Environment and Planning B: Planning and Design 2006, volume 33, pages 825 – 844

DOI:10.1068/b31123

Spatial layout and face-to-face interaction in offices—a study of the mechanisms of spatial effects on face-to-face interaction

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Received 15 October 2004; in revised form 15 November 2005

Abstract. In this paper we report a study that uses space-syntax theories and techniques to develop a model explaining how spatial layouts, through their effects on movement and visible copresence, may affect face-to-face interaction in offices. Though several previous space-syntax studies have shown that spatial layouts have significant effects on movement and face-to-face interaction in offices, none has investigated the relations among movement, visible copresence, and face-to-face interaction in offices with significantly different layouts. On the basis of statistical analyses of the spatial and behavioral data collected at four moderately large offices, this study shows that spatial layouts have consistent effects on movement, but inconsistent effects on visible copresence and face-to-face interaction; that visible copresence, not movement, is an important predictor of face-to-face interaction; that movement has negligible effects on the relationship between visible copresence and face-to-face interaction; and that functional programs have little or no effect on the culture of face-to-face interaction in these offices. Limitations of the research design for workplace study and implications of the research findings for workplace design and management are discussed.

Introduction

A great deal has changed in office design over the past few decades as office organizations have attempted to become more customer responsive, efficient, and agile. Many office organizations are dividing into smaller, more mobile, less hierarchical units that are more autonomous in their decisionmaking. More office work is now done simultaneously rather than sequentially. More office work is being seen as 'knowledge work', and the asset value of employees as 'intellectual capital' is more commonly recognized. Team contributions are more noticed and rewarded. Office organizations are continually seeking improvements through innovative processes and a much wider range of workers is expected to take part in these processes (Apgar, 1998; ASID, 2001; Becker and Sims, 2000; Bell, 2000; Brill et al, 2001; Duffy, 1998; Duffy and Tanis, 1993; Ghoshal and Bartlett, 1995; Wineman, 1986).

These changes mean that the patterns of communication that once served the office organization have become less predictable. On one hand, the relatively limited and hierarchical ways of communicating about work have evolved into communication patterns in which workers need to talk to a variety of people in different functional roles. At the same time, informal communication is increasingly recognized as a way to create and reinforce organizational culture (Allen, 1977; Becker and Sims, 2001;

Cross and Borgatti, 2002; Sundstrom and Altman, 1989; Wineman and Serrato, 1998). Rather than being a distraction, informal communication is seen as a way to build commitment, spread ideas about how 'we do things around here', and as a way to share knowledge and skills that go beyond written job requirements.

In this context, space is recognized as an organizational resource. Whether the intention is to reinforce the already existing patterns of informal communication, or to create new patterns, many new innovative offices capitalize on unplanned, face-to-face interaction traditionally associated with space. These new innovative offices generally consist of small, individual workspaces in order to push interaction out into public or semipublic territories. They are also made highly interconnected with increased visibility, openness, and accessibility in order to boost chance encounters which lead to meaningful interactions. Additionally, these offices also provide public and/or semipublic territories with a wide variety of features, such as kitchens, stocked refrigerators, central service hubs, recreational facilities, comfortable furniture, and attractive lounge-like spaces. A recent publication of the Office of the Government-wide Policy of the General Services Administration of the US Government provides several examples of such innovative offices (OGP, 2002).

There is a large body of research literature to justify why some of the design strategies used in new innovative offices may indeed enhance interaction and collaboration (for example, Allen, 1970; Becker et al, 1983; Bobele and Buchanan, 1979; Brookes and Kaplan, 1972; Campbell and Campbell, 1988; Davis, 1984; Farrenkopf and Roth, 1980; Goodrich, 1982; Hatch, 1987; Keller and Holland, 1983; Leibson, 1981; Oldham, 1988; Oldham and Brass, 1979; Oldham and Fried, 1987; Oldham and Rotchford, 1983; Sommer, 1967a; 1967b; Steinzor, 1950). However, the existing literature has many shortcomings. First, it focuses more on the local visible or observable physical properties than on the global invisible or structural properties of the environment.

Second, the literature does not offer consistent models linking face-to-face interaction and communication to the physical environment of offices. These models are often based on context-specific physical attributes that are rarely similar in any two offices. As a result, they are rarely useful for conducting any comparative studies of offices.

Third, the literature generally assumes that the physical characteristics of something like an *open-plan* office are obvious. In fact, not only is it difficult to define rigorously the nature of an open-plan layout, it is also difficult to find a pure example of the open-plan office layout. In most cases, it is a function of openness, accessibility, and visibility, for which no one valid measure has yet been devised.

Fourth, the literature generally does not describe the physical attributes in relation to the structure of office layout. As a result, it fails to recognize many important facts. For example, corner offices in different layouts may hold very different interaction and communication potentials. With the exception of office studies that use space-syntax theories and techniques, the literature also does not recognize the fact that office layout is important for face-to-face interaction and communication in its own right. [See below for a basic introduction to the theories and techniques of space syntax. For additional details, see Hillier and Hanson (1984) and Hillier (1996).]

Studies presented in the space-syntax literature show that spatial layout plays a powerful role in the communication patterns within offices (Penn et al, 1997); that patterns of space use and movement generated by spatial configuration have a direct impact on the frequency of reported encounters within offices (Penn et al, 1997); that spatial interconnectedness is a main factor affecting observed levels of interaction and eagerness to travel for interaction in offices (Grajewski, 1992; Hillier and Grajewski, 1987); that spatial interconnectedness is related to the degree to which people in one area may find people in other areas useful in their own work (Hillier and Penn, 1991);

and that spatial layout either can reinforce the separation of knowledge areas or can create a 'generative' spatial system (Hillier and Penn, 1991; 1992). However, a comprehensive model that brings together different layout attributes and behaviors to the understanding of spatial effects on face-to-face interaction is still missing in the space-syntax literature. Therefore, we begin with such a model.

The workplace-interaction model (figure 1) is an attempt to describe the relationships among space, behaviors, and organizational outcomes. The spatial attributes included in the model are visibility, accessibility, and openness. Among behaviors, there are *movement* (defined as the number of people moving along a path of observation); *visible copresence* (defined as the number of people visible from a path of observation); and *face-to-face interaction* (defined as the number of people engaged in any reciprocal exchanges involving two or more people along a path of observation and in the spaces along it). An operational definition of each of these behaviors is provided below.

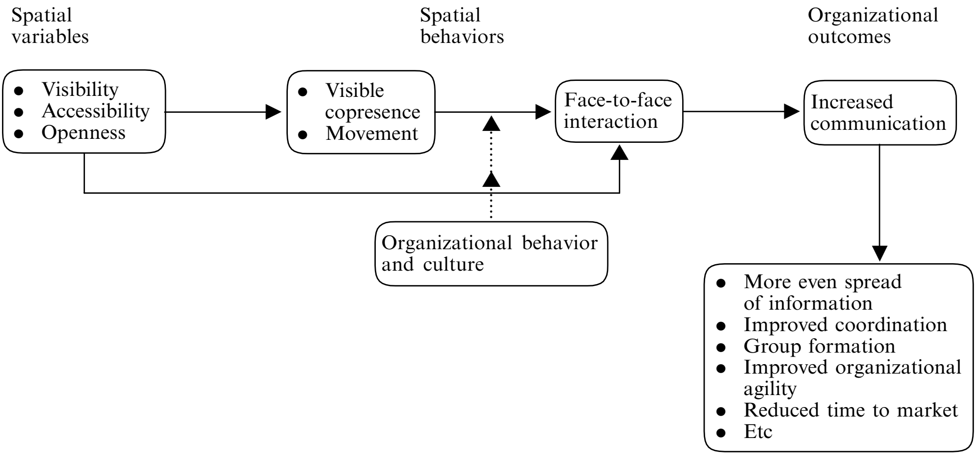


Figure 1. The workplace-interaction model.

In the model it is assumed that layout attributes may have direct as well as indirect effects on face-to-face interaction. For example, an easily accessible and visible common area may have direct positive effects on face-to-face interaction; a highly connected layout may have indirect positive effects on face-to-face interaction by facilitating movement; an open-plan office may have indirect positive effects on face-to-face interaction by increasing visible copresence; and so on. However, as the model shows, any direct and indirect relationships between layout and face-to-face interaction in an office can always be impacted by organizational culture and behavior. For example, an easily accessible and visible common area may fail to have any positive effects on face-to-face interaction in an organization that discourages interaction.

The model also shows that the assumed relationships between space and face-to-face interaction are important, because any increase in interactions may affect, depending on a particular organization, any or all of the following organizational outcomes: a more even spread of information, improved coordination, group formation, improved organizational agility, innovation, reduced time to market, reduced process redundancy, and greater organizational efficiency.

Methodology

The study reported here focused on linking spatial layout to face-to-face interaction. The impact of increased interaction on organizational outcomes was outside its scope. The study was done in three stages. In the first stage, the visibility, accessibility, and interconnectedness of an office layout were analyzed using the techniques of the axial map analysis of space syntax. The 'Spatialist' software, developed at Georgia Tech, was used for this purpose (Peponis et al, 1997; 1998a; 1998b). The *axial map* of a layout is a set of the minimum number of longest straight lines needed to cover every space and to complete every circulation ring in the layout without crossing and physical objects (figure 2). In the literature each of these straight lines is known as an *axial line*, and the complete set of lines covering the layout as an axial map. An axial map provides a rigorous way to describe how we see and move in a layout. An axial representation is important, because in a given space individuals often prefer to move along a straight line as represented by an axial line, unless there is a reason not to do so. Additionally, the way individuals move in a space is very often defined by the number of choices available from a line of movement as represented by the number of intersections an axial line has with other axial lines.

Figure 2. An office layout with its axial map.

Two important descriptors of the structure of an axial map are *connectivity* and *integration*. The connectivity value of an axial line is the number of axial lines directly connected to the line. This local property of an axial line is interesting because it describes the degree of choice present on the line: *the higher the connectivity of an axial line, the greater is the number of choices of movement from the line.*

The integration value, on the other hand, is a global property describing the degree of connectedness of an axial line to all other axial lines of an axial map: *the higher the integration value of an axial line, the easier it is to get to the line from all other lines.* The importance of the descriptor is intuitively clear. For example, an easily accessible common area needs to be located on an axial line with a high integration value; a private office needs to be located on an axial line with a low integration value; etc.

For the integration value, the software first computes the depth value, a graph-theoretic measure, of each axial line, through the use of the connectivity matrix of the axial map. In space syntax the depth of an axial line is a function of the number of steps needed to go from the given axial line to all other axial lines in a map. The process is explained in figure 3. Using depth values, the software then computes the integration values of the lines, which are inversely related to the depth values: *a line with a high depth value will have a low integration value.* The integration value is also normalized on the basis of the number of axial lines in a map, which allows us to compare the interconnectedness of axial maps with an unequal number of lines. In the last step the software colors the lines according to their integration values. However, the axial map of figure 3 and the other axial maps in this paper have the distribution

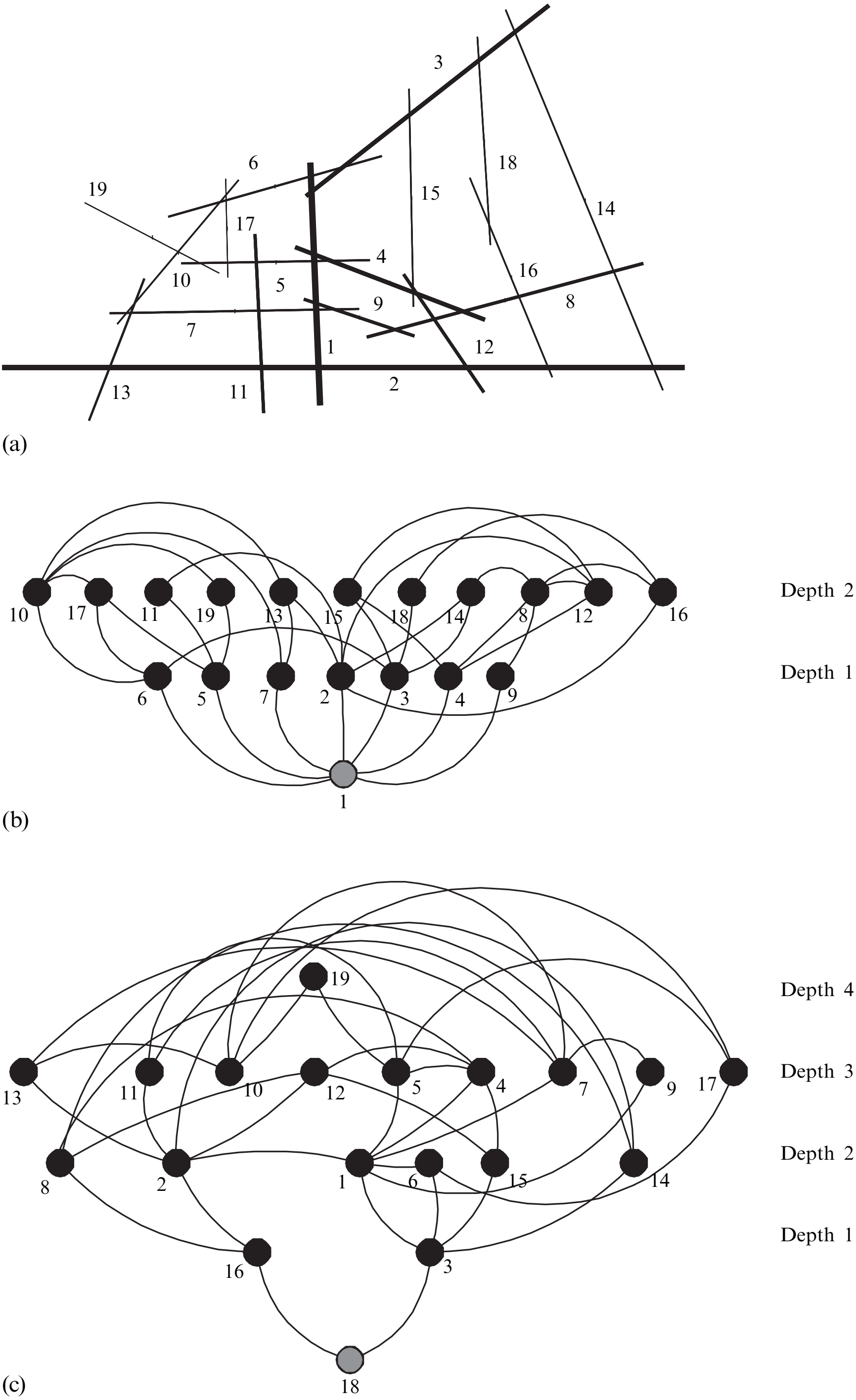


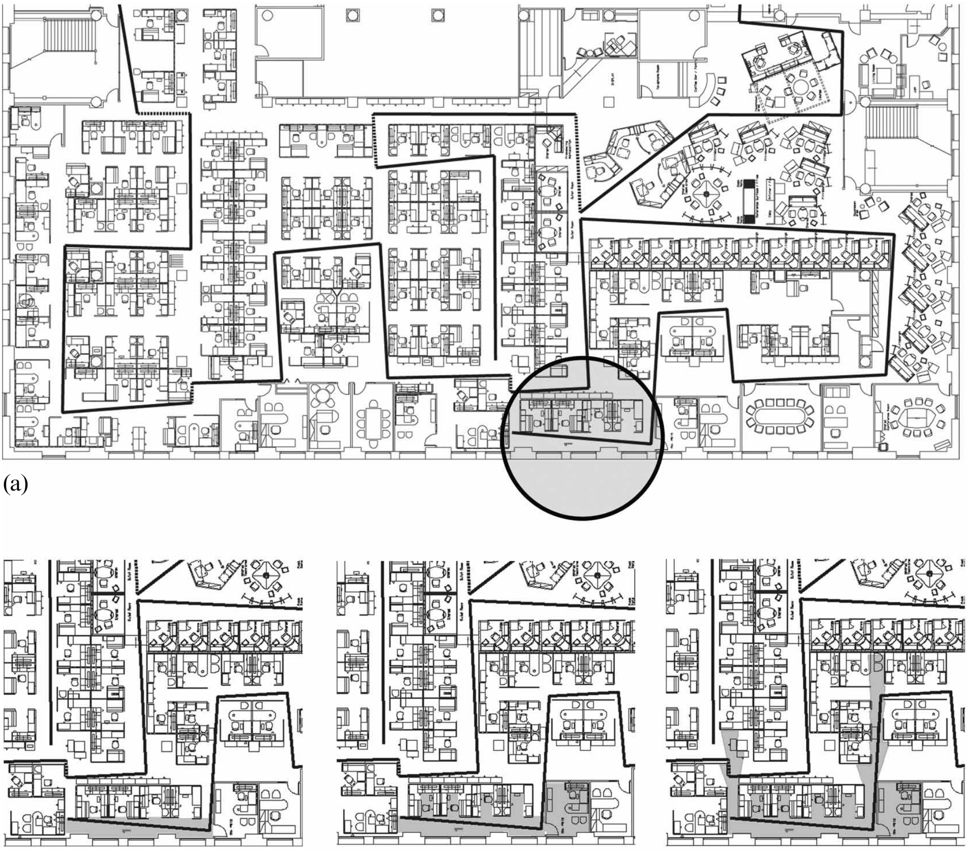
Figure 3. The techniques of the axial map analysis. (a) An axial map with the distribution of the integration value shown using line thickness: the thick lines are more integrated than the thin lines. (b) The justified graph of axial line 1 with a high integration value shows that in order to get to any axial line of the map from this line only two steps are needed. (c) The justified graph of axial line 18 with a low integration value shows that in order to get to any axial line of the map from this line at least four steps are needed.

of the integration value denoted through line thickness. In these maps, the thick lines are more integrated than the thin lines.

In addition to the integration and connectivity values, the number and the length of axial lines, representing the directions and reach of the visual field of a space, were also used in this study to describe the degree of local access and control.

In the second stage of the study, we collected organizational and behavioral data though informal interviews and systematic behavioral observations. We informally interviewed leaderships and senior level managers of each office to understand organizational goals in terms of spatial layout.

We observed three different behaviors along a predetermined route covering different types of spaces (that is, spaces with different functions and integration values) in each office. The route was composed of several linear segments of the axial map of an office layout [figure 4(a)]. A field observer observed the following three behaviors at each office as she walked along the path at a regular pace.



(a)

(b) (c) (d)

Figure 4. The behavioral observation techniques used in the study. (a) A route for behavioral observations in an office. (b) Movement is the number of people moving within an imagined band of space along an observation route. This band of space does not include any part of workspaces. (c) Face-to-face interaction is the number of people seen engaged in face-to-face interactions in the imagined band of space along a route segment as well as in the workspaces directly connected to the space. (d) Visible copresence is the number of people located within the visual field of a route segment drawn at the eyelevel of an average person.

(1) *Movement* (defined as the number of people moving on any segment of the route). In this case the observer was instructed to record anyone moving within an imagined band of space along her path. This band of space did not include any part of a workspace [figure 4(b)].
(2) Face-to-face *interaction* (defined as the number of people seen engaged in face-to-face interactions on a route segment as well as in the workspaces along the segment). In this case the observer was instructed to record any interaction involving two or more people not only within an imagined band of space along her path but also within the workspaces directly connected to this band of space [figure 4(c)].
(3) Visible copresence (defined as the number of people, active and/or inactive, visible from any segment of the route). In this case the observer was instructed to record the total number of people located within the visual field drawn from a route segment at the eyelevel of an average person [figure 4(d)].
For recording purposes, we used the up-to-date layout of an office with the route drawn on it. In total, 20 – 30 rounds of observations were made along any given route during different times of a workday over a period of three days. The data were then manually entered into a spreadsheet for further analysis.

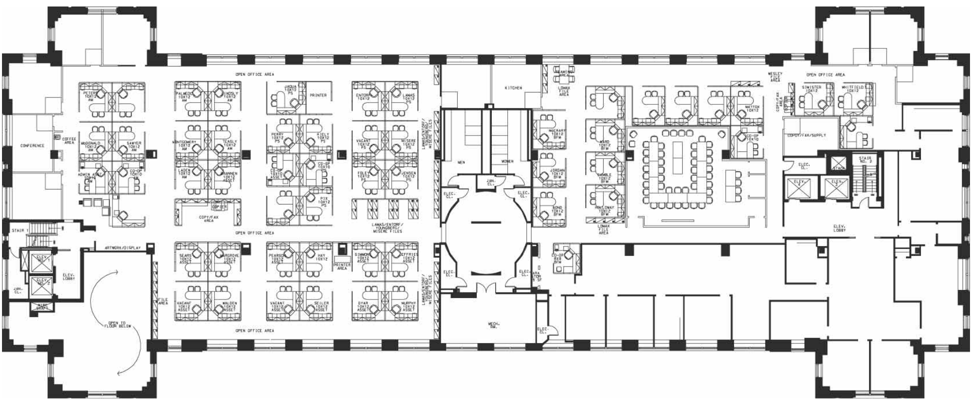
In the last stage of the study we analyzed the relationships between the spatial and behavioral data through the use of statistical techniques. For analysis purposes, we normalized the observation data for 100 ft-long segments in order to remove the differential effects of the length of route segments on movement, face-to-face interaction, and visible copresence.

Case studies
Our case studies included four US federal offices, three of which were designed recently. Three of the offices are similar real-estate organizations of the US federal government; the fourth is a clerk of court's office of a US District Court. According to our informal interviews with the organizational leaders of these offices, improving collaboration and communication through interaction had been a particularly important goal at all four offices. The majority of the workers in these offices are professionals. Besides professionals, there are large groups of administrative staff and mid-level managers in each office. Among the smaller groups there are senior and low-level managers and trainees. In general, there was an even mix of men and women in each office.

Our first case study, office A, is a public real-estate organization that has several divisions [figure 5(a), over]. (The organization has now moved into new quarters.) Each of these divisions performs different functions, and each has several groups working on different projects. The nature of communications varies with the type of work a group performs. Diversity of functions also precludes any simple generalization about the nature and pace of work groups. This diversity is reflected in the physical boundaries and grouping within the office. Divisions have somewhat defined territories, but no territorial definitions exist for the smaller groups within the divisions. Apparently, the location of a division is based on its relationships with the leadership, rather than on its functional relationships with the other divisions. It is possible that the current practices of the organization at the time of our study did not require frequent exchanges between its divisions. However, according to the leadership of the organization, group activities within a division were encouraged. Consequently, we expected behavioral patterns in the office to be affected more by the local structural and functional dynamics.

Our second case study, office B, is a new portfolio-management division of another public real-estate organization [figure 5(b)]. There are several large working groups in

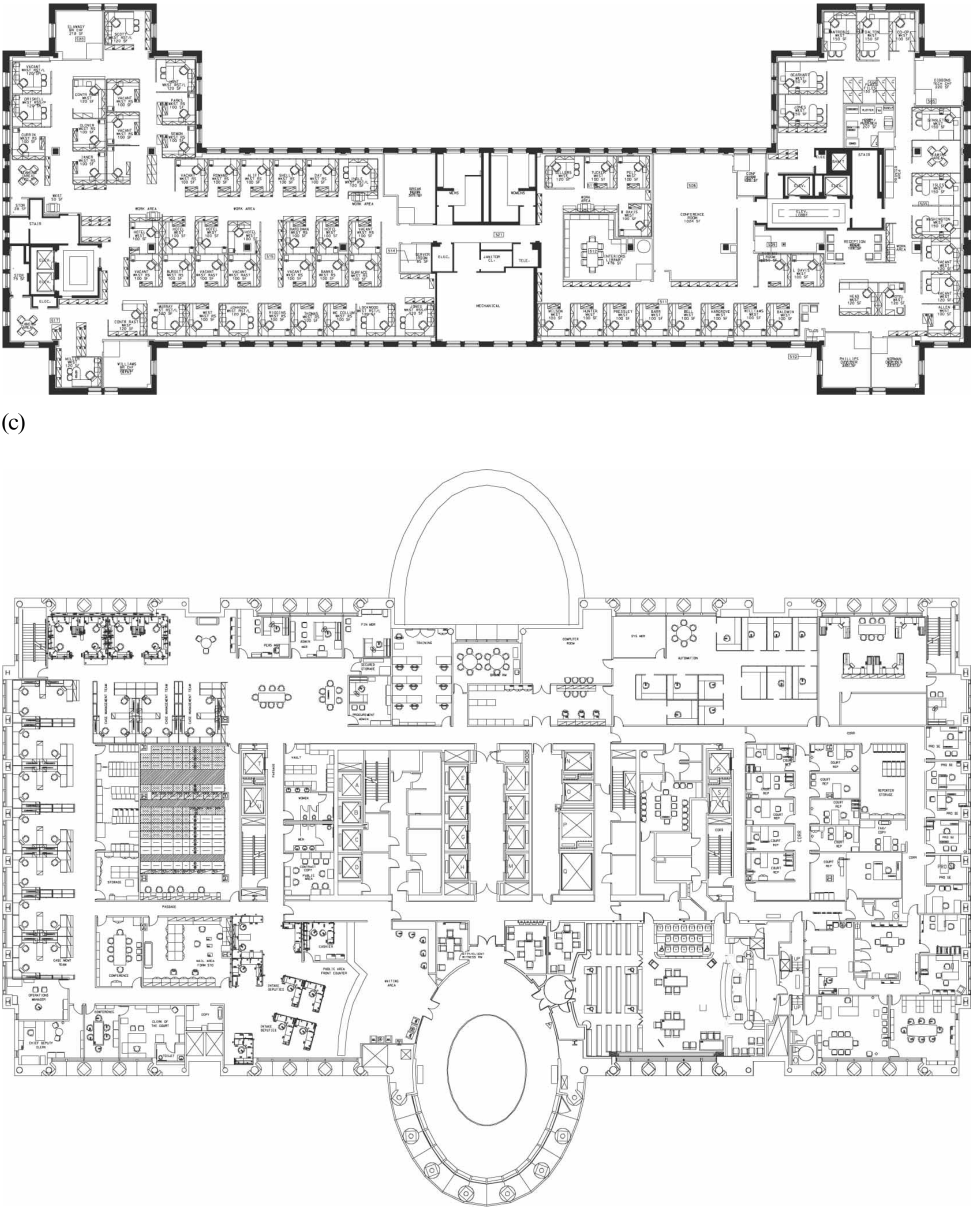
(a)



(b)

Figure 5. Office layouts: (a) office A, (b) office B, (c) office C, (d) office D.

the division. The composition, size, and functions of each group vary. The group structures and functions of the division do not lend themselves to any consistent behavioral expectation at the local level. As a result, any observed consistency in behavior may be a consequence of the spatial properties of the office, among other things. In addition, though the larger groups of the division have well-defined territories, no such territorial definitions exist for the teams within the groups. Furthermore, the



(c)

(d)

Figure 5 (continued).

functional relationships between the groups are not always explicit in the way they are laid out. Because the functions of each group are widely different, the leadership of the organization desires to enhance collaboration through the use of design.

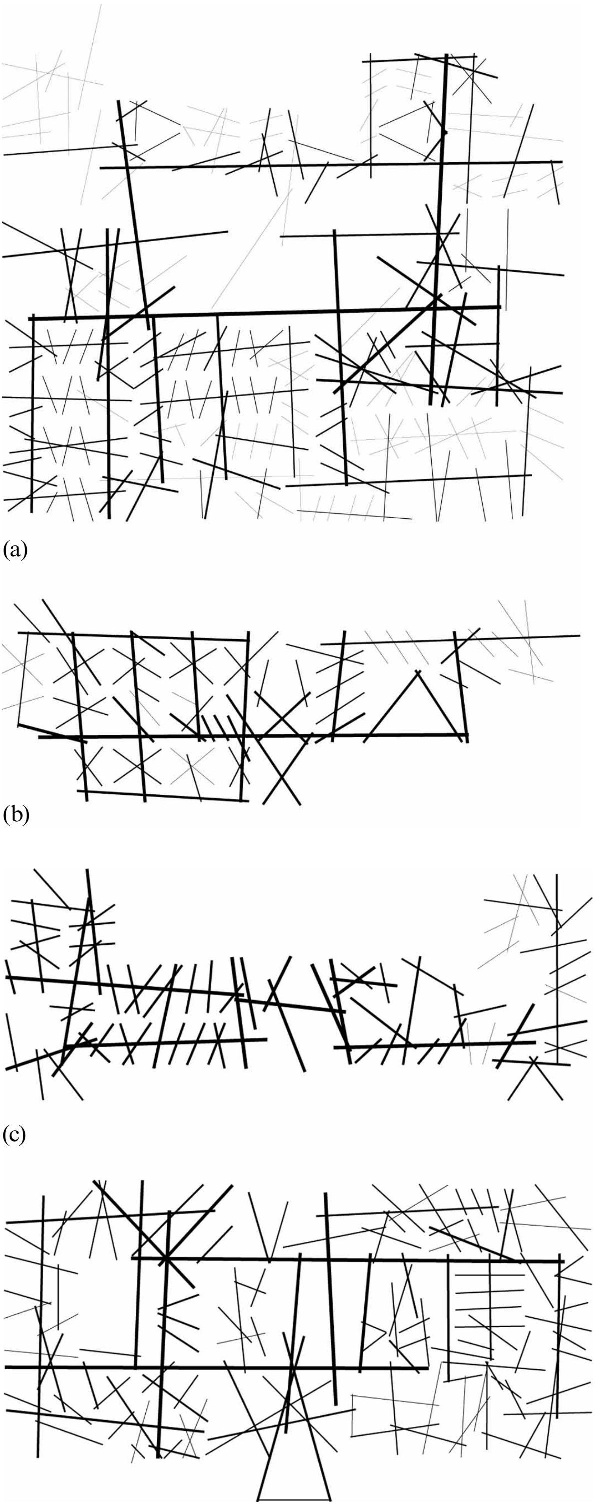
Our third case study, office C, is the realty-services division of the same public real-estate organization [figure 5(c)]. In the division, there are three main groups, each composed of several teams. Each team is responsible for the planning and scheduling of its own work. Each team performs similar work independently and is not functionally dependent on another team. Though there is a lot of communication among the members of a team, only formal communications at regular intervals among several teams are required. The three main groups of office C have well-defined territories, but the teams within each group do not have defined territories. The location of a territory is based on its functional relationships with the directors, as well as with the other groups. Even though the structural and functional logic of the division does not impose any immediate behavioral restrictions, predictable behavioral patterns may still exist between adjacent functionally related territorialities. The leadership of the organization recognizes the importance of interactions between individuals and groups in achieving organizational goals, and believes that the layout is capable of meeting the existing as well as the emerging interaction requirements.

Our fourth case study, office D, is the new clerk's office of a US District Court [figure 5(d)]. The functions of the office are diverse. Likewise, the divisions of labor are numerous. There are several small groups in the office. Members of some of these groups have different roles and functions requiring intense interaction and physical proximity. Members of the other groups have similar roles, but require very little to no interaction among themselves or with others. As a result, behavioral patterns vary from one group to another. The office is divided into several group territories. The location of a group territory is based on the strength of its perceived relationships with the other groups. Consequently, as with office C, some predictable behavioral patterns may exist between adjacent functionally related territoriality. Despite group or team differences, the current leadership recognizes that collaboration among individuals and groups is important for the success of the organization. It also acknowledges the fact that a collaborative environment must provide facilities to enhance and encourage formal as well as informal interactions between workers.

Axial-map analyses of the office layouts

Figures 6(a) – 6(d) are the axial maps of our four office layouts with the distribution of the integration value denoted by line thickness: the thick lines are more integrated than the thin lines. We present our findings in brief, because they were reported elaborately in another publication (Rashid and Zimring, 2003). We started the analysis by comparing the number of axial lines per workspace in these offices. We hypothesized that an office requiring more interaction at the local level would have less axial lines per workspace, because this would allow workers to change direction fewer times to go from one workspace to another. We believe that our findings support the hypothesis weakly: though the organizations requiring more interaction (for example, office C) have fewer axial lines per workspace than the ones requiring less interaction (for example, office B), the differences are small in some cases (table 1). Additional studies are needed to determine the lower bounds of substantive differences in the number of axial lines per workspace that would have significant impacts on interaction.

We also compared the length of axial lines per workspace in these layouts. Because the length of axial line is related to travel distance, we hypothesized that organizations requiring more interaction at the local level would have a shorter length of axial lines per workspace, to reduce travel distance among individuals. This hypothesis is also related to Allen's (1970) research, which shows that the likelihood that any two people will communicate drops off dramatically as the distance between their desks increases. Again, we believe that our findings support the hypothesis weakly: though the length of axial lines per workspace is shorter in the organizations requiring more interaction (such as office C) than in those requiring less interaction (such as office B), the differences are small in some cases (table 1). Again, additional studies are needed to determine the lower bounds of substantive differences in the length of axial lines per workspace that would have significant impacts on interaction.



(a)

(b)

(c)

(d)

Figure 6. Axial maps: (a) office A, (b) office B, (c) office C, (d) office D.

Table 1. Summary of the spatial properties of the office layouts.

	Office A	Office B	Office C	Office D
Total workspaces	244	60	76	92
Total axial lines	253	70	80	127
Axial lines per workspace	1.04	1.17	1.05	1.38
Sum of the lengths of all axial lines (ft)	8449.00	2693.35	2814.93	5653.89
Length of axial lines per workspace (ft)	34.62	44.89	37.03	61.45
Mean connectivity	3.51	3.03	3.00	3.42
Mean integration	1.24	1.60	0.92	1.44
Mean length of axial lines (ft)	33.39	38.48	35.20	44.52

We also hypothesized that an office requiring more interaction amongst all individuals and/or groups at the global level would need a well-connected spatial network allowing anybody to go anywhere easily. Our findings confirm the hypothesis: the organizations requiring more overall interaction among all individuals and groups, not just among neighboring groups and individuals, have higher mean integration values—that is, highly interconnected axial structures (compare office C, which has a mean integration value of 0.92, with office B, which has a mean integration value of 1.60, in table 1).

Additionally, we hypothesized that an office requiring more interactions would have its public spaces more easily accessible. We used the mean integration value of different categories of functional spaces to determine the accessibility of these spaces in our offices. According to our findings, in general, public spaces are located along more integrated lines, whereas private spaces are located along less integrated lines (table 2). This makes sense because axial lines with lower integration values are physically and visually less accessible within a layout.

Table 2. Rank order of different categories of spaces of the office layouts based on the spatial properties of the axial map. Values in parentheses are mean integrations.

Office	Rank order							
	1		2		3		4	
A	CIR	(1.442)	COM	(1.376)	D&M	(1.199)	WS	(1.189)
B	CIR	(2.170)	COM	(1.621)	WS	(1.403)	D&M	(1.345)
C	CIR	(1.058)	COM	(0.929)	WS	(0.896)	D&M	(0.748)
D	CIR	(1.897)	M&S	(1.665)	COM	(1.477)	WS	(1.327)

Note: CIR = circulation, COM = common areas/facilities, D&M = directors and managers, M&S = managers and supervisors, WS = workstations.

It should also be noted here that, except in one case (office C), there are very strong correlations between the local and global spatial variables of the office layouts (table 3). The finding suggests that for these offices it is possible to make reasonable judgments about the global pattern of spatial interconnectedness of a layout on the basis of the local connectivity of a line. In simple terms, each of these office layouts has an *intelligible* structure, where the intelligibility of a structure can be defined by the strength of correlations between the local and global spatial variables of the structure: *the stronger the correlation*, *the better the intelligibility.*

Table 3. Correlations between different spatial variables of the office layouts.

	Office A	Office B	Office C	Office D
Integration and connectivity	0.699	0.777	0.240	0.902
Integration and length	0.732	0.640	0.341	0.838
Length and connectivity	0.791	0.875	0.943	0.942

Note: all correlations are significant.

In sum, our analysis shows that the spatial layouts of our four offices are well defined in relation to some very important aspects of organizational function and culture. They provide sufficient differentiation in terms of accessibility and visibility to accommodate different groups and functional types. They also reflect organizational hierarchy, which is likely to foster orderliness in the office environments. More importantly, the spatial structure of each layout, as described using space syntax, reflects the interaction goals of an organization it accommodates.

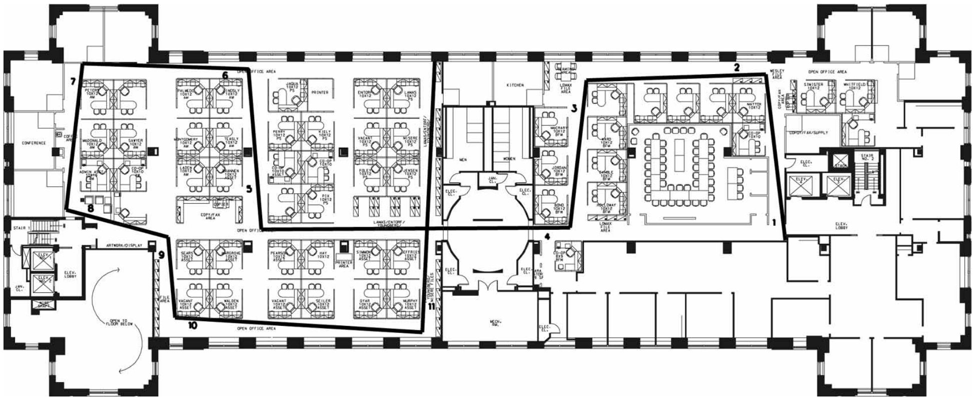
Descriptive analyses of the observation data

Figures 7(a)–(d) (over) show the routes of observation in these offices. According to our field observations, in all four offices the occupancy rate of workspaces (that is, the number of occupied workspaces expressed as a percentage of the total number of workspaces) is quite high, but the attendance rate (that is, the average number of workers present in an office expressed as a percentage of the number of occupied workspaces) is low (table 4, over). In other words, despite organizational differences, the observed similarities of the occupancy and attendance rates of our offices suggest that some generalization of our field observations may be possible.

The observed face-to-face interactions in these offices show similarities and dissimilarities (table 5, over). According to our data, the majority of interactions occur in individual workspaces of all four offices. Previous studies report similar findings (Brill et al, 2001; Serrato and Wineman, 1997; 1999). Interactions in individual spaces occur despite the fact that three of our four offices are newly designed as collaborative work environments in order to encourage interactions outside individual workspaces. In each of these new offices, individuals have much smaller offices than they had previously. In addition, these new offices also have generous corridors, common areas, and teamwork areas.

The offices show considerable differences in the other locations of interaction away from individual workstations, thus defining different *spatial cultures of interaction* of the organizations. At least three different interaction cultures are evident in our four offices. Office A has a *workspace culture*, because there is no other important interaction locus in this office apart from individual workspaces. Office B and office C have a *corridor culture*, because, in addition to individual workspaces, corridors also act as an important interaction locus in these offices. About 21.22% and 22.14% of all observed interactions occur in the corridors of office B and office C, respectively. Office D has a *common-area culture*, because, in addition to individual workspaces, common areas act as an important interaction locus in the office. About 22.15% of all observed interactions, both formal and informal, occur in the common areas of office D (table 5).

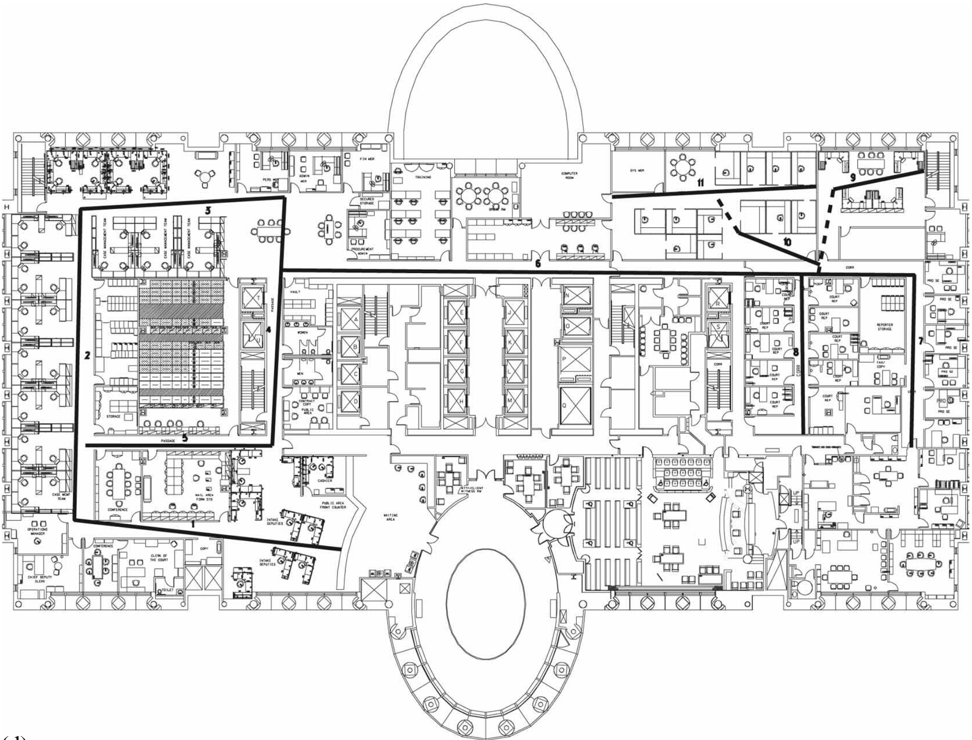
(a)



(b)

Figure 7. Observation routes: (a) office A, (b) office B, (c) office C, (d) office D.

(c)



(d)

Figure 7 (continued).

Table 4. Workspace and population data of the offices.

Office	Total number of workspaces	Occupancy rate (as percentage of the total number of workspaces)	Attendance rate (as percentage of the number of occupied spaces)
A	195	174 (89.23)	104.5 (60.05)
B	60	58 (96.67)	31 (53.44)
C	75	69 (92.00)	38.16 (55.30)
D	88	71 (80.68)	48 (67.61)

Table 5. Interactions in the offices. Values in parentheses refer to percentages.

Office	Interactions at different locations				All locations along the route
	individual workspaces	designated areas and/or meeting rooms	corridors	common and/or service areas	
A	109 (80.74)	15 (11.11)	7 (5.18)	4 (2.96)	135 (100.00)
B	60 (75.00)	0 (0.0)	17 (21.25)	3 (3.75)	80 (10.00)
C	77 (5.00)	13 (9.28)	31 (22.14)	19 (13.58)	140 (100.00)
D	99 (66.44)	5 (3.35)	12 (8.05)	33 (22.15)	149 (100.00)

Statistical analyses of the behavior and space-syntax data

According to our statistical analyses, there are very weak to very strong positive correlations between movement and interaction in our offices (table 6). The results suggest that the relationship between movement and interaction is inconsistent in these offices, and that in some cases organizational needs may be an important driver of interaction.

In contrast, there is a very strong correlation between copresence and interaction in each of the four offices. Even though the correlations between copresence and interaction are slightly reduced when accounting for movement, this mediating effect is not strong (table 6). In other words, copresence has predictable effects on interaction regardless of movement in these office spaces.

Table 6. The effects of movement and copresence on face-to-face interaction in the offices. Values in parentheses are p-values.

	Office A	Office B	Office C	Office D
Movement and interaction				
Correlation	0.132 (0.4656)	0.144 (0.672)	0.839 (<0.0001)	0.501 (0.1166)
Partial correlation with respect to copresence	−0.061	−0.011	0.498	0.365
Copresence and interaction				
Correlation	0.904 (<0.0001)	0.861 (0.0007)	0.889 (<0.0001)	0.741 (0.009)
Partial correlation with respect to movement	0.902	0.858	0.682	0.692
Copresence and movement				
Correlation	0.174 (0.3333)	0.174 (0.609)	0.785 (0.0005)	0.369 (0.2647)
Partial correlation with respect to interaction	0.130	0.099	0.158	−0.005

The previous space-syntax work showed positive correlations between movement and integration in urban settings (Hillier et al, 1993; Peponis et al, 1989). Accordingly, strong correlations between the integration value, the connectivity value, and the length of axial lines in a setting may suggest that some good correlations may also exist between the connectivity value, the length of axial lines, and movement. The findings of our study support the previous work. The spatial variables showed weak-to-strong positive correlations to movement (table 7). In simple words, in these offices spatial layout had predictable positive effects on movement.

In our offices the spatial variables generally showed negative and very weak correlations with interaction and copresence (table 7). According to these findings, people were engaged in fewer interactions in spaces, and were less visible from spaces with higher integration values, connectivity values, and longer axial lines. It is as if they avoided interacting with others in spaces and being seen with others from spaces with more visibility and accessibility, even though each of our organizations ostensibly encouraged interactions in public spaces.

Table 7. Correlations between spatial variables and observed behaviors in the offices. Values in parentheses are *p*-values.

	Office A	Office B	Office C	Office D
Integration and movement	0.325 (0.064)	0.769 (0.006)	0.393 (0.148)	0.412 (0.208)
Connectivity and movement	0.222 (0.215)	0.643 (0.327)	0.125 (0.658)	0.618 (0.043)
Length and movement	0.235 (0.189)	0.531 (0.931)	0.226 (0.418)	0.663 (0.026)
Integration and interaction	−0.252 (0.157)	−0.131 (0.701)	0.188 (0.503)	−0.273 (0.417)
Connectivity and interaction	−0.221 (0.217)	−0.078 (0.820)	−0.053 (0.850)	−0.058 (0.865)
Length and interaction	−0.130 (0.471)	−0.289 (0.389)	0.051 (0.856)	0.025 (0.942)
Integration and copresence	−0.182 (0.310)	−0.112 (0.743)	0.186 (0.506)	−0.554 (0.077)
Connectivity and copresence	−0.163 (0.363)	0.041 (0.905)	0.146 (0.604)	−0.395 (0.230)
Length and copresence	−0.132 (0.464)	−0.313 (0.348)	0.248 (0.374)	−0.240 (0.477)

Discussion

In most previous research work on the relationships between office design and behavior, the mechanisms for linking office design to face-to-face interaction remained unclear. In particular, with a few notable exceptions, much behavioral research of the office environment also appears to have left out an important factor: the overall layout of the office. In this paper we have reported a study in which we used space-syntax theories and methods to address questions of how patterns of overall layout affect movement, visible copresence, and face-to-face interactions in offices. Space syntax is interesting because it allows us to describe the generic properties of spatial layouts in a rigorous way.

Another limitation of the previous work on interaction and communication in the office environment has been that the set of environmental variables used in these studies was context dependent. For example, variables used for describing open-plan offices were often different from those used for describing cellular plans. As a result, it was difficult to perform a comparative study of widely different office offices. Space syntax eliminates the problem, because its methods of description using an axial map can be used to study any physical setting without ambiguity.

It is also necessary to note here that there is a significant lack of studies involving movement, visible copresence, face-to-face interaction, and layout attributes. Until now, there has been no consistent technique for observing these behaviors. As a result, researchers have been unable to investigate the relationships among these behaviors and layout attributes in different settings. Thus the mediating effect of any one of these behaviors on the relationships between the other two behaviors remained unnoticed. In this regard, we have presented a methodological innovation. We showed how these behaviors can be consistently and simultaneously observed by taking axial segments as units of behavioral observation.

This study of four offices, each wanting to increase organizational performance through increased interaction (that is, communication), reveals several interesting aspects. According to our space-syntax analyses, these offices were laid out to meet different organizational needs, including the needs for increasing face-to-face interactions.

However, according to our behavioral analyses, despite good design intentions, face-to-face interactions did not occur in a predictable manner.

The behavioral observations showed that, in these offices, most interactions occurred in individual workspaces, despite the fact that the organizations encouraged interactions in public spaces and provided ample public and semipublic spaces for interactions. The fact that people prefer to interact in individual workspaces when other choices are available in semipublic and public territories may point to the importance of social and cultural dimensions of interaction. In this context, the idea of the spatial culture of interaction, which is presented in this paper, may be important. It shows that different organizations require different locations for interactions besides individual workspaces, and that the factors that drive people to prefer individual spaces for face-to-face interaction must be considered both in the design of space and in the design of concomitant organizational processes and cultural norms. Designers can promote the spatial culture of interaction of an organization by investing in the right kind of spaces, or they can destroy it by investing in the wrong kind of spaces.

Another important finding of the study was that the relationships between visible copresence and face-to-face interaction were significantly consistent in all four offices, and the effects of movement on these relationships were negligible. This finding is important because it suggests that visible copresence may be important for face-to-face interaction in an office, and that an office with more visible copresence may result in more face-to-face interactions regardless of movement. The fact that visibility of people is an important factor in interaction has been observed by other researchers as well. For example, Hall (1966) reports that, when two workers face each other, eye contact and conversation are likely to increase. Parsons (1976) reports that a worker is more likely to walk over and talk with another worker if she can see the worker from her position. However, until now the effect of movement on the relationship between visible copresence and face-to-face interaction in offices remained unknown.

Finally, we must point out the importance of organizational programs in defining the relationships between spatial layout and face-to-face interaction. According to our findings, in all four offices studied, there were no consistent relationships between the spatial variables and interactions (table 7). One limitation of the research was that we did not study whether the lack of correlation between spatial layout and face-to-face interaction represented resistance by staff to the new officing strategies, or whether management had not adequately altered the organizational culture that limited the flow of ideas and collaboration. If a manager had used increased visibility in a new office to increase visual control, it would be natural to assume that workers would avoid face-to-face interaction in visible group spaces, though such interaction might serve valuable organizational purposes. Our study would suggest that spatial layout on its own might be insufficient to generate, sustain, and increase interaction without the necessary changes in the attitudes, programs, and policies of an organization.

Acknowledgements. This research was made possible by a contract (4806X37) from the US General Services Administration.

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