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Building spatial layout that supports healthier behavior of office workers: A new performance mandate for sustainable buildings

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Abstract.
BACKGROUND: The pursuit of efficiency and the permeation of communication technologies in modern workplace have increased prolonged sitting and physical inactivity among the white-collar workforce. Physical inactivity is a major risk factor for developing various chronic diseases and obesity.
OBJECTIVE: This study intends to understand the impact of physical environment on both voluntary and imperative physical activity levels in an office building, and to collect evidence for design suggestions to encourage office workers' activity level on a daily basis. This study examined how proximity from individual workstations to various shared service and amenity spaces in the workplace (e.g., meeting spaces, copy areas, kitchens, restrooms, elevators, and stairs) is associated with office workers' physical activity level (e.g., sedentary and non-sedentary behavior) and their environmental and job satisfaction.
PARTICIPANTS AND METHODS: To objectively measure physical activity, twenty-six office workers, in a three-story office building, wore accelerometers for three consecutive days at work. Environmental and job satisfaction of office workers was measured by a questionnaire. Proximity variables were measured using the floor plans of the subject building.
CONCLUSIONS: Participants on average were sedentary for 80% of the time during the study. Proximity to several service and amenity areas was positively associated with step counts and job satisfaction.

Keywords: Workplace, sedentary behavior, shared service and amenity spaces

1. Introduction

The sustainable building practice has been heavily focusing on energy efficiency improvement and renewable energy harvesting due to the recognized significant volume of energy use by the building sector and the associated greenhouse gas emissions. Ambient environmental qualities in buildings that are related to energy demand were also examined, such as thermal, visual, and air quality issues [7,9,17,22,25]. The commonly accepted definition of sustainable buildings, i.e. buildings that are environmentally responsible and resource-efficient according to the U.S. Environmental Protection Agency, is yet to be expanded to include more performance mandates such as spatial qualities to promote better quality buildings in a more holistic sense, as well as to recognize the necessity for sustainable buildings to support occupant health and well-being, in addition to achieving energy goals. The topic of how buildings could support occupant health is a relatively new topic that needs more research.

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Dramatic growth in overweight and obesity increase the incidence of many diseases such as diabetes, heart disease, hypertension and cancer [4]. Increasing non-exercise activity thermogenesis (NEAT) or spontaneous physical activity (SPA), which comprises all energy expenditure except that used during sleeping, eating, and formal exercise, plays a critical role in weight control [19,26]. Physical inactivity is also a major risk factor for developing various chronic diseases. A long-term approach for weight control should consider the impact of environments on reducing sedentary behavior and increase NEAT on a daily basis [16]. Considering the amount of time people spend inside buildings throughout their lifetime, promoting physical activity level in occupants' daily life through building design elements could have significant positive impacts on occupants' health.

Finch introduced the concept of 'embedded health design', whose goal is to provide opportunities for occupants to increase their activity level by virtue of the design [8]. The design concept was also referred to as 'activity-friendly building' [27], with the availability of activity programmed facilities and related building operation support [27]. This concept and the findings from environmental predictors for stair use [21] were reflected in New York City's Active Design Guidelines [1]. However, there were few empirical studies that examined the association between building design and the level of physical activity. The empirical studies that exist tended to focus on stair use [3,18].

In terms of the strategies and design elements that have been looked at, many studies examined motivational-point-of-decision prompts (i.e., motivational signage), aesthetically pleasing staircases, and accessible exercise facilities [3,5,12–15,20]. This paper intends to explore the effects of building layout (i.e., spatial characteristics of floor plans) on building occupants' physical activity level and sedentary behavior, a topic that few studies have investigated.

In order to understand behavioral patterns of building occupants, Rashid et al. [23] identified two kinds of activities for the workplace settings: 1) fleeting activities such as walking, spontaneous face-to-face interactions, and visible co-presence (i.e., the number of people seen from a space or a position); and 2) sedentary activities such as meeting, working on computer, talking on telephone, writing, reading, paper handling, and pausing. By their definitions, in order to increase occupants' NEAT, a building needs to facilitate more fleeting activities [23]. According to Rassia [24], pre-planned walking routes in a workplace can be achieved by reduced job clusters or scattered shared spaces, since close clustering and direct proximity appeared not to stimulate the additional physical activities required within the indoor office environment. Environmental cognition research also provided some evidence of the impact of the configuration of the environment on occupant behavior and understanding of the layout of the environment [10].

In the study reported in this paper, both types of aforesaid activities were investigated. The hypotheses tested were:

H_1: Office workers have less sedentary behavior when their workstations are located relatively further away from shared service and amenity spaces than those whose workstations are located closer to those spaces;

H_2: Office workers who have higher levels of environmental satisfaction also have higher levels of job satisfaction; and

H_3: Office workers whose workstations are anchored and further away from the shared service and amenity spaces have higher levels of job and environmental satisfaction than those whose workstations are closer to those spaces.

2. Methodology

The target population for this study was office workers who spent most of their work hours in the office setting. Office workers (staff) at a university were invited to the study via email and by field researchers. The subject building was a three-story office building without basement, with two elevators, two staircases, two main entrances, and an atrium opened up to the second floor. The building had features of typical office buildings and solely served as office space.

Three instruments were used in this study: a paper-based survey that included modified questions of a workplace collaboration environment questionnaire [11] and the International Physical Activity Questionnaire (IPAQ), an objective measure of physical activity level using ActiGraph, and an objective measure of the proximity between each participant's workstation and a variety of shared spaces (i.e., staircase, elevator, conference room, kitchen, copy area, reception, additional printer). The proximity from workstation to different shared spaces was measured by the walking distances along the corridors from the center of a cubicle or an office to the center of shared spaces, on the up-to-date floor plans in CAD format.

Table 1
Office worker profile of respondents

Demographic variables	n	%
Age		
25–29	2	7.7
30–34	4	15.4
35–39	1	3.8
40–44	3	11.5
45–49	5	19.2
50–54	2	7.7
55–59	4	15.4
60–64	4	15.4
Education		
High school graduate	1	3.8
Attended some college	5	19.2
Associate degree	1	3.8
Bachelor's degree	12	46.2
Postgraduate degree	6	23.1
Job position		
Faculty	1	3.8
Administration/Support	15	57.8
Management	3	11.5
Others	6	23.1
Number of months working in the building		
1–6	2	7.7
7–12	2	7.7
13–18	2	7.7
19–24	2	7.7
>25	17	65.4
Number of months working in the current workstation		
1–6	4	15.4
7–12	1	3.8
13–18	5	19.2
19–24	3	11.5
>25	12	46.2

Note: The total percentages for some of the items do not add up to 100% because of missing responses.

The survey also included a series of five-point Likert scale statements ranging from 1 ("Strongly disagree") to 5 ("Strongly agree") about perceived environment of the floor and self-reported uses of shared spaces. Data were collected in May 2012. Full-time office workers in the subject building were invited to take a paper-based survey and to wear an ActiGraph (GT3X+) accelerometer for three consecutive weekdays only when they were inside the building to minimize noise in data from trips to outside of the building. The participants were asked to take the accelerometer off before leaving the building and put it back on immediately when they come back. They recorded their wearing time on a time log. The research protocol was reviewed by the university Institutional Review Board (IRB), and participation was voluntary.

A total of thirty-five surveys were distributed. The realized sample size was twenty-six people participating in wearing accelerometers, with two surveys incomplete and seven people choosing not to wear accelerometers. The sample was slightly dominated by female (69.2%). The majority of respondents were white (95.8%), had worked in the building for more than a year (84%), and had been in their current workstation also for more than a year (80%). Approximately 96% of the respondents had at least some college education, with 72% holding college degrees. The age of the respondents distributed in the range of 25 and 64. About 69% of the respondents worked in administration, support, or management positions (Table 1). Table 2 shows the self-evaluated activity level by all respondents, using number of days in a week achieving 30 minutes of moderate physical activity as an indicator. The results have a wide range.

Table 2
Number of days achieving 30 minutes of moderate physical activity per week (self-evaluated activity level)

Days per week	n	%
1	3	11.5
2	5	19.2
3	5	19.2
4	1	3.8
5	2	7.7
6	4	15.4
7	5	19.2

3. Results

3.1. Descriptive statistics

Job satisfaction, environmental satisfaction, and perceived support from the work environments were measured by 5-point Likert scale in the questionnaire. Participants showed slightly higher average job satisfaction (3.64) than both environmental satisfaction (3.24) and perceived support (3.24) from the work environment. The environmental satisfaction and perceived support from the work environment were highly correlated with each other (0.80, $p < 0.05$). However, there was not enough evidence to conclude that job satisfaction was correlated with environmental satisfaction or perceived support from the work environment (Table 3). Therefore Hypothesis 2 (office workers who have higher levels of environmental satisfaction also have higher levels of job satisfaction) was rejected.

Table 4 below shows the means and standard deviations of the distances from respondents' workstations to shared service and amenity spaces (e.g., conference room, reception desk, copy area, an additional printer

Table 3
Means, standard deviations, correlations of job satisfaction, environmental satisfaction, and perceived support from work environment ($n = 25$)

Variable	Mean	Std. Deviation	Minimum	Maximum	Job satisfaction	Environ-mental satisfac-tion	Perceived support from the work environment
Job satisfaction	3.64	0.9074	1	5	1.00	0.19	0.14
Environmental satisfaction	3.24	1.0116	1	5		1.00	0.80*
Perceived support from the work environment	3.24	1.0116	1	5			1.00

$^{*}p < 0.05$.

Table 4
Distances from workstation to shared service spaces (feet, meter) ($n = 26$)

Variables	Mean	Std. Deviation	Minimum	Maximum
Conference room	77.6 (23.7)	43.8 (13.4)	15.6 (4.8)	153.3 (46.7)
Reception desk	99.5 (30.3)	48.4 (14.8)	0	193.1 (58.9)
Copy area	64.8 (19.8)	25.9 (7.9)	22.1 (6.7)	117.9 (35.9)
Printer	42.0 (12.8)	22.6 (6.9)	16.9 (5.2)	101.0 (30.8)
Kitchen	73.0 (22.3)	25.8 (7.9)	20.0 (6.1)	123.3 (37.6)
Restroom	122.5 (37.4)	30.6 (9.3)	49.8 (15.2)	173.9 (53.0)
Staircase	98.5 (30.0)	34.4 (10.5)	46.3 (14.1)	176.8 (53.9)
Elevator	118.6 (36.1)	30.5 (9.3)	55.2 (16.8)	162.9 (49.7)

Table 5
Sedentary behavior of office workers ($n = 26$)

Variables	Mean	Std. Deviation	Minimum	Maximum
Time being sedentary (%)	80.67%	5.42%	69.54%	90.07%
Time being non-sedentary (%)	19.33%	5.42%	9.93%	30.46%
Total step counts in 3 days	4,708	1,966	2,073	9,282
Longest duration being sedentary (min)	50.15	36.87	11.94	165.83
Average of maximum length of sedentary in one workday (min)	35.97	18.93	11.72	83.44

if available, kitchen, restroom, staircase, and elevator). Twenty-six participants were from four different departments, which were in different suites in the building with different layouts and had their own conference room, reception desk, copy area, printer, and kitchen. However, occupants on each floor shared two elevators next to each other, restrooms, one each for women and men, and staircases. Staircases and elevators were located close to each other in the center of the floor plan.

In order to identify participants' wearing period of the accelerometers, ActiLife software was used to screen 60 minutes of consecutive zeros with a 2-minute spike tolerance. Such defined wearing period was compared with the time logs that participants recorded. "Wearing periods" that were recorded while researchers were distributing the accelerometers were removed. Total valid wear time for the three weekdays of study after filtering using ActiLife valid wear time criteria and the time log cards showed a mean of 19 h 26 m (SD = 4 h 37 m). Average wear time per day was 6 h 31 m (SD = 1 h 21 m). Two indicators were measured to quantify workers' sedentary behavior: the proportion of time being sedentary versus non-sedentary and longest duration of being sedentary calculated by the maximum interval between non-sedentary behaviors (using both the maximum of the 3-day study period and the average of the daily maximums). Physical activity was calculated according to the current recommended adult cut points of 2 METs (Metabolic Equivalent of Task) for sedentary activity.

The data showed that participants, on average, spent 80.7% of their time during the period of wearing the accelerometer in sedentary conditions, and 19.3% of their time in light-to-vigorous activities (Table 5). In addition, patterns of sedentary behavior were also examined. The mean of participants' longest duration of being sedentary that occurred across the three days of study was 50.15 minutes (SD = 36.87 minutes). This means, on average, the participants sat no longer than approximately 50 minutes at one time. However, the standard deviation of 36.87 indicates a large variation in the longest duration of sedentary behavior among the participants (Min = 11.94 minutes, Max = 165.83 minutes). The average level of the maximum length of being sedentary in one workday had a mean of 35.97 minutes among the participants (SD = 18.93 minutes). The total number of steps walked by individual participants in the three workdays was also recorded (Mean = 4,708, SD = 1,966).

Table 6
Fit Y by X (Statistically significant ($p < 0.05$) correlations indicated)

Responses \ Predictors	Distance to confer-ence room	Distance to recep-tion desk	Distance to copy area	Distance to printer	Distance to kitchen	Distance to restroom	Distance to stairs	Distance to elevator
Job satisfaction	□	–	□	–	□	–	–	□
Environmental satisfaction	–	–	–	–	–	□	–	□
Perceived support from work environment	–	–	–	–	–	–	–	–
Percentage time being sedentary	–	–	–	–	–	–	–	–
Total step counts for 3 days	□	□	□	–	□	–	–	□
Maximum duration being sedentary (min)	–	–	–	–	–	–	–	–
Average of maximum duration being sedentary (min)	–	–	–	–	–	–	–	–

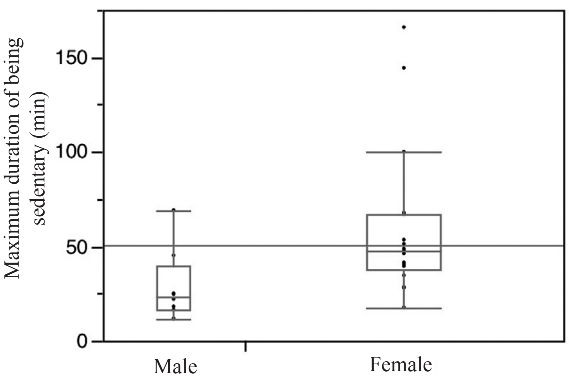

Fig. 1. Gender and maximum duration of being sedentary (minutes).

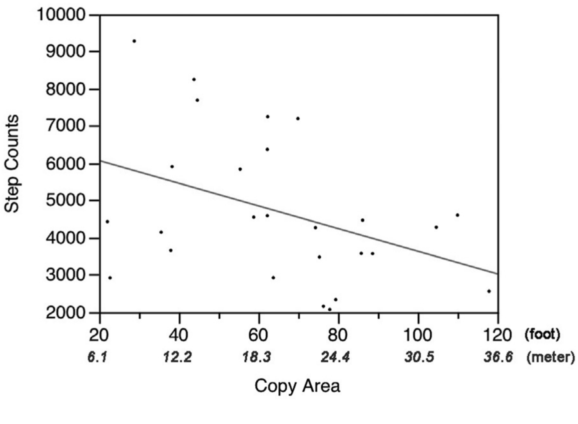

Fig. 2. Significant association between workstation-to-copy area distance (feet/meters) and office worker step counts.

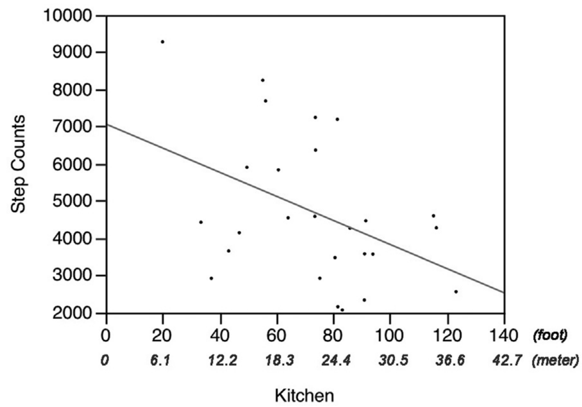

Fig. 3. Significant association between workstation-to-kitchen distance (feet/meters) and office worker step counts.

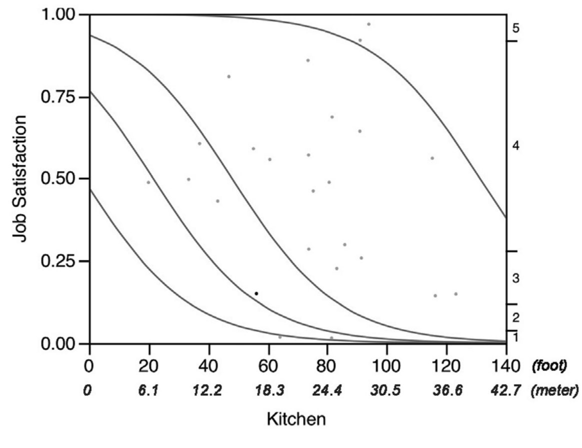

Fig. 4. Logistic fit between workstation-to-kitchen distance (feet/meters) and office worker job satisfaction.

3.2. Hypothesis testing (Inferential statistics)

There is a statistically significant difference between the male and female participants on longest duration of being sedentary (Fig. 1). The longest duration of being sedentary for female participants had a mean of 59.5 minutes, while it was 29.1 minutes for male participants. Females tend to sit 30 minutes longer than males on average among the participants in this study.

Participants' satisfaction levels and indicators of

Table 7
Whole model test

Model	LogLikelihood	DF	ChiSquare	Prob > ChiSq
Difference	4.8308	1	9.6616	0.0019*
Full	22.9619			
Reduced	27.7927			

RSquare (U)	0.1738
AICc	59.0817
BIC	62.0182
Observations (or Sum Wgts)	25

Table 8
Parameter estimates

Term	Estimate	Std error	ChiSquare	Prob > ChiSq
Intercept [1]	−0.1100	1.5325	0.01	0.9428
Intercept [2]	1.2006	1.32287	0.82	0.3641
Intercept [3]	2.6740	1.38104	3.75	0.0528
Intercept [4]	7.3063	2.11911	11.89	0.0006*
Kitchen	−0.0556	0.0206	7.33	0.0068*

sedentary behavior were associated with several physical proximity indicators (i.e., the distances from their workstations to shared service and amenity areas). Bivariate models that satisfied 5% significance level are indicated by box symbols in Table 6. Total step counts for three days were negatively associated with distances from workstations to conference rooms, reception desks, copy areas, kitchens, and elevators. Figures 2 and 3 respectively showed the associations between participant step counts and distance from workstations to copy areas (p-value $= 0.042$), and step counts and distance from workstations to kitchens (p-value $= 0.030$). Step counts tended to decrease as distances from personal workstation to these shared spaces increased. In other words, when these shared spaces were located closer to workstations, office workers tended to walk more. Therefore, Hypothesis 1 (office workers have less sedentary behavior when their workstations are located relatively further away from shared service and amenity spaces than those whose workstations are located closer to the shared service and amenity space) was rejected.

In addition, this tendency also showed in job satisfaction. People whose workstations were closer to conference rooms, copy areas, kitchens and elevators had higher job satisfaction than those whose workstations were located further from those shared service and amenity areas. Figure 4 shows the results of a logistic fit between participant job satisfaction and distance from workstation to kitchen (p-value $= 0.0019$). Therefore, Hypothesis 3 (office workers whose workstations are anchored and further away from the shared service and amenity spaces have higher levels of job and environmental satisfaction than those whose workstations are closer to the shared service and amenity spaces) was also rejected.

4. Discussion

4.1. Summary of study

The results from this study imply that proximity to certain shared service and amenity spaces in a workplace increases walking of office workers at work, likely through increasing the number of trips they make on a daily basis, though the effect of proximity to the shared spaces on the amount of time being sedentary was not statistically significant. This result is different from the literature, suggesting that scattered or non-clustered layout for shared service spaces results in more walking. Proximity to certain shared service and amenity areas also showed positive impact on job satisfaction. When comparing the layout concepts of different office suite floor plan designs, those that adopted neighborhood-type layouts or having the shared services and amenities in the center of the office suite tended to have shorter average workstation-to-service/amenity distance among all office workers in the suite, as compared to office suites that had the services and amenities at a corner. Therefore, the neighborhood and central layout of services and amenities tended to better support walking behavior and job satisfaction.

It is clear that proper design of a building's spatial layout has the potential to increase both voluntary and imperative physical activities at work. There are also potential conflicts between productivity and embedded health design. The primary concern of workplace design has been focused on optimizing the effectiveness of an organization by efficient space planning through minimizing travel time, minimizing the disruption to coworkers when circulating, maximizing space use efficiency and eliminating unused space, maximizing convenience and use of costly equipment, and maximizing productive interaction, both formal and informal [8]. On the other hand, studies [2,8] argued that the productivity of informal interaction and informal learning can be improved by increased walking, and more active work behavior may be positively associated with the inter-group interaction by increasing chances of interaction across project teams or departments. Higher job satisfaction observed in this study could be associated with better interaction, with walking behavior as a possible mediator. Therefore, an effective layout design of a sustainable building, with the goal to facilitate healthier work behavior for effective weight control and better health of office workers in general, needs to take into account the possible positive and/or negative impacts of active design on organization performance for better implementation outcomes. This also means that more research to examine the interaction of the aforementioned factors is needed.

4.2. Limitations and future research

The sample size of 26 in this study was small, though findings from this study directly informed the next step, a typological study on physical activity level at workplaces with a larger sample size and more variation in workplace layouts and settings. In terms of data analysis, ideally, hierarchical linear modeling (HLM) with floors, suites or departments, and individual levels can be done. However, HLM was not possible because of the small sample size in the current study. Participants who volunteered could consciously walk more at work as a result of being in the study. A larger sample size, multiple-building, and longer-term study will be able to generate more insights of office workers' habitual behavior patterns. Also, as the next step of continuous research on this topic, the impact of the layout of shared service and amenity spaces in the workplace on both office worker activity levels and interaction behavior patterns, as well as the interaction between the two, should be further investigated. Typology study outcomes can be compared with results from existing collaborative workplace studies [11], to find out what type of layout(s) support both goals (active and collaborative workplace).

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