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Workplace collaborative space layout typology and occupant perception of collaboration environment

Ying Hua
Department of Design and Environmental Analysis, Cornell University, Ithaca, NY 14853, USA; e-mail: yh294@cornell.edu

Vivian Loftness
School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15213, USA; e-mail: loftness@andrew.cmu.edu

Robert Kraut
Human – Computer Interaction Institute, Carnegie Mellon University, Pittsburgh, PA 15213, USA; e-mail: robert.kraut@cmu.edu

Kevin M Powell
Office of Applied Science, GSA Public Building Service, US General Services Administration, Washington, DC 20405, USA; e-mail: kevin.powell@gsa.gov
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Abstract. The value of effective collaboration has become increasingly critical for organizational performance and agility. Along with technical and managerial strategies, the workspace spatial environment needs to be recognized and studied for its impact on collaboration and interactive behavior at work. Most spatial parameters studied in the workplace research literature are workstation-scale characteristics. However, these may not sufficiently describe the variety of shared spaces in which collaborative work and interactions take place. Based on a two-year multiple-site field study of workplace settings, this paper explores the space typology of a wide spectrum of formal and informal collaborative spaces, and it introduces a new set of layout-scale quantitative indices to describe the amount and distribution of collaborative spaces in a workplace. This research tested layout-scale spatial variables and compared them with workstation-scale variables in order to determine how well these variables predict the occupants' perception of the support from their workplace spatial environment for collaborative work and the distractions from others' interactive behavior in the work environment. The design implications of the findings are explored, and future research directions are identified.

1 Introduction

A rich body of literature from various disciplines has demonstrated the impact of the workplace's physical environments on the perception, behavior, and performance of people at work. The literature examines the sociopsychological impact of spatial settings on individual reactions to work and to the work environment in particular depth. Table 1 summarizes the parameters of existing studies, which include workplace spatial parameters, occupant experience, and outcomes, as well as job characteristics and relevant personality factors. Note that most of the spatial parameters studied in the literature were characteristics of individual workstations or workstation-scale measurements.

The few variables in the literature that looked beyond workstation scale include workplace openness, visibility, and accessibility. Workplace openness refers to "the ratio of total square footage of the office to the total length of its interior walls and partitions" (Oldham and Rotchford, 1983, page 542). In a strict sense, it is not exactly a layout variable. For two workplaces with the same square footage, the one with fewer walls and partitions is considered to be more open. Defined this way, openness does not account for variance in the height of partitions; however, partitions of the same length and differing height do make quite a difference in the sense of 'openness'. In some studies, the word 'openness', as in visual openness, has been used interchangeably with visibility.

Table 1. Parameters studied in the literature of workplace research.

Workplace spatial parameters	Individual environmental experience	Interperson experience	Outcomes/ reactions	Job characteristics	Personality
Having a door (open cubicle vs closed office) (Hatch, 1987)	Privacy (Oldham, 1988; Schuler et al, 1981; Sundstrom et al, 1980; Zalesny and Farace, 1987)	Frequency of interpersonal contact (Allen, 1977; Gullahorn, 1952; Kraut and Streeter, 1995)	Job (work) satisfaction (Oldham and Brass, 1979; Oldham and Fried, 1987)	Job type/position (Zalesny and Farace, 1987)	Need for privacy (Oldham, 1988)
Workspace size (Oldham and Rotchford, 1983; O'Neill and Carayon, 1993; Veitch et al, 2003)	Concentration/ distraction (Oldham and Brass, 1979)	Interpersonal satisfaction (Oldham and Brass, 1979)	Work environment satisfaction (Charles and Veitch, 2002; Oldham, 1988)	Skill variety (Oldham and Brass, 1979)	Stimulus screening ability (Oldham, 1988; 1991)
Level/degree of enclosure (partition height and number of partitions) (Charles and Veitch, 2002; Hatch, 1987; Oldham and Brass, 1979; Oldham and Fried, 1987)	Crowding (Desor, 1972; Evans et al, 1994; Oldham, 1988)	Interpersonal relationship (Zalesny and Farace, 1987)	Self-perceived performance (Brennan et al, 2002)	Autonomy (Oldham and Brass, 1979)	Adaptability (Schuler et al, 1981)
Interpersonal distance/proximity (Allen, 1977; Gullahorn, 1952; Kraut and Streeter, 1995; Kraut et al, 2002; Oldham and Fried, 1987; Olson et al, 2002; Schuler et al, 1981; Sundstrom et al, 1980)	Stress (Sparks and Cooper, 1999; Watson et al, 1986)	Interpersonal relationship (Brennan et al, 2002; Zalesny and Farace, 1987)	Supervisor rating of performance (Sundstrom et al, 1980)	Task interdependence (Schuler et al, 1981)	Sociability (Hatch, 1987)
Desk position (in relation to office entrance) (Hatch, 1987)	Work area's adequacy (Zalesny and Farace, 1987)	Supervisor feedback (Oldham and Brass, 1979)	Office turnover (Oldham and Fried, 1987)	Task complexity (Oldham et al, 1991)	
Visible to superior/coworker (Sundstrom et al, 1980)		Coworker/agent feedback (Oldham and Brass, 1979)	Motivation (Oldham and Brass, 1979)	Task identity (Oldham and Brass, 1979)	
Distance from corridor (Sundstrom et al, 1980)		Friendship opportunities (Gullahorn, 1952; Oldham and Brass, 1979)	Discretionary withdraw (Oldham and Fried, 1987)	Task significance (Oldham and Brass, 1979)	
Density (Dean et al, 1975; Fried et al, 2001; May et al, 2005; Oldham and Fried, 1987; Oldham and Rotchford, 1983)		Trust (Zalesny and Farace, 1987)			
Openness (Oldham and Rotchford, 1983; Peponis and Wineman, 2002)					
Accessibility (Oldham and Rotchford, 1983; Peponis and Wineman, 2002; Schuler et al, 1981; Sundstrom et al, 1980)					
Visibility (Peponis and Wineman, 2002)					

Results from studies on the relationship between visual openness and workplace interaction were not consistent. For example, Gutwin and Greenberg (2002), who focused on situation awareness, stated that the visibility of others and their behaviors allow for easy interactions and shared understanding of the overall context, while Brill et al (2001) believed that physical openness does not support open communication.

Another spatial variable related to the workplace layout is accessibility, the "extent to which an employee's individual workspace is accessible to the external intrusions of others" (Oldham and Rotchford, 1983, page 543). However, often the only differentiation made has been whether or not the workstation was in an open setting or enclosed by a door. The application of space syntax theories and techniques, originally developed for street and neighborhood design, enables us to look into more details regarding accessibility and visibility.

The analysis of building interiors using the space syntax methodology looks at lines of movement and visual fields to explain how spatial layouts affect face-to-face interactions through their effects on movement and visible copresence (Peponis and Wineman, 2002; Rashid et al, 2006). This methodology was also used to examine other features of the workplace, such as the shape of floor plates (Shpuza, 2006) and furniture systems (Bafna, 2004). The strength of space syntax methods is that they create a way to describe the overall layout of the workplace. However, the link between the spatial variables used in this method—that is, accessibility, openness, and visibility—and workplace design features (the location and size of various types of spaces in workplace) is not strong. These factors make space syntax a more powerful tool for evaluating an existing layout than for directly assisting workplace design.

When we look at the changing nature of white-collar work, the trend toward interactive and collaborative work is among the biggest changes (Lawler, 2001; Nadler et al, 1997), along with more dependence on social skills (Heerwagen et al, 2004). The current workforce is specialized in terms of knowledge and skill sets, and multidisciplinary and cross-functional collaboration is becoming an important element—critical for the efficiency, profitability, and competitive advantage of organizations (Duffy and Powell, 1997; Ilozor et al, 2002). The value of the workplace itself in stimulating successful collaboration has attracted our attention (Becker, 2004; Davenport, 2005; Duffy, 1992; Worthington, 1997). Though not responsible for creating actions or behaviors themselves, certain spatial settings may facilitate or inhibit desired behaviors and thus affect the use of time and energy in an organization (Porras and Robertson, 1992).

After examining the behavioral research on workplace environments, it appeared that most of them focused on individual workstations while ignoring an important factor: the overall layout (Rashid et al, 2006). Further, the spatial variables have been mostly of workstation scale, and new research is needed to explore the layouts of a wide spectrum of shared spaces in terms of both workplace-scale and layout-scale spatial variables.

The aims of this research are: to explore the typology of collaborative spaces in a sample of office layouts; to develop quantitative indices that describe the distribution and amount of collaborative spaces in a workplace; and to explore how well these indices predict the occupants' perception of the influence of workplace layout on support for collaborative work and distractions from interactive behaviors. Identifying effective floor-plan layout variables will contribute to the theories of workplace design in supporting collaborative performance.

Though this paper emphasizes the value of interaction and collaboration in the workplace, it is clear that most white-collar workers experience an iterative process of individual and collaborative tasks. Their ability to accomplish both types of task is important to work performance. This study of collaborative spaces in the workplace also reflects that iterative process.

2 Hypotheses

The hypotheses tested in this paper are the following:

Hypothesis 1: *There are clear differences between workplace layouts on the basis of distances between workstations and various collaborative spaces—for example, meeting space, shared service space, and amenity space.*

Hypothesis 2: *The distribution and number of collaborative spaces in the workplace impact occupants' perceptions of how a spatial work environment supports or inhibits collaborative work.*

Hypothesis 3: *Layout-scale spatial measures are better predictors of how well occupants rate the capacity of a work environment to support collaboration, in comparison with workstation-scale measures.*

3 Methodology

3.1 Field study

This paper reports an empirical study of office layouts carried out from March 2005 to February 2007 in eleven office buildings in eight different US cities. All buildings studied were public workplaces. The sites were selected with help from the General Service Administration, on the basis of building accessibility and the similar level of need for collaboration in the work activities which these buildings accommodate. The vintage and spatial layout of the buildings studied were representative of the profile of workplaces in the public sector.

Within those buildings, twenty-seven different workplace settings were studied, and 308 office workers participated in this study. Demographic information of the participants is shown in table 2.

Table 2. Demographic and organizational information of participants. Percentage values are given in parentheses.

Gender			*Age*		
Female	161	(52.3)	<20	10	(3.2)
Male	147	(47.7)	20 – 29	56	(18.3)
			30 – 39	58	(18.7)
Job category			40 – 49	81	(26.3)
Executive/managerial	53	(17.1)	50 – 59	85	(27.7)
Professional/technical	219	(71.2)	$\geqslant 60$	18	(5.8)
Clerical/support	34	(11.0)			
Other	2	(0.7)			

3.2 Definition of collaborative spaces at work

A collaborative work environment features "highly diverse places that recognized and accommodated, even celebrated, the value of giving people lots of choice in where and when and how they worked" (Becker, 2004, page xix). By collaborative spaces, we mean not just spaces explicitly identified or designed for collaborative work, such as team rooms or conference spaces, but also spaces that may potentially be used for collaborative work and casual interactions.

There is a wide spectrum of formal and informal collaborative places at work. Three categories of collaborative space were classified in this study: team-work-related, service-related, and amenity-related spaces in which interactive behaviors take place. Team-work-related collaborative spaces include conference rooms in

formal settings, open meeting areas in less formal settings, and team rooms in which certain work groups have priority for their meetings and group work. Service-related spaces refer to shared service areas in which large-volume copiers, printers, and other shared office equipment are located. Examples of amenity-related spaces at work in which conversations and collaborative work may take place include kitchens, coffee areas, and lounges. All the above spaces are either dedicated or readily accessible spaces for meetings and impromptu interactions. In addition, we are aware that conversations also take place in circulation areas, although they are not the focus of this paper.

Different types of collaborative places at work have different advantages in facilitating certain types of interaction and collaboration. For example, meeting rooms are often used for scheduled meetings and training. A significant amount of social networking, information transfer activities, and some coordinated work occur in shared service areas when people are waiting for printouts or run into each other. In kitchens and coffee areas, social networking, information transfer, and the creative development of ideas that lead to future collaborative work are commonly observed activities. As an important component of the platform for activities at work, the layout of these places impacts the possibility, frequency, duration, and content of communication and collaborative work among individuals at those locations. The arrangement and design of these places also reflect the image and management style of an organization.

3.3 New spatial variables

Six layout-scale spatial variables are proposed in this paper to describe the distribution and number of collaborative spaces in a workplace. We studied their relationship to the occupants' satisfaction with the spatial work environment's ability to support collaboration using the following variables:

- distance from individual workstation to nearest meeting space;
- distance from individual workstation to nearest shared copy or print area;
- distance from individual workstation to nearest shared kitchen or coffee area;
- percentage of floor space dedicated to meeting spaces;
- percentage of floor space dedicated to shared service and amenity spaces; and
- openness.

Distances in this paper were computed using 'graph metric' geometry, which is the shortest distance between two points along an orthogonal path that passes inside the shape (floor plate). This method was chosen in lieu of other approaches to compute distance between spatial units in a plan—for example, the taxicab or rectangular distance, the Euclidian or straight-line distance (Matela and O'Hare, 1976a; 1976b; Shpuza, 2006)—because the graph metric distances reflect the circulation routes in workplaces—that is, the distance that occupants travel to get from one place to another. The openness variable was calculated as the percentage of workstations in open settings—that is, cubicles—out of the total number of workstations, including both cubicles and closed offices.

In addition to the new layout-scale variables, five frequently used workstation-scale spatial variables identified in the literature were included in the analysis, and these variables were critical for testing hypothesis 3. They are workstation size, partition height, distance to the nearest coworker, workstation density, and the presence of a door to the workstation.

3.4 Method

Spatial documentation, a floor-plan analysis, and a workplace collaborative environment questionnaire were conducted in the twenty-seven workplace settings. The spatial variables for each participant's workstation were calculated on the basis of the best available floor plans, combined with an 'expert walk-through'. In addition to recording the layout characteristics of each workgroup, detailed spatial documentation was carried out for each collaborative space at all of the sites. The information collected included the location of these places on the floor plans, the level of enclosure, furnishing and arrangement, the presence of tools and technology, the availability or scheduling protocol (if applicable), and any other spatial characteristics, such as views to the outside, plants, or art.

The workplace collaborative environment questionnaire was administered to collect data about office workers' satisfaction with the size, location, enclosure, and arrangement of various collaborative spaces. The fifteen environmental satisfaction items from the questionnaire were reduced to two scales through the use of factor analysis. One scale indicated occupant-perceived support from the work environment for collaboration (nine items); the other indicated occupant perceived distraction from others' interactive behavior in the work environment (six items). Participants were also asked to report on the locations in a workplace that they prefer to use for collaborative work and casual interactions.

In order to test the hypotheses a typology study was carried out on the twenty-seven workplace settings, according to the three types of collaborative spaces at work: team-work-related, service-related, and amenity-related spaces. Additionally, correlation and regression analyses were performed to test the spatial variables' capacity to predict occupant perception.

4 Analysis

4.1 Typology study

4.1.1 *Teamwork-related space (meeting space)*

Of the twenty-seven workplace settings studied, seven meeting space layout types were identified (figure 1) on the basis of combination of number, size, distance, and ownership characteristics of meeting spaces. The average distance from individual workstations to the nearest meeting space for each layout type appears in table 3. An ANOVA test showed that the workstation-to-meeting distance was significantly different among these diverse layout types, with an F-value at 56.98 and a p-value < 0.0001.

For the seven meeting space layout types, the average levels of occupant-perceived support for collaboration and perceived distraction are also summarized in table 3. Respondents in workgroups with meeting layout type M6 (distributed meeting rooms around the core) and layout type M7 (distributed meeting rooms both around the core and at the corners) have a significantly higher level of perceived support for collaboration from their work environment than have respondents in other layout types (figure 2), and they also have a lower level of perceived distraction.

Besides the location of meeting spaces, the percentage of floor space dedicated to conference rooms or open meeting areas could also impact collaboration and interaction activities at work. Figure 3 summarizes the relationship between the two spatial characteristics of meeting space—amount of space and layout—for the twenty-seven settings. For the floors with no dedicated meeting space, the average workstation-to-meeting distance shows as 250 ft only symbolically, which is greater than the maximum

workstation-to-meeting distance identified in this study. In general, more floor space dedicated to meeting use is associated with a shorter distance between workstations and meeting spaces. Figure 3 also shows that when the percentage of floor space dedicated to meeting space exceeds 10% its impact on reducing workstation-to-meeting distance is no longer obvious.

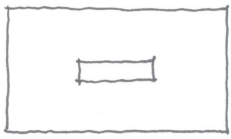
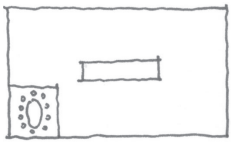
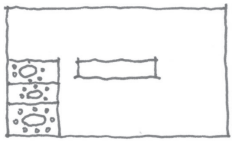
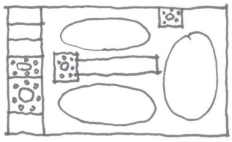
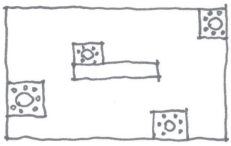
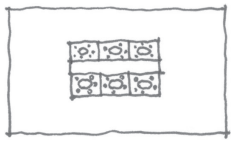
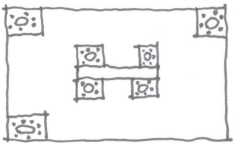
	Diagram	Description
M1		No dedicated meeting space on the floor (often cases with meeting space in supervisor's office).
M2		One big meeting room for the whole floor.
M3		Group meeting rooms with various sizes.
M4		Distributed meeting rooms, not reflecting occupant density (often concentrated close to closed offices).
M5		Evenly distributed meeting rooms, reflecting occupant density.
M6		Distributed meeting rooms, located around the core (easy to find).
M7		Distributed meeting rooms, around the core and at the corners (with views to the outside).

Figure 1. Typology of meeting space layout.

Table 3. Workstation-to-meeting distance for different layout types and occupant ratings.

	Number of settings	Number of participants	Mean distance from workstation to the nearest meeting space (ft)	Standard deviation (SD) (ft)	Perceived *support* from the work environment		Perceived *distraction* from the work environment	
					mean	SD	mean	SD
M1	5	16	n/a	n/a	3.15	0.61	3.14	0.75
M2	3	21	130.1	45.0	2.56	0.78	2.96	0.78
M3	2	22	117.0	49.0	2.23	0.50	2.72	0.81
M4	7	114	84.6	43.9	2.94	0.79	2.94	0.81
M5	6	54	73.7	37.4	2.64	0.96	2.93	0.67
M6	2	14	35.5	21.3	3.60	0.76	2.89	0.63
M7	2	24	39.5	18.5	3.88	0.54	2.78	0.60

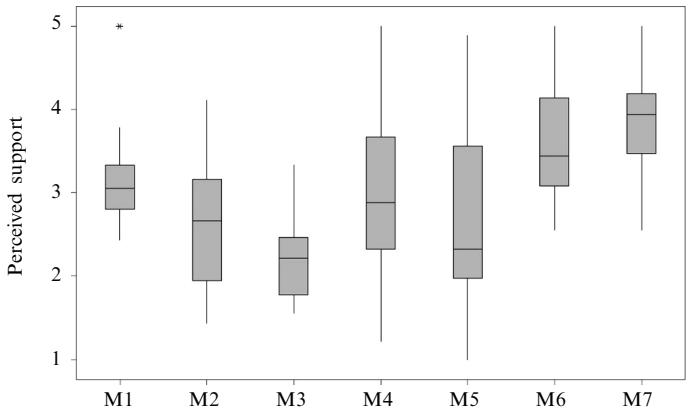


Figure 2. Perceived support for collaboration by meeting layout type (higher is better). An asterisk indicates an outlier.

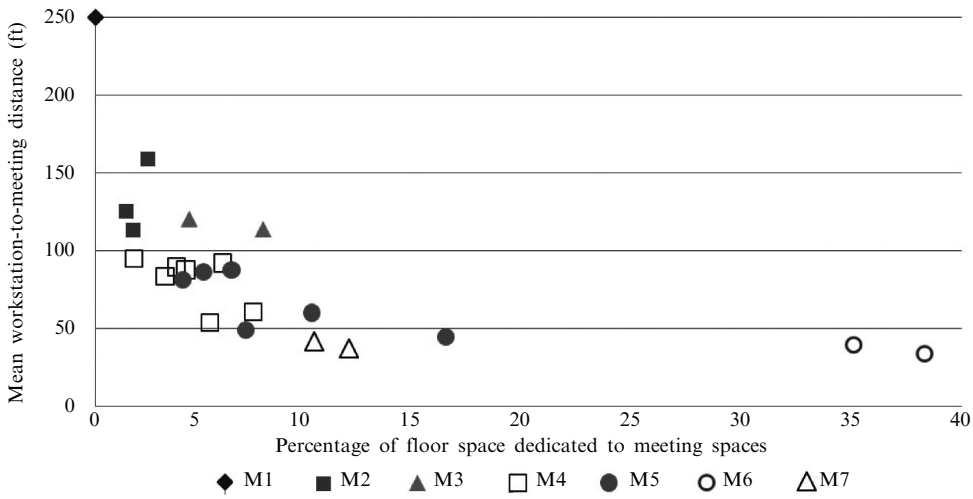


Figure 3. Amount of meeting space and mean workstation-to-meeting distance.

4.1.2 *Service-related spaces (shared print/copy areas)*
Four layout types were identified for the shared print/copy areas in the twenty-seven workplace settings (figure 4). The average distances from individual workstations to the nearest shared print/copy area for each layout type are summarized in table 4. An ANOVA test revealed that the workstation-to-service distance was significantly different among layout types, with an F-value of 3.02 and a p-value of 0.05.

For the layout type in which shared printers and copiers were located on main circulation aisles (C2), the average workstation-to-copier distance was the shortest, followed by the layout type in which shared printers and copiers were in dedicated hubs distributed to serve neighborhoods of workstations (C4). The shared print/copy areas with C4 layout type were often in enclosed or semienclosed rooms, which had a more clearly defined space and better acoustic insulation. For workgroups for which shared print/copy areas were in dedicated central locations (C3), such as the building core, the average workstation-to-copier distance was the longest.

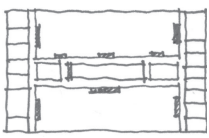
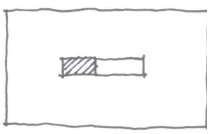
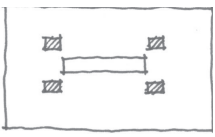
	Diagram	Description
C1		Copiers located randomly in vacant workstations.
C2		Copiers located on circulation aisles.
C3		Copiers in dedicated space, centralized (often in the building core, serving the whole floor).
C4		Copiers in dedicated hubs, distributed to serve neighborhoods of workstations.

Figure 4. Typology of shared print/copy space layout.

For the four shared print/copy space layout types, the average levels of occupant perceived support for collaboration and perceived distraction are also summarized in table 4. Respondents in workgroups with layout type C4 (copiers in distributed but dedicated spaces) have a significantly higher level of perceived support (figure 5), and they also have a lower level of perceived distraction (figure 6). In contrast, the layout types C1 and C2 have shared printers and copiers either in vacant workstations or on main circulation aisles. They are the most common in workplaces and are associated with significant distraction for occupants working in nearby workstations.

Table 4. Workstation-to-service distance for different layout types and occupant ratings.

	Number of settings	Number of participants	Mean distance from workstation to nearest shared service space (ft)	Standard deviation (SD) (ft)	Perceived *support* from the work environment		Perceived *distraction* from the work environment	
					mean	SD	mean	SD
C1	12	144	65.1	52.1	2.55	0.82	3.02	0.70
C2	7	32	36.1	18.9	3.23	0.68	2.96	0.66
C3	5	61	87.2	48.5	3.18	0.71	2.75	0.92

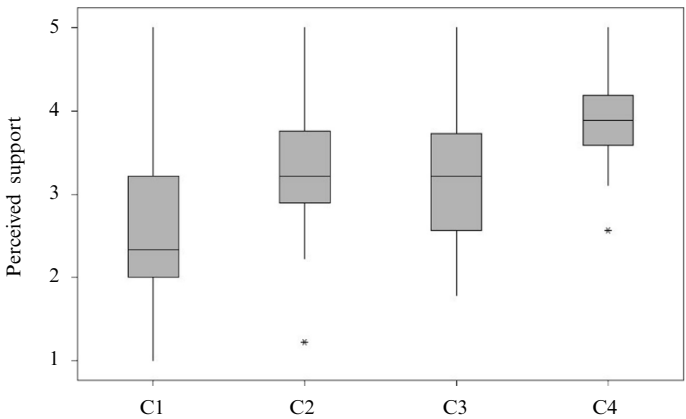


Figure 5. Perceived support for collaboration by service layout type (higher is better). Asterisks indicate outliers.

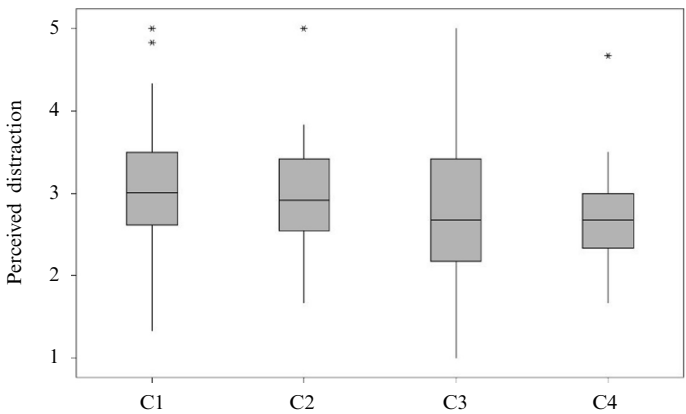


Figure 6. Perceived distraction from work environment by service layout type (lower is better). Asterisks indicate outliers.

4.1.3 *Amenity-related space (shared kitchen or coffee areas)*

Finally, five layout types were identified for the shared kitchen or coffee areas in the twenty-seven workgroup settings (figure 7). The average distance from individual workstations to the nearest shared kitchen or coffee area for each layout type is summarized in table 5. An ANOVA test showed that the average distance from an individual workstation to the nearest shared kitchen or coffee area was significantly different among the layout types, with an F-value of 166.96.

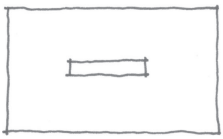
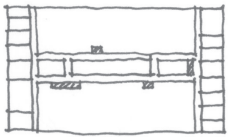
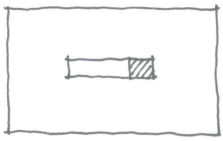
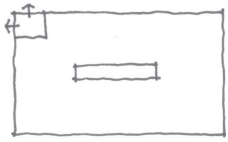
	Diagram	Description
K1		No kitchen or coffee area on the floor.
K2		Kitchen or coffee area located in vacant workstations.
K3		Kitchen or coffee area located in main circulation aisles.
K4		Kitchen or coffee area in dedicated space, centralized in the building core (without views to the outside).
K5		Kitchen or coffee area in dedicated space, on the perimeter (with views to the outside).

Figure 7. Typology of shared kitchen/coffee space layout.

Table 5. Workstation-to-amenity distance for different layout types and occupant ratings.

	Number of settings	Number of participants	Mean distance from workstation to nearest shared amenity space (ft)	Standard deviation (SD) (ft)	Perceived *support* from the work environment		Perceived *distraction* from the work environment	
					mean	SD	mean	SD
K1	4	20	n/a	n/a	3.32	0.63	3.01	0.73
K2	2	34	105.0	54.8	2.99	0.92	3.07	0.66
K3	3	25	58.2	40.0	2.93	0.66	2.93	0.61
K4	14	148	100.0	55.2	2.99	0.90	2.92	0.79
K5	4	38	133.2	53.1	2.35	0.76	2.70	0.75

The average workstation-to-kitchen distance was longer for the layout types in which the shared kitchen or coffee areas were in dedicated spaces (K4 and K5), compared with the types in which coffee pots and microwaves were allocated in vacant workstations (K2) or on circulation aisles (K3). In general, the kitchen or coffee area in dedicated spaces was both better furnished and better equipped.

The average levels of occupant perceived support for collaboration and perceived distraction regarding the five shared kitchen or coffee space layout types are summarized

in table 5. The results are less conclusive than those for the meeting space and shared print and copy space layouts. Overall, respondents in workgroups with layout type K4 (kitchen or coffee area in dedicated space, centralized in the core) have a fairly high level of perceived support and a low level of distraction. The expected positive impact of having a view to the outside from kitchen or coffee areas (K5) was not supported by the data collected in this study. However, K5 has the lowest level of perceived distraction on average, compared with other types.

4.2 Correlation

Results from the correlation analysis (table 6) revealed a significant association between occupants' perceived support from the work environment for collaboration and several workplace spatial characteristics, including both layout-scale variables and workstation-scale variables. A significantly higher level of perceived support was associated with a shorter distance from the workstation to meeting space, a lower level of floor-plan openness, and a higher percentage of floor space dedicated to meeting, service, and amenity spaces. Both the comparative location between workstations and collaborative spaces and the amount of space allocated for various collaborative spaces have an impact on occupants' perception of how well their spatial work environment supports their collaboration and interaction at work. Two workstation-scale variables were significantly associated with perceived support: longer distance to the nearest coworker and lower density, which both correlated with stronger perceived support.

At the same time, occupants' perceived distraction from interactive behavior in the work environment was significant only in association with two of the layout-scale spatial variables. A higher level of distraction was significantly associated with a shorter distance from the workstation to the shared service area and a lower percentage of floor space dedicated to service and amenity spaces. No workstation-scale variables were significantly associated with perceived distraction.

4.3 Regression analysis

A regression analysis was carried out to determine which features of the work environment best predict the degree of occupants' satisfaction with its capacity to support or detract from collaboration. A mixed-effects model was used because the data have a clustered structure. The model assumed two sources of variation, one within a workplace setting among individual occupants and another between workplace settings. Together with occupant demographic variables and five workstation-scale spatial variables, the six layout-scale variables proposed in this paper were the independent variables. Dependent variables included the occupants' perceived support for collaboration and distraction from interactive behavior in the work environment.

For perceived support the regression analysis started from a null model, which included the occupant's age, gender, and job type as independent variables. None of these independent variables turned out to be a significant predictor of the dependent variable. For the only fixed effect, the intercept, the estimate of 3.230 gave the average perceived spatial support for collaboration across the twenty-seven settings studied in a five-point scale, where a 3 signifies a neutral effect. Larger variance was found within workplace settings than between settings. In the next step five workstation-scale spatial variables (workstation size, partition height, distance to the nearest coworker, workstation density, and having a door to the workstation) were added to the model as additional independent variables (model 1). The model's fit significantly improved, as indicated by the $\Delta(-2\ \text{log-likelihood})$ (table 7). However, none of the workstation-scale variables was a significant predictor of perceived support, with p-values ranging from 0.134 to 0.758.

Table 6. Correlations among all variables ($N = 308$).

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age	0														
Gender	−0.005														
Job category	0.077	0.198**													
Perceived facilitation	−0.096	0.067	−0.047												
Distractions	0.057	−0.059	−0.018	−0.305**											
Distance to meeting	0.174**	−0.144*	−0.080	−0.196**	0.31										
Distance to shared copy/print	0.163**	−0.007	−0.061	0.079	−0.160**	0.097									
Distance to shared kitchen/coffee	0.024	0.019	0.025	0.060	−0.003	0.226**	0.154*								
Floor-plan openness	0.276**	−0.162**	−0.099	−0.127*	0.049	−0.061	0.057	0.150*							
Percentage of floor space for meeting	−0.409**	0.208**	0.085	0.177**	−0.029	−0.427**	−0.100	−0.224**	−0.627**						
Percentage of floor space for service and amenity	0.172**	−0.109	−0.078	0.142*	−0.137*	0.018	−0.036	−0.330**	0.101	−0.192**					
Workstation size	0.179**	0.134*	0.427**	0.067	−0.051	0.047	0.140*	0.231**	−0.299**	0.117	−0.069				
Partition height	0.016	0.129*	0.450**	0.022	0.025	0.033	−0.151*	0.127*	−0.357**	0.274**	−0.162**	0.684**			
Distance to nearest coworker	0.051	0.112	0.170**	0.229**	−0.120	−0.098	0.150*	0.145*	−0.277**	0.292**	−0.019	0.565**	0.377**		
Density	0.079	−0.112	−0.076	−0.190**	0.059	0.118	0.193**	0.138*	0.230**	−0.294**	−0.185**	−0.136*	−0.079	−0.258**	
Having a door	−0.002	0.180**	0.512**	0.048	−0.032	−0.086	−0.087	−0.033	−0.508**	0.335**	−0.075	0.679**	0.839**	0.385**	−0.097

*p-value <0.05; **p-value <0.01.

Table 7. Regression model fit statistics for perceived support.

	Null model	Add workstation-scale variables	Add layout-scale variables	Reduced model
−2 log-likelihood	585.2	604.9	641.9	
Δ(− 2 log-likelihood)		19.7	37.0	
Degrees of freedom	3	8	14	3
χ^2 distribution (Δ df, $\alpha < 0.05$)		11.07	12.59	
χ^2				34.15 ($p < 0.0001$)

By adding the six layout-scale spatial variables (workstation-to-meeting distance, workstation-to-service distance, workstation-to-amenity distance, percentage of floor space dedicated to meeting spaces, percentage of floor space dedicated to shared service and amenity spaces, and floor-plate openness), the fit of the model improved further (table 7). The within-setting and between-setting variance remained significant ($p < 0.05$). In this model three independent variables were identified as significant predictors of the perceived support from the work environment for collaboration. All of them are layout-scale variables. They are: distance from individual workstation to the nearest meeting space, distance from individual workstation to kitchen or coffee area, and the percentage of floor space dedicated to shared service and amenity areas. Again, no workstation-scale variables showed significance.

A reduced model with only the three significant predictors as independent variables for the perceived support remained statistically significant, as indicated by the χ^2-statistics ($p < 0.0001$) (table 7). Occupant perceived support for collaboration from the work environment increases with decreasing distance (in feet) from the occupant's workstation to the nearest meeting space; decreases with decreasing distance (in feet) from workstation to shared amenity area; and also decreases with a decrease in the percentage of floor space in workplace settings that are dedicated for shared service and amenity areas:

$$\begin{aligned}\text{perceived support} = {} & 3.124 - (0.003 \times \text{distance to nearest meeting space}) \\ & + (0.001 \times \text{distance to shared amenity area}) \\ & + (0.056 \times \text{percentage of floor space as shared service and amenity places for casual interactions}).\end{aligned}$$

Similar approaches were taken for the mixed effects regression analysis of the perceived distraction from interactive activities in the work environment. The model's fit improved with the addition of workstation-scale and layout-scale spatial variables. Only one independent variable was found to be a significant predictor for the perceived distraction: the distance from individual workstation to shared copy/print area. Step-by-step model fit statistics are shown in table 8. Occupant perceived distraction from interactive behavior in the work environment increases as the distance (in feet) from the occupants' workstations to shared service area decreases:

$$\begin{aligned}\text{perceived distraction} = {} & 3.105 - (0.003 \times \text{distance from workstation to shared service area}).\end{aligned}$$

Table 8. Regression model fit statistics for perceived distraction.

	Null model	Add workstation-scale variables	Add layout-scale variables	Reduced model
−2 log-likelihood	609.2	627.8	675.4	
Δ(− 2 log-likelihood)		18.6	47.6	
Degrees of freedom	3	8	14	1
χ^2 distribution (Δ df, $\alpha < 0.05$)		11.07	12.59	
χ^2				3.93 ($p < 0.0475$)

4.4 Preferred places for interaction

Though the focus of this study is shared spaces in the workplace, according to occupants' answers to the 'preferred places for collaborative and interactive behavior' question in the questionnaire there is a clear preference for individual workstations as places for collaborative work and casual interaction. Figure 8 shows a summary of the results. Individual workstations were reported by most participants (82.3%) to be used for casual conversations at work, followed by kitchen or coffee areas, reported as being used by 32.8% participants, and meeting rooms by 31.8%. Open meeting areas, shared print/copy areas, and circulation areas are also reported to be used for conversations, though less frequently, by 23.7% to 24.7% of participants. For collaborative work closed meeting rooms are reported by most participants (88.6%), followed by individual workstations (52.8%), and open meeting areas (24.7%). Shared print/copy areas, kitchen or coffee areas, and circulation areas are much less frequently reported to be used for collaborative work and were reported by 3.7% to 6.0% of all participants. Workstations are still critical elements in workplaces, and they need to be carefully designed and tailored to the nature of work in a particular organization in a way that considers their relationship with shared spaces in the workplace.

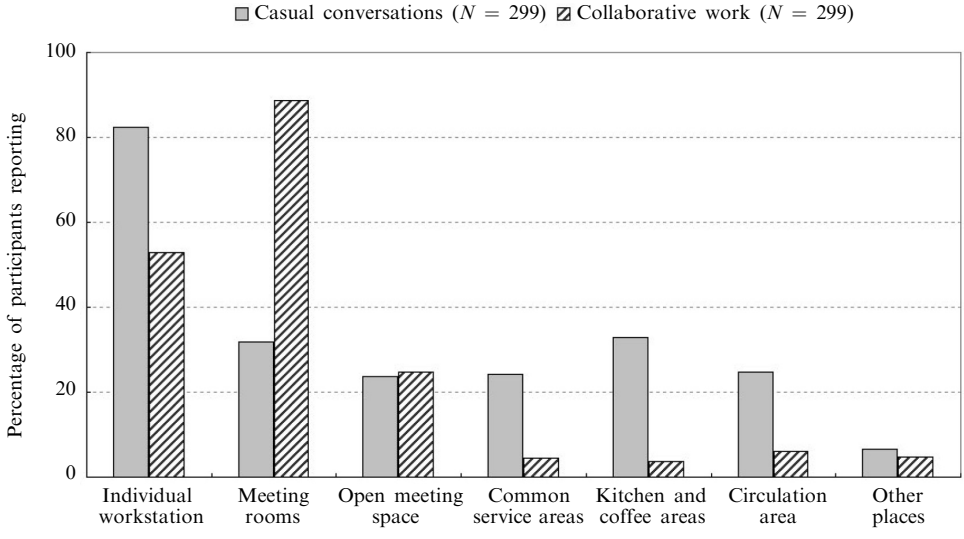


Figure 8. Self-reported preferred places for interaction and collaboration.

5 Conclusion

This paper is intended to bring attention to the collaborative spaces in workplaces and to identify layout scenarios of these spaces on the basis of an extensive literature review and a large-scale field study of twenty-seven workplace settings. Six new layout-scale spatial variables were proposed for workplace studies to amend the workstation characteristics studied in the existing literature. They are: distance from individual workstation to nearest meeting space; distance from individual workstation to nearest shared copy/print area; distance from individual workstation to nearest shared kitchen or coffee area; percentage of floor space dedicated to meeting spaces; percentage of floor space dedicated to shared service and amenity spaces; and openness. The new variables were preliminarily tested for their ability to predict occupant satisfaction with support from a collaborative work environment.

Three hypotheses were tested: hypothesis 1—there are clear differences between workplace layouts on the basis of distances between workstations and various collaborative spaces (eg meeting space, shared service space, and amenity space); hypothesis 2—the distribution and number of collaborative spaces in the workplace impact occupants' perceptions of how a spatial work environment supports or inhibits collaborative work; hypothesis 3—layout-scale spatial measures are better predictors of how well occupants rate the capacity of a work environment to support collaboration, in comparison with workstation-scale ones.

Hypothesis 1 was supported by the results from the typology study. On the basis of distances between workstations and various collaborative spaces there are clear differences between layouts. Hypothesis 2 was supported by the correlation and regression outcomes. The distribution and number of collaborative spaces in workplaces as indicated by the six new layout-scale variables impact occupants' perception of how a work environment's space supports or inhibits collaborative work. The empirical data provided strong and consistent evidence that the layout of various collaborative spaces in a workplace directly impacts office workers' perceptions of how well the work environment supports collaboration. Hypothesis 3 was supported by the results of the mixed-effects regression analysis. Layout-scale descriptors of how collaborative spaces are organized in floor plates were found to be more significant predictors than workstation-scale variables of how well occupants rate the capacity of a work environment to support collaborative work.

6 Discussion

Meeting space layout types M6 and M7, which have distributed meeting rooms located around the core or at the corners of a floor plate, often have a shorter average distance from workstations to a meeting space. These two layout scenarios were also found to have the highest perceived support from the work environment for collaborative work and low perceived distraction. Shared service space layout type C4, with copiers in dedicated hubs distributed to serve neighborhoods of workstations, has the highest perceived support and the lowest distraction reported among all service space layout types, though its average workstation-to-service distance is not the largest among all types. For the shared amenity space layout types, the difference between the capability of different settings to support collaboration and minimize distraction was not very obvious. The tendency for a longer workstation-to-amenity distance to be associated with higher perceived support and lower distraction was observed. Floor space dedicated to collaborative spaces, especially informal collaborative spaces such as shared service and amenity areas, was found to be critical for perceived support for collaboration.

As a platform for both individual and interpersonal work activities, the workplace spatial environment is a resource that has functional, technical, social, and economic implications; however, in most instances the effect of space has yet to be recognized. The accomplishment of individual concentrated tasks and high quality teamwork are both key elements in organizational performance. While the two have very different and sometimes even contradicting requirements for the workplace spatial environment, the designer must properly address the tension between the needs for concentration and interactions through spatial design schemes in order to design a workplace for effective collaboration. Different schemes of workplace spatial design can either facilitate or inhibit desired behaviors at work, and thus they can yield different results in spatial satisfaction, work performance, and further economic outcomes. In this paper we have taken this tension into account and conducted a preliminary exploration of the spatial solutions to address it. Our approach was to examine both the perceived support from the work environment for collaboration and the distraction from interaction behaviors at work. The findings from this study have design implications.

In general, the regression models generated clear suggestions regarding the design of collaborative space in a workplace. Meeting spaces need to be located close to neighborhoods of workstations to ensure a high level of occupant-perceived support for collaboration. Nearby meeting rooms enable occupants to use those spaces to carry out their collaborative work and casual interactions as needed. Importantly, these meeting spaces need to have good acoustic enclosure to avoid distracting occupants in nearby workstations.

Unlike the case of meeting spaces, the value of shared service and amenity areas in workplace collaboration lies largely in their ability to accommodate impromptu encounters among coworkers, which can initiate interactions for socialization, information exchange, work coordination, and creative development. However, it is also a fact that the encounters and interactions at those locations can generate both visual and acoustic distractions for occupants in nearby workstations. Thus, carefully designed dedicated spaces for shared functions are preferred over the solution in which printers, copiers, and coffee pots clutter circulation aisles or occupy vacant workstations. Dedicated locations not only provide an opportunity for better enclosure and technically superior services, but they also recognize these important functional spaces as attractive interaction and collaboration nodes. In addition to the layout, more floor space dedicated to service-related places for casual interactions is also preferred because it increases the possibility of moving noise-generating activities away from workstations.

The results in this study present a coherent view of how particular layouts can support or inhibit collaborative work. They also suggest a particular type of spatial organization to support collaborative work—namely, a uniformly distributed clustered organization of shared spaces (M6, M7, and C4)—as preferable to centralized space solutions or randomly distributed spaces.

7 Future research

Future research directions are indicated by some limitations of this study.

(1) The outcome variables in this study were self-reported perception data. Observation or behavioral mapping studies in the future may reveal more insights into the behavior pattern of how workplace occupants actually use the various types of shared spaces. An effort to collect measured collaboration performance data in the future will enable us to examine the effect of workplace spatial settings on collaboration effectiveness.

(2) This paper proposed six new layout-scale variables and preliminarily compared the capacity of these variables, relative to workstation-scale variables, in order to predict occupants' perceptions of collaborative spaces in the workplace. Global indices, such as the level of integration of a floor plan used in space syntax, were not examined or compared with the six layout-scale variables.
(3) The self-reported data in this study indicated an overwhelming preference for individual workstations, both for collaborative work and for casual interaction, though none of the workstation-scale spatial variables turned out to be a significant predictor of perceived support and distraction in the regression model. Besides adopting behavioral mapping methods in future studies to explore the actual use of individual workstations and shared spaces in workplaces for collaborative work and casual interactions, the survey instrument needs to be developed further to examine, in greater detail, an occupant's perception of an individual workstation's ability to support collaboration and to reduce distraction caused by interactive behavior taking place in it, by expanding items inquiring about various aspects of individual workstations.
(4) In the future, in addition to spatial layouts, the quality of collaborative places is also an interesting topic to explore. Many other design features could also have significant impacts on collaborative behavior, such as size, enclosure, furnishing, artifacts, tools, and technology, as well as the relationship between different types of collaborative spaces in a workplace.
(5) In the mixed-effects regression model a fairly large amount of between-group variation in perceived support from the work environment for collaboration remained unexplained. This study included occupant age, gender, and job type as demographic and organizational control variables. In future studies organizational variables could be examined in greater detail to understand their impact, including job characteristics and personality variables, as indicated in table 1.

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