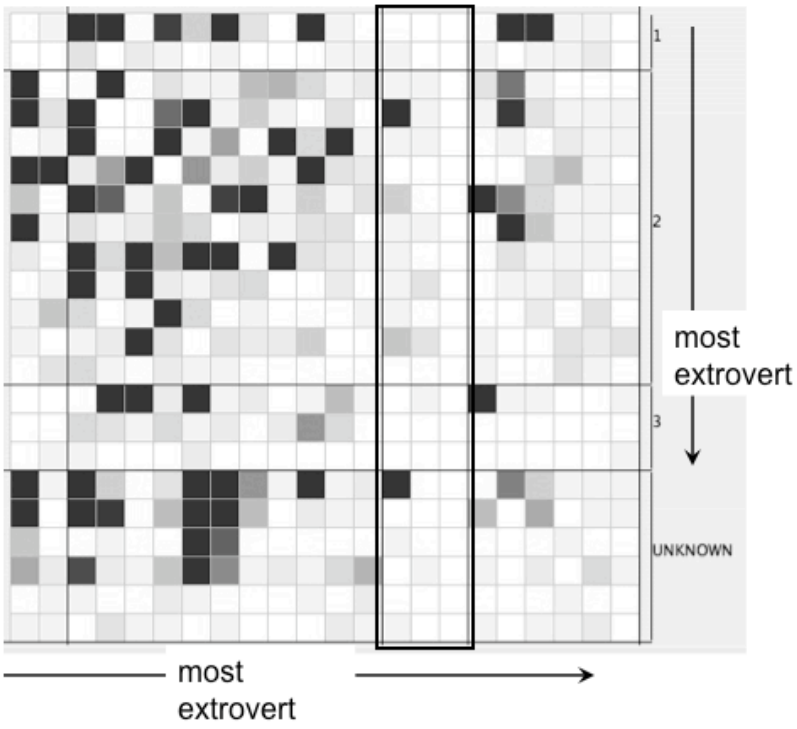

Figure 6. Adjacency matrix of actors, sorted by extroversion, coded by 1=least extrovert, 2=moderately extrovert, 3=highly extrovert (N=22)

(Are you sure about the N? It seems that you have more than 22cases in the figure: no it is 22 by 22, i.e. all possible relationships among 22 actors).

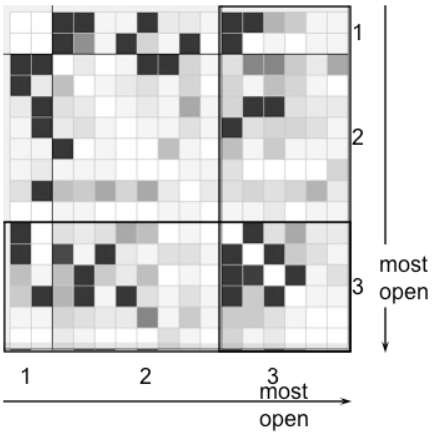

Figure 7. Adjacency matrix (e-mail & infrared) of actors, sorted by openness coded by 1=least open, 2=moderately open, 3=very open (N=16)

(Are you sure about the N? It seems that you have more than 16 cases in the figure – yes, the others did not answer)

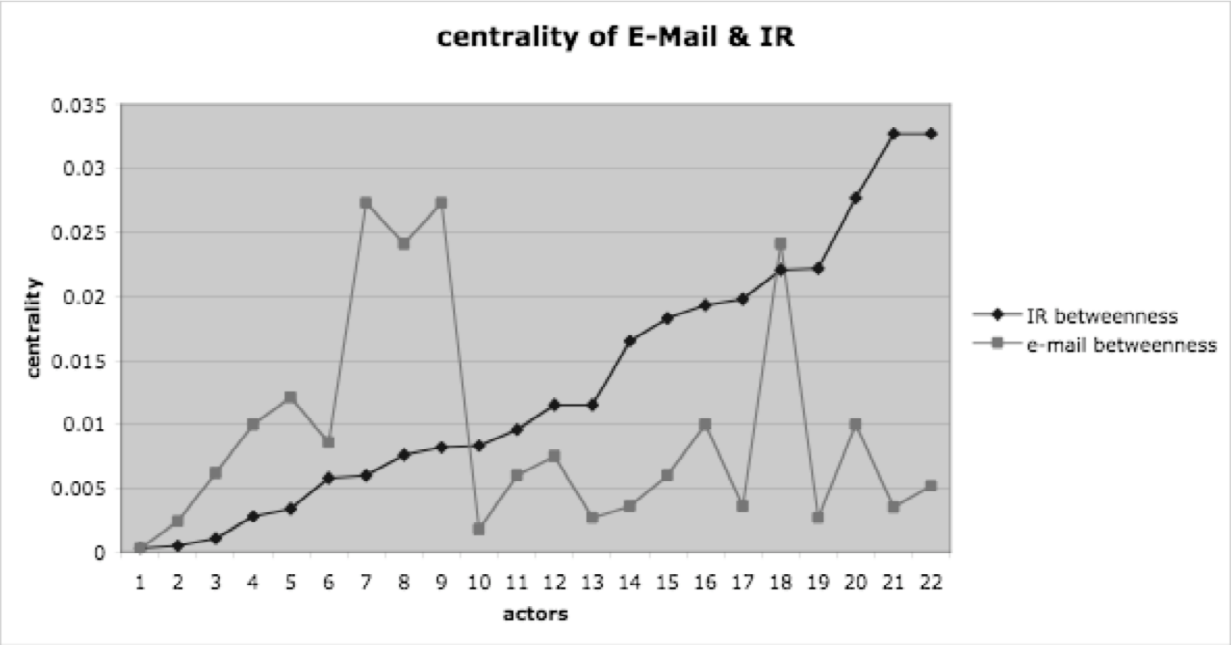

Figure 8. Actor betweenness centralities of IR (black) and e-mail (grey) networks are different (N= 22)