

Sensing Informal Networks in Organizations

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Abstract

We present an examination of informal network structure within the sales division of a global manufacturing organization. Sociometric Badges were used to collect data on face-to-face interactions over a total of 8 weeks, the latter half of which was spent in a redesigned workspace. These data were supplemented by employees' e-mail and instant messaging log activity. The allocation of an individual's communication among colleagues reflected the company's structure as a post-bureaucratic organization. The observed interteam communication patterns differed from those expected to arise based on the various functions performed by each team throughout the sales cycle, suggesting that the communication needs of each team were not wholly provided for by the available media. A subset of workers who were encouraged to utilize flexible seating arrangements in a remodeled space had a higher proportion of face-to-face interactions with colleagues outside of their team, while employees seated far away from each other were less likely to exchange e-mail. This research has implications for companies hoping to understand the structure of informal networks within their organization as well as those considering workplace redesign as a method of stimulating communication within these networks.

Keywords

organizational communication, face-to-face communication, workplace redesign, Sociometric Badges

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Introduction

Although the relationship between informal networks and employee productivity was initially revealed by the Hawthorne studies (Roethlisberger & Dickson, 1964) in the early 20th century, researchers still seek to understand how informal networks facilitate task completion. Organizations moving toward a knowledge-based model are motivated to understand how invisible assets within the workplace contribute to output. Data on employee communication can reveal how informal networks facilitate the exchange of knowledge held within the firm. This exchange is critical not only to the operations of organizations whose products consist solely of knowledge but also to manufacturing organizations in which processes, an idea that encompasses the activities that occur within an organization, ultimately leads to a finished product (Zack, 2002).

Employees increasingly function as part of multiple teams with different goals, forming interdepartmental relationships with colleagues who may not be geographically colocated. Internet-based communication technologies such as e-mail, instant messaging (IM), and video conferencing enable employees to collaborate remotely with coworkers and are partly responsible for accelerating the movement toward networked work in organizations (Rainie & Wellman, 2012). Thus, understanding the structure of informal networks requires the synthesis of data from a variety of media (Dennis, Fuller, & Valacich, 2008). Previous studies have used a combination of survey data and electronic metadata to examine the social context of media use by individuals working within an organization (Quan-Haase, Cothrel, & Wellman, 2005) and establish relationships between technology use and productivity (Aral, Brynjolfsson, & Van Alstyne, 2007). Relatively recent advancements in social sensing technology have provided new opportunities for the integration of automatically generated information on face-to-face (F2F) interaction into research on employee communication. Notably, it has been found that the omission of such data from consideration leads to an incomplete reconstruction of employees' informal networks (Olguín, 2007).

In this article, we examine the patterns of informal relations in a U.S. manufacturing company. We combine digital and sensor data to examine mediated and F2F communication, thereby providing a complete picture of informal communication in the organization. We will argue that informal communication is an important component in an organization's culture (cultural dynamic) and functionality. The article contributes to networked work by accounting for the informal layer of communication as a crucial component when investigating networked work.

Communication Distribution Among Colleagues

The practices within the organization we examined are aligned with the characteristic of post-bureaucratic organizations as defined by Heckscher and Donnellon (1994). Although work within the division we studied is specialized, it is not governed by rigid processes. Each employee within the organization is considered an expert capable of making the decisions necessary to meet customer demands while functioning as part of a larger team. Supervisors expect employees to work across teams to compile the information necessary

for providing a high-quality deliverable. The company provides a standardized scale for measuring aptitude in these areas, and both managers and employees are encouraged to supplement these measures with a verbal description of how their actions exemplify the company's values. Documents detailing this information are available to employees and have been translated into several languages to increase accessibility.

As stated in Powell (1990), communication within post-bureaucratic organizations is characterized by an increased emphasis on lateral forms of communication. However, a recent study by Oberg and Walgenbach (2008) demonstrated that even in an organization with post-bureaucratic values, communication among employees can reflect patterns typically present in bureaucratic organizations. The organization we studied has only two reporting layers to manage the planning, execution, quality, and development of products. We seek to determine how well this flat structure is reflected in the communication we observed. This leads us to the following:

Hypothesis 1: Given the presence of post-bureaucratic values within the organization and the lack of a rigid hierarchical reporting structure, we expect that a majority of communications pursued by employees will be directed toward teammates and nonmanagerial colleagues.

Within this organization, as in others, the sales process follows a logical order and is mostly governed by the demands of the client. Employees are encouraged to engage in global teamwork and pursue both intrateam and interteam communication to fulfill their responsibilities. However, interteam communication is more essential for teams participating in the consecutive stages of the sales process. For example, members of the Sales Support team advise colleagues in the field who are meeting with potential clients. Requests obtained during this stage are forwarded to members of the Proposals team, who consult with one another in order to converge on an idea that best meets the needs of the client. After completing a content-rich deliverable, they must work with members of the Mock-ups team to clarify their intentions and preserve important elements of the design. Finally, Mock-ups hands off the conceptual design to the Applications team, who integrate the previous teams' efforts into a final offering. Teams with roles that facilitate the completion of projects at a more administrative level—such as Pricing, Contracts, and Finance—contribute throughout the sales process. The relationships among and between teams in the sales process (Figure 1) leads us to the following:

Hypothesis 2: Although all teams will engage in intrateam communication, we expect interteam communication among individuals to be focused toward colleagues on teams that are adjacent to each other in the sales cycle.

Media Preference Based on Communication Needs

A collection of theories has arisen out of the desire for a greater understanding of how media facilitate effective communication within organizations (Fulk & Boyd, 1991;

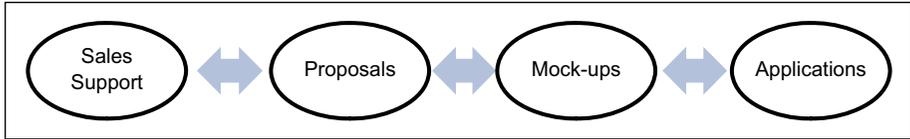


Figure 1. The flowchart of teams who complete related tasks throughout the sales cycle.
Note. We expect interteam communication from one team to be directed toward team immediately following it in this process.

Putnam, Phillips, & Chapman, 1999). Media Richness Theory (MRT), one of the most commonly applied frameworks within the organizational context, ranks a variety of media by their ability to process rich information. The richness of information depends on its ability to change understanding within a certain period of time. To this end, F2F communication is ranked highest, while numeric documents are ranked lowest. The alignment between the richness of the information being communicated and the chosen medium results in a reduction of uncertainty or ambiguity with regard to information held within the organization (Daft & Lengel, 1986).

An alternative to the MRT was proposed by Dennis et al. (2008), called Media Synchronicity Theory (MST), which focuses on each medium's ability to foster "a shared pattern of coordinated behavior among individuals as they work together" (p. 575). The authors do not directly compare the media considered via a ranking system, but instead ascribe high communication performance to an alignment between the level of synchronicity supported by the chosen media and the type of communication process. For example, conveyance processes that involve the transmission of new information can be effectively communicated by media that support low levels of synchronicity, while convergence processes, or those intended to align the perspectives of multiple parties regarding known information, are best supported by media with high levels of synchronicity.

The framework of MST prescribes to each medium a level of ability to support synchronicity. This level is derived from a combination of five attributes that, when matched with the needs of conveyance and convergence processes, will improve communication performance. These attributes are transmission velocity, parallelism, symbol sets, rehearsability, and reprocessability. While IM is able to support interactions that require a high transmission velocity and fulfills requirements for situations that require a medium level of rehearsability (e.g., one employee e-mails another for a quick clarification), e-mail communication is conducive to interactions that require a high level of rehearsability and slower transmission velocity (e.g., employees exchange information on their experiences with a client). The MST framework is appropriate when investigating communication within organizations because content required for organizational performance should be transmitted by media that supports the information.

Over time, we expect that employees will develop a tacit understanding of the appropriateness of conveying different types of information over varying media

channels. Furthermore, we expect communication behavior within each team to be relatively stable among individuals, given the length of time the division has been operational and employees' previous exposure to the various media examined. This leads to our next hypothesis.

Hypothesis 3: We expect employees to engage each other in their team using e-mail and IM to resolve issues related to task completion and work-related processes. Such issues and processes tend to have a medium to high level of rehearsability which is aligned with the framework of MST.

Workplace Design and Communication

Although theories such as MRT and MST can help align the media type used with the information or purpose of communication, which can in turn increase employee performance, they do not address the external factors that affect an employee's choice of media. It has been shown that spatial layout of the workplace can contribute to the density of social interactions and thus influence productivity via idea-generating communication (Peponis et al., 2007). Allen (2000) has demonstrated that the probability of communication between a pair of employees depends on their departmental and project relationships, the size and growth of these groups, and the proximity between their workstations. The author goes on to describe a series of spatial attributes that can facilitate communication within the organization, suggesting the avoidance of linear forms and vertical separation while encouraging the use of layouts that facilitate visual contact between employees.

The manipulation of existing spaces within an organization is particularly appealing to those not able to construct a new space that incorporates the optimal set of workplace design elements. Consider the open office floor plan, a solution that organizations continue to utilize with the intent of bolstering F2F communication in spite of a growing body of research demonstrating its negative effects on stress, job performance, and coworker relations (Brennan, Chugh, & Kline, 2002). The continued implementation of this layout demonstrates that there are cases in which, despite negative effects on employee well-being, its potentially positive effects on F2F communication render it a desirable option. However, despite widespread use, it remains difficult for such organizations to gauge precisely how spatial manipulation affects communication (Sailer, 2007). This difficulty has been partly attributed to a lack of consideration for experimental design to measure the effects of changes in workplace layouts (Davenport, Thomas, & Cantrell, 2002).

Until relatively recently, measuring F2F communication in the workplace required the collection of observational data. Although such data are certainly useful for assessing employees' perceptions of the workplace, it is often costly to obtain, requiring the use of trained observers or surveys, and may be susceptible to response bias. The development of social sensing technology has enabled researchers to construct a reliable representation of F2F interactions within the workplace at a much lower cost to users (Olguín et al., 2009). This technology makes it feasible for organizations to

change the spatial layout of the workplace gradually and measure their effects on F2F communication iteratively. Such an approach to workplace redesign could help researchers better understand precisely what changes have an effect on F2F communication, a task currently hampered by the fact that redesign efforts typically encompass a wide variety of simultaneous changes.

Our final hypothesis explores the effect of a low-cost change in workplace configuration, giving employees the opportunity to choose their seating location instead of following permanent seating assignments. The concept of a free-seating configuration has been explored in organizations hoping to provide employees with flexible working solutions, although research demonstrating its effect on F2F communication appears to be lacking. Senoo, Magnier-Watanabe, and Salmador (2007) describe the implementation of free seating in one organization, though the description of behavioral changes in the workforce is limited to informal observations by an executive director within the company. At the organization we studied, we measured the effect of assigning a subset of employees to a free-seating design on F2F communication, leading to our final hypothesis.

Hypothesis 4: Employees who were moved to flexible seating arrangements in the redesigned space have a higher percentage of interteam F2F interactions than colleagues in fixed seating locations.

Method

Our research took place within the headquarters of a large U.S. manufacturing company whose work focuses on the development of office products for worldwide distribution. Management at the organization had become concerned with the layout and design of the floor occupied by the global sales division, particularly since employees frequently host prospective customers in this space. Although visitors could clearly view the company's products in areas specifically designed for collaboration, the interior design of the remaining space made it difficult to discern how those same products facilitate teamwork among the company's own workers.

Employees on the floor were separated from one another by high barriers formed by some combination of cubicle walls, storage closets, and several rows of stacked drawers. Similar barriers restricted exposure of natural light from a wall lined with windows to those whose cubicles were within just a few feet. Navigating the space was difficult, leading to repeated use of a single route to enter and exit the floor. Spaces between cubicles were often narrow and sometimes filled with material that had not been placed into more permanent storage.

Collaborative spaces included several glass-walled meeting rooms, equipped with whiteboards and multimedia technology suitable for video conferencing. Multiple workstations provided four to eight seats for employees who wanted to work while maintaining line-of-sight contact with one another. Glass-walled enclaves equipped with whiteboards and small tables provided a more private space for four to five employees. A break area with coffee and vending machines was housed in the center of the floor, out of view of employees' workstations.

While employees occupied the existing space, an adjoining floor was remodeled. This new space made liberal use of workstations with low partitions, or no partitions at all, and provided seating for six to eight people at a time. Small open seating areas for impromptu meetings were also provided. In addition, a new open café space was added in the office's center, complete with tables and bench seating for 15 to 20 people, while the coffee machine was also relocated to a more central, open location within the space. On relocating to the new space, employees were provided with a floor plan reflecting the designers' ideas for space utilization throughout the floor. The document designated each area as being appropriate for either individual or team-based work and specified whether it was to be shared or owned by a subset of the employees. Here, owned spaces were dominated by fixed location seating for a single team, while shared spaces allowed for flexible seating arrangements.

We examined communication within the global sales division during two 4-week phases, before and after employees moved to the adjacent, redesigned floor. A total of 62 employees participated during the first phase, with 7 more employees joining the study after relocation. Our sample consisted of participants spanning the following teams: Applications, Sales, Sales Support, Finance, Mock-ups, Pricing and Contracts, Proposals, and Services. The organization provided floor plan measurements along with seating locations, tenure, gender, and the identities of reporting managers for participants in both phases. We used logs from e-mail and IM exchanges to reconstruct the employees' social network and provided all participants with Sociometric Badges to collect information on F2F interactions. We supplemented our data collection with additional information gathered by the organization, one example of which included a one-sheet with employee concerns related to communication between teams in the sales process.

Sociometric Badges

The Sociometric Badge is a wearable device developed by the Human Dynamics Lab at MIT (Olguín, 2007) and now commercialized by Sociometric Solutions, Inc. The badge permits a more accurate assessment of the social network structure within the division than those provided by e-mail data alone by gathering data on activity levels, speech signals, and proximity between users (Olguín et al., 2009).

Proximity and location detection. The Bluetooth sensor within the badge is capable of detecting other devices within a range of approximately 10 m. Each detection is associated with a value for the received signal strength indicator, making it possible to consider detections only between badges within a distance of approximately 1 m. Eagle and Pentland (2009) have shown that Bluetooth sensors can be used to predict F2F communication with more than 95% accuracy.

The infrared sensor serves as a substitute for F2F interaction as it detects and records when two badges are within line-of-sight of one another at a distance less than 1 m, and within $\pm 15^\circ$. The infrared transmitter scans for badges in close proximity once per second. Choudhury (2004) showed that it was possible to detect F2F

conversations using the *SocioMeter* badges with 87% accuracy when looking at segments that lasted at least 1 minute.

We create the adjacency matrix of F2F interactions by combining the matrix of infrared detections with a scaled version of the Bluetooth matrix. We construct the latter using only detections with received signal strength indicator values corresponding to detections within 1 m; although two individuals may not be interacting with each other at this distance, we can ascertain that they are easily reachable for F2F interaction.

Ensuring privacy. In this study we followed procedures that ensured the privacy of the users and the security of their data. To encrypt the user identity we used serial numbers for badge data instead of users' names. The key for the number/name conversion was kept in hard copy on our premises and was not uploaded to an online database. The raw audio data (i.e., content) were never saved to disk and was only used to calculate speech features. The data are encrypted on the badges with an AES-128 cipher and stored in a secured server.

Several of the privacy concerns expressed by participants in previous projects employing the use of Sociometric Badges are identified and discussed in a recent article on reality mining and privacy (Madan, Waber, Ding, Kominers, & Pentland, 2009). The authors address the potential for loss of privacy within the workplace by proposing a policy that would provide participants with a level of control over and protection of their data that go beyond what is currently required by U.S. law and complies with stricter European standards of privacy. This policy includes collecting data only from those who have provided their informed consent prior to the start of data collection, and even providing "dummy" badges that do not collect data if requested so employers do not know who is participating. In the investigation described in this article, participants signed consent forms that legally affirm this policy and in which they volunteer to wear Sociometric Badges to collect their behavioral data. The researchers also signed the agreement, giving their legal assurance that individual data will not be revealed at any way. Employers also signed contracts affirming that they would be granted no access to individual data and faced legal action if they attempted to do so. The agreement also provides examples of how individual data are secured both in terms of technical means of data protection and in terms of special scenarios (e.g., in situations where a team consists of a small number of members and identification of individuals might be more sensitive). A typical consent form describes study participation and withdrawal procedures (participants are free to abstain or withdraw from the study at any point), the types and format of the data collected by the badge, survey questions that will be distributed during the course of the study (if any), and the format of supplementary digital communication collected during the study (e.g., e-mail communication fields). It describes the efforts made to conceal the identity of the participant, such as hashing e-mail fields and omitting personal identifiers from all statistics. The agreement assures the participant that no individual data will be displayed or shared with third parties outside of the participant and Sociometric Solutions, Inc.

A separate document signed by the employer specifies that they may not dictate that employees be required to complete a consent form as a condition of employment or

apply undue pressure on an employee to participate. Furthermore, this document specifies the levels of encryption that will be employed by Sociometric Solutions, Inc., to transmit and store data, as well as dictating that the company will destroy data after a specified period of time (e.g., e-mail addresses are maintained for no longer than a period of 3 months after the conclusion of the data collection).

Informal Interviews

After the conclusion of our study, we found that the organization had conducted an informal assessment to discover employee concerns regarding the communication between teams during the sales process. Management sought common themes in the employee responses and aggregated the results into a one-sheet; the following are a few examples of their statements:

- “Wouldn’t it be great if we could hear about best practices and trends from Sales Support? We could leverage relationships and learn information.”
- “Who do I call? Who is the knowledge expert? How can our work benefit others?”
- “Wouldn’t it be great if we could bring in groups earlier to be more strategic in our connections?”
- “Wouldn’t it be great if we had intentional cross-pollination of expertise?”
- “Wouldn’t it be great if we all knew what each other did?”

These high-level observations encompass two areas of difficulty with regard to communication within the organization. First, employees seem unable to determine who best to contact in times of need, and a desire to better understand the work and knowledge possessed by others is evident. Second, employees express their willingness to make more strategic connections with colleagues and proactively share knowledge. These high-level observations are meaningful, but difficult to act on directly without a more nuanced understanding of communication within the organization.

Results

We addressed the first hypothesis by considering the communication matrices for each type of media (IM, F2F, and e-mail) and the corresponding demographics of each participant (Table 1). We modeled the number of messages exchanged between participants using a Poisson regression with terms for media type, whether the recipient of the communication was a manager, whether the sender and recipient were on the same team, and the senders’ team size. Results are summarized in Table 2. We found that the communication patterns within the organization we studied reflect those expected in a post-bureaucratic organization: participants sent managers only three-quarters the number of messages they sent to nonmanager colleagues, supporting Hypothesis 1. Individuals directed most of their communication toward teammates, sending 10 times more messages to intrateam colleagues than to interteam colleagues.

Table 1. Sample Sizes by Team and Phase.

Team	Phase 1	Phase 2
Applications	3	4
Sales	6	7
Sales Support	11	13
Finance	9	11
Mock-ups	3	3
Pricing and Contracts	5	5
Proposals	7	7
Services	18	19
Total	62	69

Table 2. Poisson Regression Relating Number of Messages Sent by Team and Manager Relationship Between Sender and Recipient.

Variable	Model 1			Model 2		
	B	SE B	e ^B	B	SE B	e ^B
Same team	2.54***	0.09	12.72	2.49***	0.09	12.08
Manager				-0.25***	0.07	0.78
Null deviance		1,605,407			1,605,407	
df		22,796			22,796	
Residual deviance		984,632			981,319	
df		22,792			22,791	

Note. Control variables are media type and sender team size (omitted from the table). Data from both phases were pooled in this analysis. Sender and recipient on a different team in a nonhierarchical relationship is the reference category. e^B = exponentiated B. SE B is adjusted for overdispersion in both models.

*p < .05. **p < .01. ***p < .001.

Furthermore, employees on small teams, identified here as teams with fewer than seven members, sent 73% as many messages to nonmanager, nonteam colleagues compared with those on large teams.

We tested the second hypothesis by considering the average number of messages exchanged between any pair of participants. We constructed this value by creating adjacency matrices for communication between teams and divided each entry by the number of possible communication pairs containing one member from each group. We suspected that communications between teams may be driven by a few individuals, and so we adjusted the denominator in our average to consider only individuals that used each communication media. However, this adjustment did not result in a significant main effect.

We then performed a two-way analysis of variance on this defined quantity with the two variables being the sender’s team and whether the recipient came from a team that

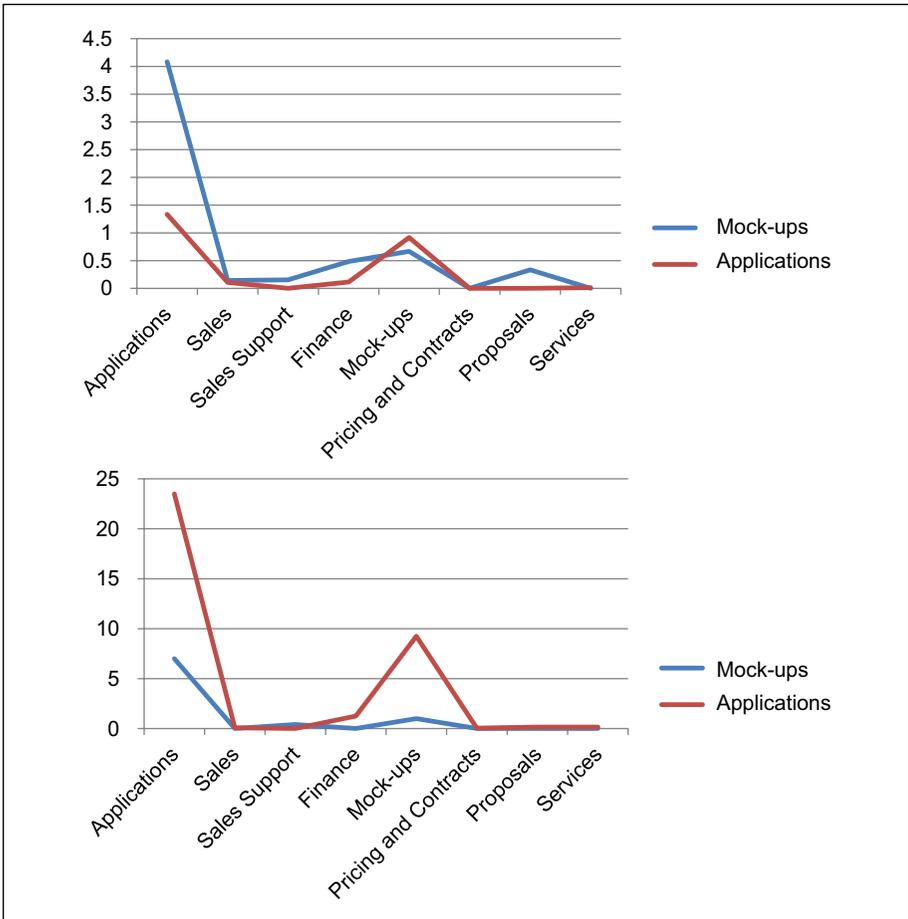


Figure 2. Average pairwise number of e-mail and IM messages sent from Mock-ups or Applications toward other teams.

Note. Applications and Mock-ups were the only adjacent teams within the sales cycle to focus a majority of interteam communication toward one another.

was adjacent to that of the sender in the sales process. The result of, $F(7, 1) = 0.70, p > .05$, for the sender team variable and, $F(7, 1) = 0.09, p > .05$, for the team adjacency variable showed that neither variable had an effect on this quantity, thus not supporting Hypothesis 2. The only teams to direct most of their external communication toward individuals on the team adjacent to their own in the sales cycle were Mock-ups and Applications. Mock-ups directed more of its interteam communication toward Applications than any other team over all three types of media. This communication was reciprocated by employees from the Applications team using IM, whose interteam averages were highest for Mock-ups (Figure 2).

Table 3. Poisson Regression Analysis Relating Number of People Contacted to Media Type and Sender Team.

Team	Face-to-face			Instant messaging		
	B	SE B	e ^B	B	SE B	e ^B
Sales	-0.88*	0.43	0.42	-0.07	0.30	0.93
Sales Support	0.005	0.29	1.01	0.09	0.25	1.09
Finance	1.03***	0.30	2.81	0.21	0.29	1.23
Mock-ups	0.38*	0.19	1.47	-0.15	0.17	0.86
Pricing and Contracts	-0.24	0.46	0.78	0.19	0.37	1.20
Proposals	-0.28	0.28	0.75	0.07	0.23	1.08
Services	0.11	0.22	1.11	-0.19	0.19	0.83

Note. The Applications team and e-mail are reference categories (omitted from table). Team size is a control variable (omitted from table). Data from both phases were pooled in this analysis. SE B is adjusted for overdispersion.

p* < .05. *p* < .01. ****p* < .001.

Table 4. Media Adoption by Team.

Team	Instant messaging	E-mail	Team size
Applications	3	3	4
Sales	3	6	7
Sales Support	3	12	13
Finance	9	11	11
Mock-ups	2	3	3
Pricing and Contracts	4	4	5
Proposals	6	7	7
Services	16	19	19

We addressed the third hypothesis by testing whether the average number of people contacted by an individual using IM or e-mail was greater than zero. Participants used IM (*M* = 3, *SD* = 4, *t*[69] = 7.53, *p* < .001), as well as e-mail (*M* = 14, *SD* = 11, *t*[69] = 10.36, *p* < .001) to contact coworkers; however, the use of these technologies for communication varied by team. We performed a Poisson regression to determine whether people on different teams exhibited a preference regarding the use of each type of media to contact colleagues. Results are summarized in Table 3. We found that individuals on teams with fewer than seven employees contacted 58% as many people as employees on larger teams. As further illustrated in Table 4, IM usage in particular varied greatly between teams. As a result, in some groups there is high adoption of both communication technologies, while in others there is a heavy skew toward one or the other, lending only partial support to Hypothesis 3.

The fourth hypothesis was tested by combining information on each employee's F2F interactions as measured by the Sociometric Badge and seating arrangements. Results indicate that employees who used flexible seating arrangements in the redesigned workspace ($M = 0.49$, $SD = 0.31$) had a higher proportion of interteam F2F contact ($M = 0.33$, $SD = 0.29$, $t[51] = -2.14$, $p = .04$) than those using fixed seating arrangements, supporting Hypothesis 4. Interestingly, a similar result was also observed using IM interactions as employees in the same location ($M = 0.28$, $SD = .35$) had a lower proportion of interteam interactions than those using flexible seating arrangements ($M = 0.60$, $SD = 0.40$, $t[21] = -2.50$, $p = .02$).

Discussion

For decades, researchers and practitioners relied on formal organizational charts and processes to understand and measure organizations. This was partly due to a paucity of alternative data sources, which was previously largely limited to surveys and human observations.

In this study, we investigated whether or not the perceived rise in importance of informal networks and the proliferation of communication technologies has changed this equation. Changes in physical office layouts and new organizational paradigms have also not been thoroughly investigated in the literature, so examining the interplay between these different factors is critical to enhance our understanding of organizations and networks more generally.

In this article, we worked to further this understanding using data from one organization, and as such contextual factors may have played a role in the results reported above. While this presents concerns about the generalizability of our findings, we believe that our results will provide a framework for the field to build on. As, to our knowledge, this is the first study to combine sensor and digital data into a holistic picture of informal networks, these results should provide some suggestions for the field moving forward.

Future work should expand on our results by replicating these investigations in additional organizations. Over time, we hope that this body of knowledge will be able to determine systematic differences in organizations by the degree to which formal hierarchical structures and informal networks influence communication.

Our data demonstrate that the description of interteam workflow provided by the company does not reflect the actual communications across teams. The firm's real working processes are less well-defined while problems and exceptions are more common than the company manuals would suggest. This also indicates that the company might not have a clear picture of how its employees accomplish their tasks.

This contrasts in an interesting way with the feedback we received from participants' self-reports. In general, participants seemed unsure of who to contact when they had an issue at work. In theory, formal processes should make these contact points clearer, but as we observed when investigating Hypothesis 2 these processes have very little impact on shaping communication patterns.

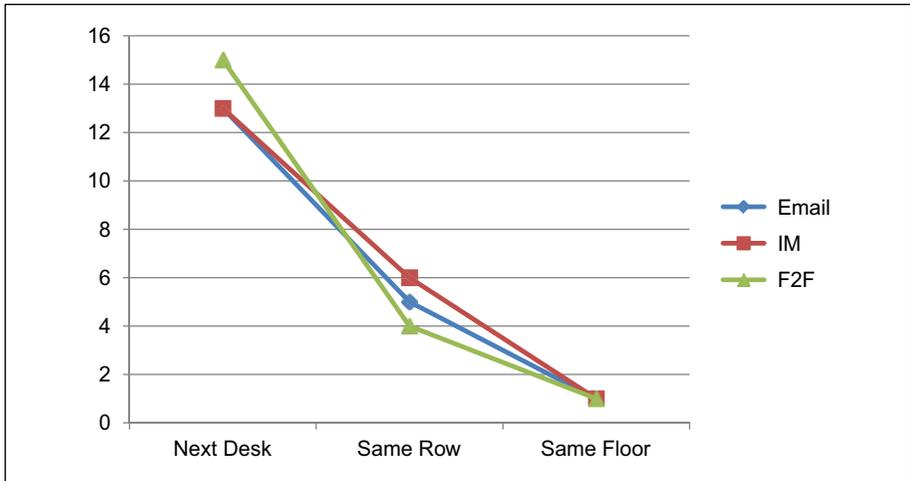


Figure 3. The average percentage of communication allocated toward individuals at varying distances from the sender's desk.

Whether this points to a larger organizational problem or a side effect of the high volume of communication running through informal networks is unclear. It does appear, however, that people seem quite adept at navigating networks within their team and less so outside of it. This suggests that critical interteam formal processes must be supplemented to a greater degree by other methods, thus lending further support to the importance of networks in organizations.

Our results from Hypothesis 4 clearly argue for the increased adoption of flexible seating and similar arrangements. These seating arrangements not only affected F2F communication but also IM communication. We also observed that the likelihood of communication between employees was inversely related to the distance between their seating locations (Figure 3), a finding aligned with existing research (Olguin et al., 2009). This observation, along with our findings regarding employees using flexible seating, highlights a potential way for organizations to facilitate communication within an organization: seating locations could be reassigned to encourage communication among specific subsets of employees. This adaptive approach could help alleviate some of the communication issues observed in this study, namely, individuals on teams completing work on adjacent stages of the process could be seated closer to each other, thus promoting F2F communication during transitory phases.

These findings may also explain the continued adoption of a seating arrangement that has been found to have negative impacts on employee wellness. Future research should expand on the nonbureaucratic tools organizations can use to influence interteam networks, as well as quantify the effects of the many office layout methodologies that are at our disposal using sensor and IM data.

IM usage itself, however, varied greatly between teams, and we did not observe any consistent usage of IM to lend full support to Hypothesis 3. The level of adoption we

observed is lower than other reported research in the field, leading to further questions about the generalizability of any findings using solely IM data (Muller, Raven, Kogan, Millen, & Carey, 2003). This is an important consideration for researchers moving forward, as data from any one tool is likely to provide a skewed picture of an organization, as even e-mail was not fully adopted. Future research on organizational networks should take this into account by endeavoring to collect a more holistic data set that incorporates media from many sources.

Admittedly, in our examination of Hypothesis 3 we were unable to investigate the content of these messages, leaving the exact purpose of IM and e-mail use somewhat unclear. However, the usage differences between teams indicate that the intent of these communications is channeled according to the norms of each particular group, rather than by cultural norms at the organizational level. Further examination with manual and automatic coding of content will be necessary to investigate this hypothesis and tease apart these factors at the team level.

Conclusion

We believe that the use of social sensing technology can help companies make more informed decisions when it comes to facilitating informal communication. The analysis of F2F data alongside that collected from Internet-based technologies can enable an organization to establish a baseline value for communication occurring among its employees. Using this baseline, the company can take an experimental approach to workplace redesign, introducing small changes to a representative sample of the population and measuring their effects. After companies have a sufficient amount of information regarding the potential effects of a change, they can determine whether to introduce it at a larger scale.

These new management approaches and data collection techniques open new avenues of research that were previously inaccessible, and also challenge long-held beliefs about the efficacy of single-medium data collection techniques. Unfortunately, the proliferation of communication technologies and the rising importance of informal networks have made mining these data a necessity. We cannot study and manage these networks unless we know their structure, and our results show that a holistic approach is critical.

Organizations can no longer count on formal hierarchical structures as the primary tool for managing information flow. Informal tools, such as office layouts, group lunches, and chats by the coffee machine, are the management tools of tomorrow as the informal relationship that they enable becomes more and more meaningful than hierarchical formal procedures. While it may seem fantastic, it appears that the identity of your boss is less important than the identity of your neighbor.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Benjamin Waber and Jeremy Doyle work for Sociometric Solutions, Inc., which sells commercial services based on the platform described in the article.

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Alex (Sandy) Pentland has helped create and direct MIT's Media Lab, the Media Lab Asia, and the Center for Future Health. He chairs the World Economic Forum's Data for Development council, is academic director of the MIT-Harvard-ODI Big Data and People Project. In 2012, *Forbes* named him one of the "seven most powerful data scientists in the world," and in 2014, he was elected to the U.S. National Academies. His most recent book is *Social Physics* (2014).