Mining Face-to-Face Interaction Networks Using Sociometric Badges: Evidence Predicting Productivity in IT Configuration

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Introduction

Information workers now account for more than 70% of the U.S. labor force and 60% of the total value added in the U.S. economy (Apte & Nath 2004). As the information content of work increases, the role of information has become central to understanding the performance of workers and organizations. Previous research links the structure of individuals' and groups' networks to performance (Burt 1992) and information worker productivity (e.g. Aral, Brynjolfsson & Van Alstyne 2006; Aral & Van Alstyne 2006). By analyzing email communication networks, message content and employee performance Aral, Brynjolfsson and Van Alstyne (2006, 2007) find that network structure predicts productivity and shapes the types of information employees access.

But while electronic communication has become ubiquitous, face-to-face (F2F) interactions also remain a powerful conduit for information exchange, especially for complex or tacit information. While previous research has shown that email social networks predict worker productivity and the ability to access novel information, it is unclear what effect F2F networks have on productivity. As F2F communication allows richer and deeper information exchange, understanding what types of F2F network structures enhance information access and productivity is important. We address this question by examining the physical interactions and F2F communications of 37 employees at an IT configuration firm. Specifically, we investigate how F2F communications impact productivity and performance, and if the impact is different from electronic communications.

Theory & Data

To address these questions, we build hypotheses linking characteristics of network structure to employee performance. We use network size, total number of interactions, betweenness centrality and network reach to proximate the breadth and range of a worker's network (Burt 1992). However, breadth and range alone may not matter if each additional contact is embedded in the same social circle, providing redundant access to the same pool

of information (Aral & Van Alstyne 2007, see Figure 2). Therefore, structural diversity may be more salient in predicting performance.

Table 1: Network Characteristics and Description	
Network Characteristics	**Description**
Direct Links	Total number of contacts with whom *i* exchanges at least one message
Total Interactions	The total number of face to face contacts *i* experienced during the experimental period
Betweenness Centrality	The probability of an actor that falls on the shortest path between any two other factors
Cohesion (Constraint)	Degree to which an actor's contacts are connected to each other
Reach	The number of other people an actor can reach in two links or less

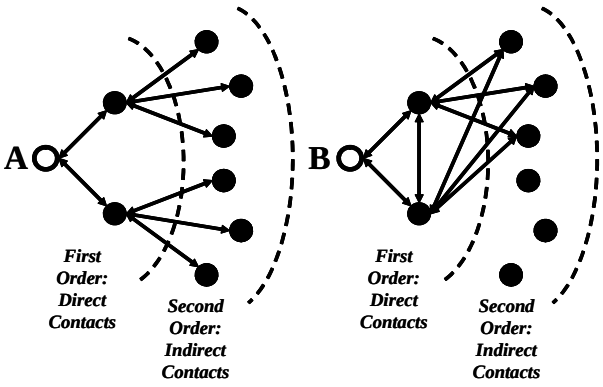


Figure 1. Wearable *Sociometric* badge

Structural Holes & Structural Equivalence

We studied an IT configuration facility with 37 employees whose primary job is to guide, solicit and capture clients' IT configuration requirements, and to produce IT products according to those specifications. Interviews indicate that the data configuration process is information intensive, requiring employees to quickly analyze the feasibility of specifications and build the system. To measure worker performance, we collected data on 911 configuration tasks during the experimental period of 25 days. For each task, we gathered data on duration, difficulty level, the number of follow-ups and information about the employee who performed the task. To collect F2F and physical proximity interactions, we utilized a wearable sociometric badge that can collect and analyze behavioral data from many individuals over time (Waber et al. 2007). In particular, these badges are capable of:

- Detecting people in close proximity by measuring received signal strength from a 2.4 GHz radio.
- Capturing face-to-face interaction time using an IR sensor that can detect when two people wearing badges are facing each other within a 30 degree-cone and one meter distance.
- Detecting speech using a microphone that records tonal variation and prosody, but not content.

With these badges, we recorded the duration of F2F interactions between workers when they are facing each other and engaging in conversation. We also measured physical proximity, calculated as the weighted average of physical distance between two workers and the duration of F2F contact. Combining the task performance data and the network data, we empirically tested whether F2F and proximity networks were correlated with productivity and performance and if these effects were different from those for electronic communication networks.

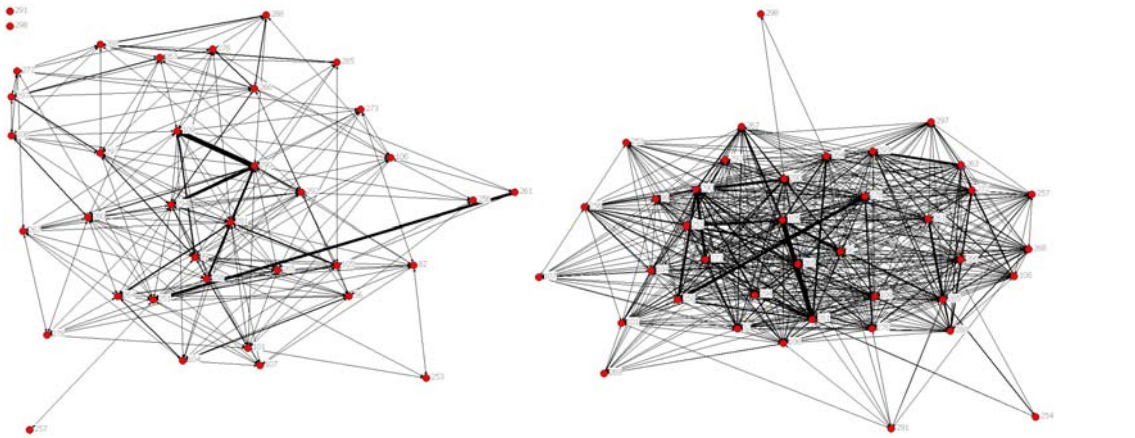
Empirical Methods and Results

We employ a Cox proportional hazards model to examine the effect of network characteristics on project completion rate:

$$HazardRate(R) = f(size, betweenness, cohesion, reach, task\_complexity, job\_title, number\_followups, employee\_animation),$$

$$R(t) = r(t)^b e^{\beta X}$$

We tested this specification on both F2F networks and proximity networks as shown below, where heavier lines indicate more numerous interactions between workers.[1]



Face to Face Conversation Network **Weighted Face to Face & Proximity Network**

We first tested the effect of the F2F network on task compeletion (Table 2). As predicted, complex tasks and tasks that require more follow-ups increase the completion time significantly. While the total number of F2F interactions has no effect on completion time, the network size—the number of unique contacts—is associated with a 5% decrease in the speed with which employees complete tasks on average. In contrast, network reach and network betweenness increase the speed of task completion by 3% and 11% respectively. This shows that the sheer

volume of interaction between workers is irrelevant for worker productivity. However, the number of unique workers one interacts with matters. Although network size reduces speed, the ability to connect to a broad range of workers that span the office significantly increases the task completion rate. This result mirrors the effect of electronic communication on productivity. However, network cohesion—the ability to access non-redundant contacts—has the opposite effect in a F2F network.

Table 2: Effect of F2F and Proximity Networks on Completion Rate

	F2F Hazard rate	**Physical Proximity Hazard rate**
Complexity	0.8902**	0.870**
	(-0.05)	(-0.05)
Function	0.8431***	0.887**
	(-0.06)	(-0.05)
Follow up	0.8738***	0.884
	(-0.02)	(-0.01)
Interactions	1	1
	(0)	(1.52E-05)
Network Size	0.9469*	1.001
	(-0.03)	(-0.02)
Network Betweenness	1.106*	1.021
	(-0.06)	(-0.08)
Network Constraint	2.053***	0.121***
	(-0.25)	(-0.56)
Network Reach	1.033***	0.346
	(-0.01)	(-0.24)
Worker Animation	1	1
	(-6.96E-09)	(7.64e-09)
Observations	911	911
*** p<0.01, ** p<0.05, * p<0.1		

Instead of reducing speed and productivity as in the email network (Aral & Van Alstyne 2007), F2F network cohesion doubles the speed of task completion, demonstrating that the power of strong cohesive ties in a face to face network is *more* conducive to productivity than weak diverse ties. As the inherent richness of F2F communication enables the exchange of deep tacit knowledge, it may be that having a strong cohesive network can ease such information exchange in F2F communication networks.

In contrast to F2F communications, we see that the physical proximity network has a lesser effect on performance, demonstrating that actual conversations matter more than physical proximity alone. In the physical proximity network, network constraint reduces the task completion speed by 89%, exhibiting a similar effect on productivity as the email communication network (Aral & Van Alstyne 2007).

Conclusion and Future work

We show initial evidence that F2F networks are indeed different from electronic networks in terms of their relationship to worker productivity. In F2F networks, cohesion is more conducive to worker productivity while the opposite is true in email communication. We also show that conversations are more important than physical proximity. In future work, we intend to perform robustness checks, identify other intermediate mechanisms that link network structure to productivity, and investigate fixed effects models that control for endogenous individual characteristics, to lend support to causal interpretations.

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[1] As shown in the figures, there are many more interactions between workers in the physical proximity network than in the F2F network. This makes sense because when people are engaging in F2F conversation, they are by definition close to each other, whereas two people who are not talking could still be sitting in close proximity to each other. Therefore, the F2F interactions are always encompassed by the proximity network. The interaction patterns of the two networks are highly correlated; the key information brokers in the F2F nework are also the key nodes in the physical proximity network.