SPATIAL AND COMMUNICATION PATTERNS IN RESEARCH & DEVELOPMENT FACILITIES

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Keywords:

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0 Abstract

At the First International Syntax Symposium, this study was presented with some initial observations developed from very preliminary data. The analysis is now complete, and the full results are presented as follows: This paper presents an investigation of the relationship between the layout of research and development facilities and communication patterns among research scientists. Previous studies confirm that communication among scientists is a significant determinant of performance and productivity. The hypothesis tested in this investigation is that differences in spatial layout in the settings of otherwise similar groups of scientists affect their communication patterns. Teams of scientists were studied at the research and development facilities of two major medical products manufacturers. Frequency, location and status of interactions were compared to various physical measures, including syntactic measures of spatial layout. Results indicated that location and frequency of communications were related to spatial configuration. In both facilities, spatial layout enhanced local networks; however, in one of the labs these local networks were separate from the global spatial system, while in the other lab, the interface between these systems was strong.

1 Background

Studies of the productivity of research and development teams suggest that communication is an important indicator of performance (Allen, 1977; Pelz & Andrews, 1966; Shilling & Bernard, 1964). Workers talk (face-to-face) with others who are in close proximity. As early as the classic Hawthorne studies, initiated in 1924, research has demonstrated that social relationships (social interaction, friendship formation, and informal group liaisons) are affected by the physical proximity and accessibility of work stations. These results have been corroborated by numerous subsequent studies (see Sundstrom, 1986, for a review). Beyond a distance of about 30 meters, workers are not likely to talk (directly) unless it is a particularly important matter (Allen, 1977). Physical distance, and physical barriers (such as door, stairs, changes in corridor direction) will act as deterrents (Allen, 1977; Fernald, 1986). If group members are distant from one another, they may be unable to coordinate activities (Hackman, 1987). Although similar 'proximity' may be achieved through computer-based interface, at this time the best predictor of interaction continues to be physical distance.

Hillier & Grajewski (1987) found occupation density and mean spatial integration as two main factors affecting observed levels of interaction. This study also found that workers occupying more segregated offices traveled farther than those in more integrated locations.

In the study of research laboratories, Penn and Hillier (1992) found that mean integration of floor area was related to the mean degree to which staff located in that area were found to be 'useful in their work' by people from other work groups. Furthermore, Hillier and Penn (1990, 1992) suggest the importance of local to global interface. Penn et al. (1997) found a significant correlation between frequency of reported encounter within a work area, and the local to global integration value for that area.

As Hillier and Penn discuss (1991, 1992), the organizational program in research laboratories tends toward separation by knowledge area. For these organizations where the goal is the creation of new knowledge, the opportunity exists for the spatial layout to either reinforce the separation by knowledge area or to create a more 'generative' spatial system. This study explores this relationship through an examination of spatial layout and communication patterns in two research facilities.

A number of subordinate questions are also raised by this earlier work: Do face-to-face conversations occur more often along the more traveled, and presumably more integrated, circulation routes? Are these 'serendipitous' or unscheduled interactions? Are scientists who occupy more integrated offices likely to communicate more than others?

1.1 Comparative Study of Labs

The present study examines communication patterns of researchers in two research facilities in relation to spatial layout. Both facilities are located in the Atlanta (Georgia, US) area, and are engaged in lab based research. The first organization, Lab A, is a research and development division of an international pharmaceutical products company; the second, Lab B, is a research and development division of an international ophthalmic products company. In both organizations, the research and development division was one of several divisions housed in different buildings in campus-like settings. For this project, we focused on one division (housed in one building) within each organization. In Lab A, a division of about 64 employees, we collected data on the communication patterns of three (out of the 4) research groups. In Lab B, with about 42 employees, we sampled communication patterns from each of the two research groups.

In the case of both of these organizations, and typical of research laboratories in general, the organization is subdivided according to knowledge areas, with relatively few layers of managerial hierarchy, and an array of hierarchically equivalent research groups each focused in a particularly defined area of knowledge. Thus, in both cases, the organization creates a set of boundaries of knowledge.

However, the spatial accommodation of these two organizations is quite different. The spatial organization of Lab A tended to follow lines of organizational separation, with research scientists located in fairly segregated areas. Managers for these work groups tended to be co-located separate from their working groups. Lab B, in contrast, had recently experienced a reorganization around a particular project effort. Although organizationally the workers were subdivided by knowledge area into two groups, there was a concerted effort on the part of management to merge the efforts of these individuals. These objectives had spatial implications, as we will discuss further.

2. Methods and Procedures

Participant Data. The primary data set consists of 2367 recorded events for 25 participants at Lab A, and 2212 recorded events for 22 participants at Lab B. Over a total data collection period of four weeks, participants carried a pager (vibration, not sound activated) and microrecorder during business hours. They responded to ten 11.3
random pages per day by recording their location; activity; and, if they are engaged in face-to-face interaction, with whom they are speaking (i.e. group or non-group colleague, administrative personnel, outside consultant or sales representative). During the data collection for Lab B, data was also collected on whether the interaction was 'scheduled' (planned prior to the interaction) or 'unscheduled'.

Physical Descriptors. Description of the physical setting was based on analysis of floor plans and site visits. Syntax analysis was applied using the Axman analysis program developed at the University of London. Syntax analysis is a technique for the analysis of form based on spatial characteristics (more specifically topologic relationships). This technique has been found to be highly predictive of movement pattern in buildings. Its predictive strength is based on characteristics of space, irrespective of function (Hillier and Hanson, 1984).

Syntax analysis looks at the relationship of a space to every other space in a total system of spaces. Through syntax analysis, the Real Relative Asymmetry (RRA) can be calculated for particular spaces (convex analysis) or lines through space (axial analysis). These values indicate the spaces/lines that are the most integrated (those that are predicted to have the highest movement) and those that are the most segregated (those that are predicted to have the lowest movement) for the global (entire) system of spaces. It is also possible to look at the spatial layout of the system at a more local level. The calculation of Real Relative Asymmetry 3 (RRA3) indicates the relationship of each space to those spaces that are three spaces away. In contrast to RRA which indicates the extent to which the system of spaces is integrated as an entire system, RRA3 suggests the extent to which the system consists of more localized regions. Syntax analysis permits comparisons across systems.

3. Results

3.1 Lab A

Communication Data. At Lab A, 25% of all responses were TALKING. Of these, the largest portion, or 47% occurred in private offices. Of those in offices, nearly half occurred in the offices of the group leaders or lab directors. 23% of all TALKING occurred in the labs, followed by 5% of TALKING in the hallways. The remainder of the data identified as WORKING (not talking), was generally located in the labs or private offices.

Physical Data. As illustrated in Figures 1A and 1B, the staff that were surveyed at Lab A are located in labs and offices on two floors of their R&D building. All walls are full-height and every office and lab has a traditional, full height door. There are numerous doors located within the hallway system, although most have some glazing. Due to the maze-like nature of the plan, there is very limited visibility down corridors, into labs, or between offices. With the exception of one coffee station, the corridors do not contain any support services; they act merely as circulation conduits. There are three sets of stairs and an elevator that connect the two floors. Each floor has a conference room, and the breakroom is located downstairs.

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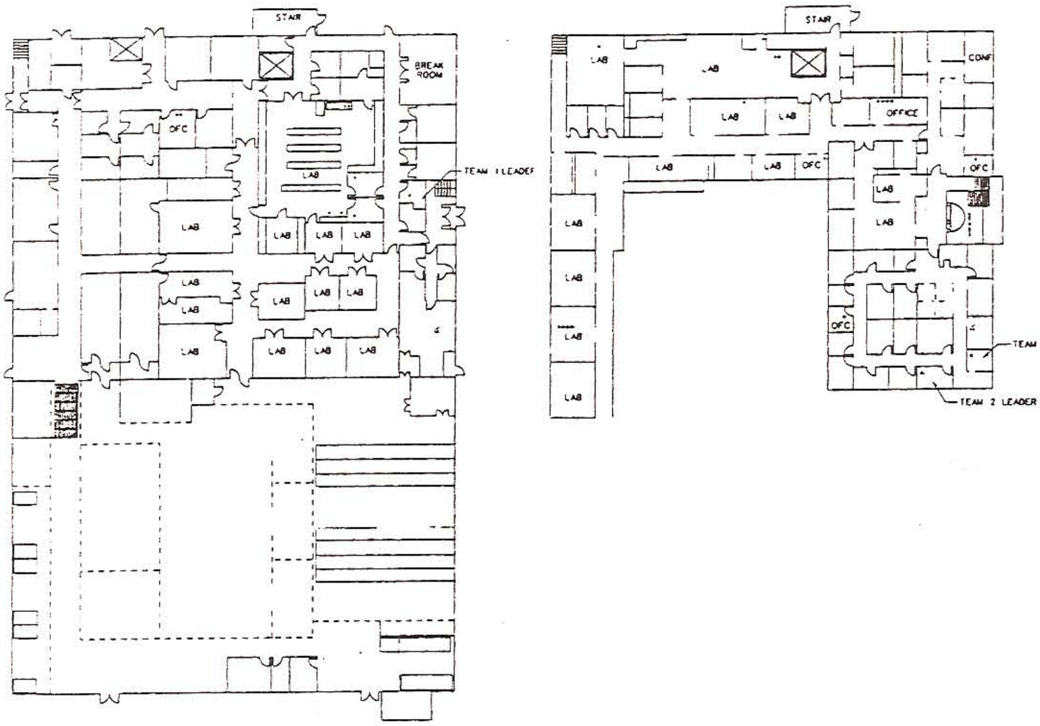


Figure 1. Lab A, first and second floors

3.2 Lab B

Communication Data. At Lab B, 47% of all responses where identified as TALKING. 3% of the responses where identified as E-MAIL with the remaining 50% WORKING. Of the TALKING responses, the largest portion, or 55% occurred in private offices. While TALKING occurs in every office, there is a concentration in several offices in one part of the building. The offices in this area include those of the lab director the division heads, and division managers. 6% of TALKING occurred in the hallways.

Physical Data. As illustrated in Figure 2, the participants at Lab B are located in labs and offices on one floor of their R&D building. The offices are located together in one half of the building, and the labs in the other half. The halves are connected by two hallways. Offices around the perimeter of the building are traditional, enclosed spaces with full height doors and side light. The majority of the office spaces are in a cluster of open workstations with standing-height walls. The whole office space is arranged in a fairly strict grid pattern, with major and minor paths. Support services, such as mailboxes, coffee station, copy machines and printers are located in and along the major path which encircles the main workstation zone.

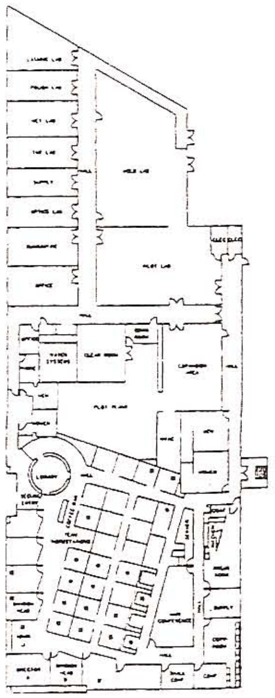


Figure 2. Lab B

One of the strengths of this research is that we have, in essence, a time sampling of activity over the course of several days. As illustrated in

Figure 3, clearly most activity takes place in participants' workspaces. In Lab A, given the location of many of the workspaces within the lab, there is quite a high level of activity in the lab, as well as in the offices. In Lab B, with no one located in the lab, activity is concentrated in the offices. A small proportion of time is spent in the hallways of both facilities (3 percent of events in Lab A and 4 percent of events in Lab B).

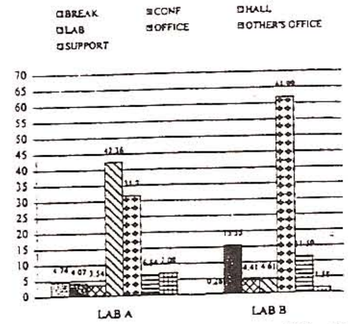


Figure 3. Location of all activity

In Lab A, respondents are engaged in face-to-face communication about 25 percent of the time as illustrated in Figure 4. These events are generally either in the workspace of the respondent (lab or office) or someone else's workspace. 14 percent of talking is in the conference rooms. Respondents are talking close to twice as often in Lab B (47 percent of events are talking). As illustrated in Figure 5, these interactions take place generally in the workspace of the respondent or someone else's workspace. A large percentage of communication (33%) takes place in the conference rooms.

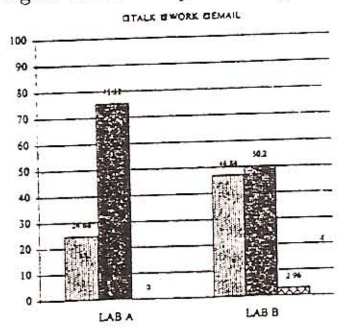


Figure 4. Activity

In Lab B, we had the opportunity to look at scheduled as compared to unscheduled interactions. We found that, as one would expect, the talking that occurs in the hallway is almost entirely unscheduled. We found also that, as one might expect, the major proportion of talking that occurs in the conference room is scheduled (..%).

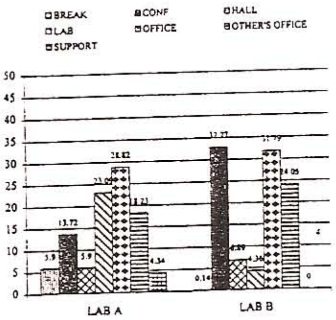


Figure 5. Location of all talking

In order to look more closely at the relationship between unscheduled face-to-face interaction and characteristics of spatial layout, we examined the relationship between talking events occurring in the major circulation spaces and an axial analysis of these spaces. For this and the subsequent analysis, in order to better reflect unscheduled interactions, all conference rooms were removed from the analysis for both Labs A and B. (For Lab B, almost all interactions in the conference rooms were scheduled, our assumption was that the same holds true for Lab A.) For both Labs A and B, there was no relation between the integration of the corridor (RRA) and interaction (see figures 6 and 10). When we looked at local integration (RRA3) there was also no relationship in either lab (see figures 7 and 11).

Since interaction was more frequent in the office spaces in both facilities, we examined interactions that occurred not only along the corridor but also in spaces that were linked to the corridor, one space away. We found a more suggestive relationship between the integration of the corridor (RRA) and this linked measure of interaction (see figures 8 and 12). The relationship improves if we look at the local integration (RRA3) (see figures 9 and 13).

Hillier and Penn have suggested the importance of the local to global interface. If we compare the two laboratories as spatial systems, we find that Lab B exhibits a stronger correlation between the local measure of connectivity and global integration (R=.66) than Lab A (R=.48) (see figures 14 and 15). Given that Lab B demonstrates close to twice the rate of talking as found in Lab A, these findings support the notion that a stronger local to global interface supports higher levels of communication.

To explore the local to global interface more fully, we examined the relationship between the linked interaction measures (as above) and the local to global relationship of the corridors (see figures 16 and 17). Analysis for Lab A shows a significant rela-

LAB A

FIGURE 6. LINKED INTERACTION

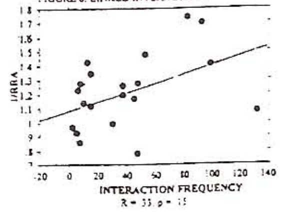
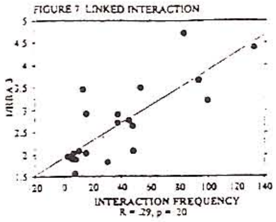


FIGURE 7. LINKED INTERACTION



LAB B

FIGURE 10. UNLINKED INTERACTION

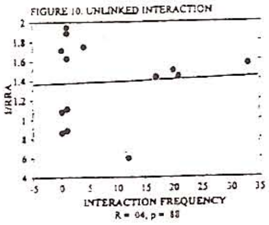


FIGURE 11. UNLINKED INTERACTION

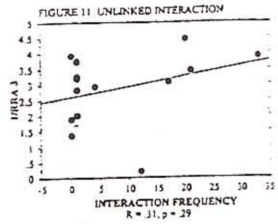


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FIGURE 8. UNLINKED INTERACTION

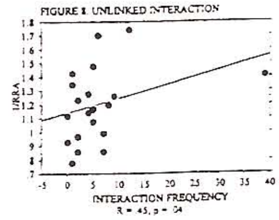


FIGURE 9. UNLINKED INTERACTION

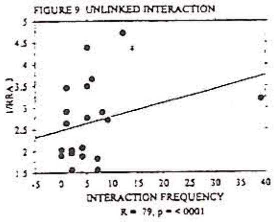


FIGURE 12. LINKED INTERACTION

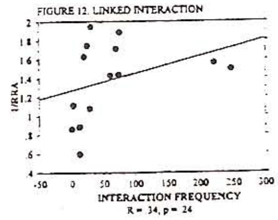
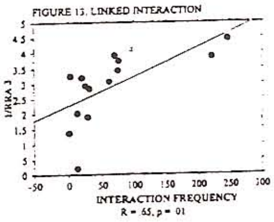


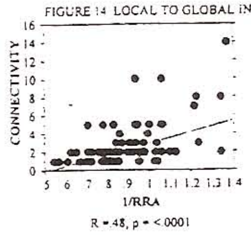
FIGURE 13. LINKED INTERACTION



tionship (not quite as strong as the local measure of integration alone), and for Lab B indicates a trend (although not significant). This may be due to the lack of variability among the integration values for many of the offices in this facility.

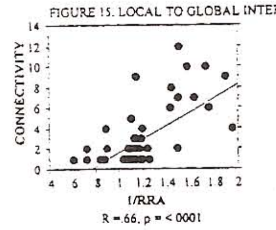
We did find a strong correlation between rate of communication and distance (from the individual's office to the location of the interaction) (see figures 18 and 19). Thus, those scientists whose communication rates were high generally did not travel as far from their office to engage in those interactions as the lower rate talkers. These results suggest that the higher rate communicators occupy offices whose location is close to 'available' others.

FIGURE 14. LOCAL TO GLOBAL INTERFACE LAB A



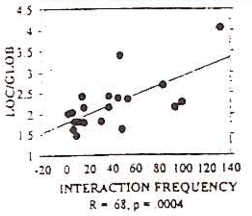
To explore the spatial variables that influenced individual scientist's rate of communication, we examined the relationship between several spatial characteristics of the scientist's own office and his/her rate of communication: occupation density (the number of workers within 30 meters of the primary office); visual density (the number of doorways to other offices within the visual isovist from the doorway of the primary office); and the spatial integration (of the primary office).

FIGURE 15. LOCAL TO GLOBAL INTERFACE LAB B



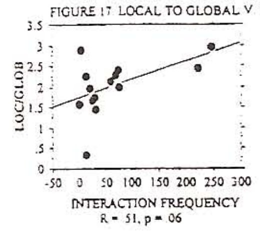
Results indicate that neither occupation density nor visual density were strong predictors of communication rate. Furthermore, the relationship between integration (of the primary office) and rate of communication was not significant. Apparently the sheer existence of potential talking partners is not the critical factor. Penn et al. (1997) examined observational data of sitting people, standing people, and moving people, and found that (metric) density of moving people was the strongest predictor of rate of talking.

FIGURE 16. LOCAL TO GLOBAL V. INTERACTION LAB A



This result suggested we might look at the integration value (reflecting the amount of movement) of the corridor linked to individual offices. This relationship was not significant for either Lab A or B. We find a significant relationship to the local integration value of the corridor (RRA3) for Lab A. However, a more powerful predictor was the local to global relationship of this corridor. In other words, the stronger the local to global integration of the corridor linked to an individual's office, the higher the communication rate for that individual. This was a strong predictor for Lab A (see figure 20, R=.70). Results for Lab B were not significant, although again this

FIGURE 17. LOCAL TO GLOBAL V. INTERACTION LAB B



may be due to the lack of variability among the integration values for many of the offices in this facility. Apparently, an important determinant of rate of communication is not the integration value of a scientist's own office, nor the global integration value of the hallway adjacent to the office, but the extent to which that hallway is an integral part of the local circulation system, and the way in which that local circulation interfaces with the global system of movement in the office.

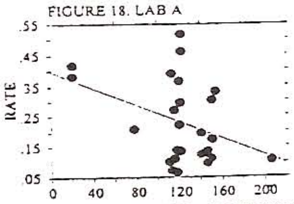
4. Conclusions

The spatial layout of the two research units in this study are fundamentally different. In Lab A, the spatial layout reflects a correspondence to the organizational description. Working groups, defined by knowledge area, are distributed throughout the building generally in local clusters of office space in proximity to labs or actually in the lab space (about half of the respondents occupied desks located in a lab). Lab B, in contrast, is an example of non-correspondence. The organizational description defines two working groups, reflecting two knowledge areas. These groups, however, are spatially co-located, and even within the local area, workers from the two groups are interspersed. The labs are quite separate from the offices, linked to the office area through two hallways.

Focusing on unplanned interactions, the 'serendipitous' encounters of Peters and Waterman (1982), the data analysis reveals some interesting differences. Although most talking occurs in offices, and movement is only a small percentage of all events (3 percent of events in Lab A and 4 percent of events in Lab B), 40 percent of events in the hallway at Lab A were talking, and 72 percent in the hallways at Lab B were talking.

Axial analysis results for interactions in hallways suggest that interactions are not well correlated with integration or even with local integration. However, if one considers interactions that occur in spaces that are linked to the corridor, one space away, the results are more suggestive, and the strength of this relationship increases for local integration. Strong local links among a set of offices enhance opportunities for interaction.

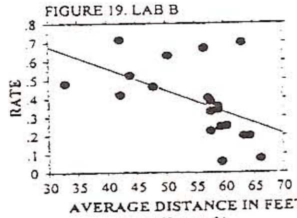
FIGURE 18. LAB A



AVERAGE DISTANCE IN FEET
R = -.40, p = .064

Results demonstrate almost twice as many interactions in Lab B than in Lab A. The greatest number of interactions were for workers who did not travel far to communicate. These results lend support to the importance of the 'availability' of others, although density of other workers within (Tom Allen's suggested) 30 meters was not a strong predictor of interaction, nor was the number of others' doorways within view from one's office.

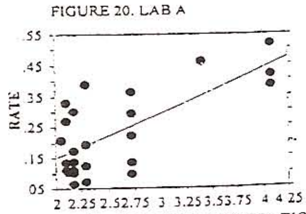
FIGURE 19. LAB B



AVERAGE DISTANCE IN FEET
R = -.53, p = .01

A critical spatial measure of 'availability', and the most powerful predictor of communication in this study, is that suggested by Hillier and Penn, the local to global interface. This appears to be important as a characteristic of the spatial system as a whole, as well as a powerful predictor of both the rate of interaction taking place along various corridors and individual scientists' rates of interaction.

FIGURE 20. LAB A



HALL LOC/GLOB INTEGRATION
R = .70, p = <.0001

For both of these labs, spatial layout supports localization. The major difference occurs in the composition of the groups that are 'localized', and the interface of this local system with the global spatial system. At Lab A the localization reflects the pattern of subdivision by knowledge area, maintained apart from the global patterns of spatial movement. At Lab B the localization mixes knowledge areas, and creates collaborative interface within the global spatial system, establishing conditions for generative production of knowledge.

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