THE CENTER FOR HEALTH DESIGN®

Health Environments Research & Design Journal
2015, Vol. 8(4) 77-97
© The Author(s) 2015
Reprints and permission:
sagepub.com/journalsPermissions.nav
DOI: 10.1177/1937586715573736
herd.sagepub.com
SAGE

Effects of Newly Designed Hospital Buildings on Staff Perceptions: A Pre-Post Study to Validate Design Decisions

Eliane Schreuder, MSc[1], Liesbeth van Heel, MSc[2], Rien Goedhart, MSc[2], Elise Dusseldorp, PhD[3], Jan Maarten Schraagen, PhD[1], and Alex Burdorf, PhD[4]

Abstract

Objective: This study investigates effects of the newly built nonpatient-related buildings of a large university medical center on staff perceptions and whether the design objectives were achieved. **Background:** The medical center is gradually renewing its hospital building area of 200,000 m.[2] This redevelopment is carefully planned and because lessons learned can guide design decisions of the next phase, the medical center is keen to evaluate the performance of the new buildings. **Method:** A pre- and post-study with a control group was conducted. Prior to the move to the new buildings an occupancy evaluation was carried out in the old setting ($n = 729$) (pre-study). Post occupation of the new buildings another occupancy evaluation (post-study) was carried out in the new setting (intervention group) and again in some old settings (control group) ($n = 664$). The occupancy evaluation consisted of an online survey that measured the perceived performance of different aspects of the building. Longitudinal multilevel analysis was used to compare the performance of the old buildings with the new buildings. **Results:** Significant improvements were found in indoor climate, perceived safety, working environment, well-being, facilities, sustainability, and overall satisfaction. Commitment to the employer, working atmosphere, orientation, work performance, and knowledge sharing did not improve. The results were interpreted by relating them to specific design choices. **Conclusion:** We showed that it is possible to measure the performance improvements of a complex intervention being a new building design and validate design decisions. A focused design process aiming for a safe, pleasant and sustainable building resulted in actual improvements in some of the related performance measures.

Keywords

pre-post occupancy evaluation, staff satisfaction, built environment, nonpatient-related buildings, longitudinal multilevel analysis

[1] TNO Earth, Life and Social Sciences, Soesterberg, the Netherlands
[2] Directorate of Corporate Real Estate, Erasmus Medical Center, Rotterdam, the Netherlands
[3] TNO Earth, Life and Social Sciences, Leiden, the Netherlands
[4] Department of Public Health, Erasmus Medical Center, Rotterdam, the Netherlands

Corresponding Author:
Eliane Schreuder, MSc, TNO Earth, Life and Social Sciences, Soesterberg, the Netherlands.
Email: eliane.schreuder@tno.nl

Introduction

In health care design, there is a growing interest in conducting post-occupancy evaluations (POEs; Guinther et al., 2014; Pati & Pati, 2013) to support future design decisions. The value of a POE is to assess how well the building performs compared with the design objectives and to feed forward the knowledge gained into new designs. While the use of and resources for POEs have grown and several well-developed techniques exist (Guinther et al., 2014; Riley, Moody, & Pitt, 2009; Zeisel, 2006), POEs are not (yet) commonplace and the lessons learned are not generally available for use in practice. Barriers include issues of cost and time, the lack of research expertise within firms, and the unwillingness of design firms to publicly expose problems or failures within a designed environment (Bordass & Leaman, 2005; Guinther et al., 2014). Although these barriers are not easy to overcome, taking small steps by publishing strong examples as case studies may help to bring down these barriers. Therefore, the aim of this study is to provide an example of how to measure the performance improvements of new buildings in a large university medical center in the Netherlands.

The medical center is renewing 200,000 m^2 of its hospital buildings in a phased approach. Initially started in the late 1990s with innovative ideas about providing tertiary health care in dedicated patient themes (centers of excellence), the building's exterior design was finalized in 2007. Groundbreaking for the first phase took place in October 2009. Due to the necessary phasing on the building site, buildings aiming to house the nonpatient-related functions, such as diagnostic and research laboratories, central sterilization, and health sciences, were built first and brought into use. The hospital started to use these buildings from February 2013 onward, while work was still being carried out on the interior design of patient-centered functions such as wards and outpatient clinics to be realized in the next phase, due to be finished by mid-2017.

The Main Objectives for the New Buildings Were to Create a Safe, Pleasant, and Sustainable Environment for All Users

The main objectives for the new buildings were to create a safe, pleasant, and sustainable environment for all users. The project team was keen to learn whether the resulting design of the new buildings and workspaces indeed achieved these design objectives. Furthermore, due to the phased approach, lessons learned from the first phase could guide design decisions in the next phases and could help communicate the optimal use of the building to future users. Therefore, a pre- and post-study with a control group was designed to investigate whether staff would perceive the new buildings more positively than the old buildings of the medical center and to validate the design objectives. The project team hired an independent research organization to conduct the study. The following section describes the design objectives and high-level design decisions that were assumed to realize an effect in performance.

Design Objectives

Table 1 shows how the main objectives, a safe, pleasant, and sustainable building were addressed into aspects of the building that were improved to achieve the objectives. The hierarchy among the aspects is also indicated in terms of effort put into these aspects. Concerning the hierarchy among the main objectives, the following should be noted. All objectives were equally prioritized, however, when conflicts arose between the objectives, the safe alternative was chosen over the pleasant or sustainable alternatives and the pleasant alternative over the sustainable one. The design decisions that were taken to improve the aspects indicated in Table 1 are described subsequently.

Safe

The primary objective of the design was to create a safe working environment that supports job tasks. To that aim, design decisions were made to improve the working environment and perceived safety.

Table 1. Aspects Related to Design Objectives and Hierarchy.

Effort \ Main objective	Safe	Pleasant	Sustainable
Much	Working environment	Indoor climate	Sustainability
	Perceived safety	Orientation	
		Knowledge sharing	
		Facilities	
		Physical activity	
		Working atmosphere	
Somewhat		Commitment	

Figure 1. Old (left) and new (right) lab design. © Levien Willemse.

Working environment. The new buildings consisted of two laboratory buildings (laboratories) and one office building (office tower). The design decisions are discussed for each function. To improve the working environment for both functions, the design focused on process support, spacing, and the interior design.

Process support. Emphasis was put on the laboratory design. Compared with the old settings, the workspaces were better designed to facilitate best practices and the newest rules and regulations (safety and hygiene protocols at ML-2 level [micro-organism laboratory containment level 2]). For instance, before entering the labs there were separate changing rooms and sluices to facilitate safety protocols and in some sluices autoclaves were installed. Figure 1 shows an example of a new lab design. The design forced employees to put lab coats in/behind the sluices (right) instead of in the corridor (left). Laboratories and offices were separated to stimulate that analysts do not conduct office work and lab work at the same workbench. Concerning the equipment and installations, a state-of-the-art working environment was created.

To support job tasks in the office tower, information technology facilities were improved: faster networks, higher WIFI standards, and improved reception for mobile phones (which resulted in fewer wired phones). Furthermore, collaborating departments were located close to each other (both in the office tower and in labs) to facilitate cooperation.

Spacing. The design was aimed to generate enough space and distance to work safely and comfortably. In the labs, storage, waste, and chemicals all had their appropriate places and spaces. Spaces were also designed to store equipment to avoid equipment being stored in the general traffic area (as happened in the old setting). Storing spaces for goods were reduced due to the implementation of just in time management.

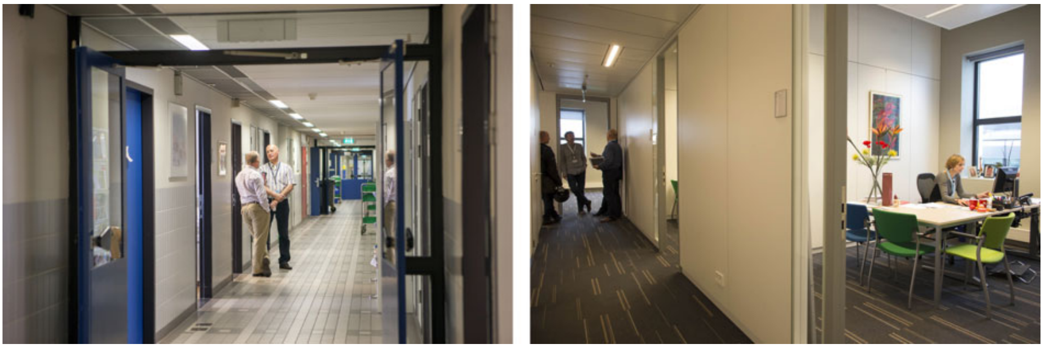

Figure 2. Old (left) and new (right) lines of sight. © Levien Willemse.

Furthermore, more workspaces, especially for the assistants, were created. In the old settings, rooms were overcrowded. In the office tower, more workspaces were created than in the old buildings. Workspaces were also more spacious that allowed more space between the tables.

Interior design. In the workspaces, up-to-date equipment (biohazard cabinets, height-adjustable workbenches and ergonomic furniture) was installed, ensuring staff safety and well-being. Computers were equipped with antireflection monitors and light fixtures were improved to reduce blinding. Lighting levels also adapted automatically to ensure sufficient lighting levels for the workspaces.

The focus on process support, spacing, and interior design led to the following:

> **Hypothesis 1:** The *working environment* in the new buildings better supports job tasks than in the old buildings.

Perceived safety. Next to design decisions that support working safely, decisions were also made to increase perceived safety.

Accessibility. A new access system was implemented in all new buildings (labs and office tower). Entrance to floors was managed at the elevator core/staircases and floors could only be accessed with an authorized pass. As a consequence, no locks were designed for individual rooms, and personal items could only be locked in drawers or lockers at the department. Furthermore, traffic flows were separated (goods and staff), diminishing the risk of collusion and increasing oversight due to less traffic.

Transparency. A lot of glass was used in the new buildings, not only to bring in daylight, but also to enhance orientation and overview. This was expected to contribute to a safe and neat working attitude (as people can see you working) and perceived safety (you see when others are around and people see you). In the old setting, lines of sight from the corridor into the labs or offices or vice versa were limited. Figure 2 shows an example of the newly designed lines of sight (right). Also, in the new space, lights were switched "on" automatically. Therefore, employees never entered dark areas. Furthermore, departments were more clearly structured compared with the old setting, which created better overview. For instance, at departments often only one turn was required to reach a destination from the building core, separation of labs, and offices made it more clear how the department was organized, and due to dedicated storage spaces corridors were free from equipment and clutter.

Fire safety. Fire safety measures (compartments, etc.) were in accordance with regulations, however, extra precautions were taken in the installment of sprinklers in all buildings (although by law this was not required) and escape routes. Spaces were designed in a way that there are always two escape routes. The focus on accessibility, transparency, and fire safety led to the following:

Hypothesis 2: The new buildings are *perceived as safer* than the old buildings.

Pleasant

The second main objective was to create a pleasant and healing environment for all users. The most important design decisions to support this aim were made in the indoor climate and orientation of the building but also decisions to stimulate knowledge sharing, improve facilities, physical activity, working atmosphere, and commitment to the organization were expected to contribute to this aim. Perceived well-being, overall satisfaction, and work performance were regarded as general outcome measures that were impacted by many design decisions aimed at creating a pleasant, safe, and to a lesser extent sustainable environment and therefore are discussed first. The specific decisions that were taken to create a pleasant working environment are discussed next.

Perceived well-being and overall satisfaction. It was expected that the measures that were taken to create a pleasant environment (indoor climate, orientation, facilities, and physical activity), safe and supportive working environment (working environment) and sustainable environment would also positively impact perceived well-being and overall satisfaction. This led to the following:

Hypothesis 3: *Perceived well-being* is better in the new buildings than in the old buildings.

Hypothesis 4: *Overall satisfaction* is better in the new buildings than in the old buildings.

Work performance. It was also expected that the measures that were taken to create a safe, supportive (perceived safety, working environment), and pleasant working environment (indoor climate, orientation, facilities, and knowledge sharing) would positively impact perceived work performance. Also, production environments (central sterilization department and pharmacy) were specifically designed to improve work processes, however, only a relatively small number of staff worked in these departments. This led to the following:

Hypothesis 5: Perceived *work performance* is better in the new buildings than in the old buildings.

Indoor climate. The following investments were made to create a comfortable indoor climate.

Ventilation and temperature. Ventilation rates, cooling and heating requirements were all set above regulation standards. Ventilation air was not recirculated and air was conditioned to improve comfort. Due to concrete core heating in the offices, controllability of the temperature was limited. In the laboratories, temperature could be regulated to a certain extent due to radiant ceilings along the facade. As opposed to the old settings, all windows could be opened (except in laboratories and when it was forbidden by regulation). This gave autonomy to users in adapting their workspace/indoor climate to their own preferences.

Light, daylight, and view. Access to daylight and outside view was maximized for workspaces and traffic areas. In the old laboratory setting, storage was often located in front of the windows (Figure 3, left). In the new buildings, windows were enlarged and a dedicated storage facility was created (Figure 3, right), improving access to daylight and the outside view. Furthermore, the laboratories were located higher in the building than in the old setting, which also impacted view and daylight. All rooms in the office tower had direct access to daylight and the majority of the office rooms had great views over the city and city park. Green roofs were installed, also for sustainability reasons, meaning that on higher floors the view was improved by these green roofs. In the old setting, the view was often blocked by other buildings.

Lighting levels adapted to ensure sufficient lighting levels for the workspaces (see also working environment). Requirements for lighting were set to 500 lux on workbenches and 200 lux in corridors (above regulation standards). Switching was done automatically based on presence and daylight.

Noise. Several investments were made to optimize acoustics. Requirements for room-to-room

Figure 3. Old (left) and new (right) dedicated storage space. © Levien Willemse.

noise, for instance, were all set above regulation standards. Sound sources were shielded as much as possible by creating separate rooms, carpeting was included in the offices, as were heavy walls, and noise absorbing finishes. Traffic flows of goods and staff were separated, especially in the laboratory areas. Also, storage of goods was located at the entrance of the departments which resulted in less traffic in the corridors compared to the old setting, and as an effect to a more peaceful environment. The focus on ventilation, temperature, lighting, views, and noise reduction led to the following:

> **Hypothesis 6:** The *indoor climate* in the new buildings is better appreciated than in the old buildings.

Perceived orientation. Orientation and way finding were deemed important to create a pleasant building. The following design decisions were made.

Daylight and view. In the office tower, extra care was taken that staff and visitors coming out of the elevator core would experience daylight and outside view to improve orientation. The corridors (in the office tower and laboratory) had translucent or glass partitions at the end, for the same reason (also see Figure 2, right). As a result, the majority of corridors had direct or indirect access to daylight.

Layout. In the old settings, the connections of the buildings and the structure of the departments could be confusing. In the new setting, the old and new buildings were connected by a 12-m high glass-roofed "street" and plaza, supporting the complex's main public infrastructure to increase orientation (Figure 4). Departments were also more clearly structured (see perceived safety). Furthermore, in the atrium the stairs were prominently located opposite the elevators, providing a route alternative, which was expected to improve orientation. The focus on daylight, lines of sight, and a clear layout led to the following:

> **Hypothesis 7:** *Perceived orientation* of the employees is better in the new buildings than in the old buildings.

Knowledge sharing. Some design decisions were made to increase knowledge sharing. A learning environment was a key element for research and specialized education, therefore specific meeting and colloquium rooms were created that contributed to this "learning environment." Furthermore, informal meeting areas next to the coffee machine in the office tower, or dedicated break rooms for the labs (Figure 5), were created to stimulate collaboration and knowledge sharing. For this purpose, collaborating departments in the office tower as well as in the laboratories were

Figure 4. Glass roofed street. © Erasmus Medical Center.

situated close by (the departments were consulted by the design team). For instance, hospital hygienists were housed next to the microbiology lab. Finally, glass partitions in the office tower and laboratories showed colleagues to be available for consultation (see Figure 2, right). The focus on (in)formal meeting rooms, location of departments, and transparency led to the following:

> **Hypothesis 8:** The new buildings provide more *incentives to knowledge sharing* than the old building.

Facilities. In order to create a pleasant working environment for employees, efforts were made to centralize facilities. Facilities such as pantries with coffee machines, copiers, and an informal meeting area were uniformly introduced to all office floors. As a consequence of the implementation of paperless working, personal storage space was reduced. In the laboratories, dedicated space for leisure rooms, sometimes next to the lab, sometimes in the office tower were created to stimulate the meeting of analysts and consultants (see Figure 5). These rooms also allowed analysts to have lunch at the department instead of the restaurant. In the old setting, this was not facilitated. Furthermore, staff were involved in the department layout. They could indicate relevant departments that should be located close to their department and determine the functionality of flexible spaces in their department. Finally, a public infrastructure was designed with restaurants and a few shops. The focus on centralized facilities, codesign, and a public infrastructure led to the following:

> **Hypothesis 9:** Employees are *more satisfied with the facilities* in the new buildings than in the old buildings.

Physical activity. Effort was made into the design of staircases to stimulate stair use and physical activity of users. When possible (although not in the office tower) stairs and elevators were combined in one lobby and stairs were mostly situated on daylight/views for orientation to invite people to use them (Figure 6). Collaborating health science departments (12 floors in the office tower) were situated close by, to allow researchers to easily go up 1 or 2 floors to consult colleagues by taking the stairs. These stairs, however, were less inviting as they also functioned as emergency pathway with no access to daylight. Nevertheless, it was believed that:

> **Hypothesis 10:** The new buildings provide *more incentives to be physically active* than the old buildings.

Working atmosphere. It was assumed that the interventions that aimed to stimulate collaboration and knowledge sharing would also have a positive effect on the working atmosphere. Furthermore, the implementation of a state-of-the-art working environment (especially concerning equipment and installations) might have indirectly affected working atmosphere via a more positive perception of the working environment. The carpeting in the offices, implemented for its acoustic effects, also created a less institutional atmosphere that might have contributed to

Figure 5. Dedicated breakout rooms. © Levien Willemse.

the working atmosphere. Therefore, it was assumed that:

> **Hypothesis 11:** The *working atmosphere* is better in the new buildings than in the old buildings.

Commitment. It was assumed that the new buildings and the effort undertaken to bring the nonpatient hospital function to a state-of-the-art level would influence staff's perception of the organization, making them more proud. Therefore, it was hypothesized that:

> **Hypothesis 12:** Employees are more *committed to the organization* in the new buildings than in the old buildings.

Sustainable. Alongside the focus on a safe and pleasant environment, the design was also focused on sustainability. Although many sustainable solutions were integrated in the building installation and therefore not visible to staff and other users, some might have been visible and are described subsequently.

Sustainability

Indoor climate. An important decision was the installation of concrete core heating and cooling powered by an aquifer thermal energy storage installation in the office tower (also see indoor climate in pleasant section). Ventilation was adapted to the use of spaces (e.g., offices or meeting rooms), and proper measures were taken to keep out heat, combined with the use of maximum natural daylight in the office tower.

Smart technology. Smart technology was implemented for lighting (switching based on presence and daylight), elevators (more efficient allocation system and energy recovery), and central copiers (follow-me system, which avoided unnecessary printing) for energy savings and waste reduction purposes.

Interior design. For the interior design, sustainable materials were used, such as FSC-wood (certified by the Forest Stewardship Council). Unhealthy or environmentally unfriendly materials such as polyvinyl chloride and aluminum

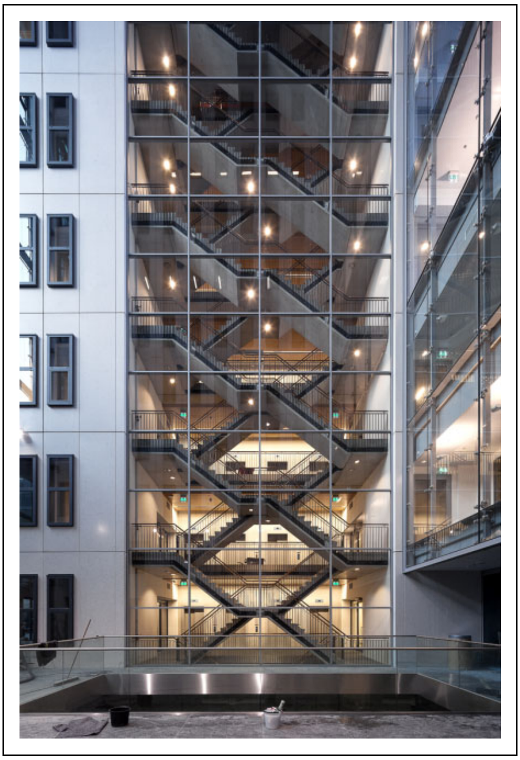

Figure 6. Staircase and lift lobby. © vanbeekfotografie.nl.

were avoided. Also, water-free urinals avoiding excess use of water for flushing purposes were installed. Storage spaces for goods were reduced due to the implementation of just in time delivery. In office rooms, personal storage space was reduced due to the implementation of paperless working.

Other sustainable solutions in the building included green roofs for sustainable rainwater management purposes and to improve the view. Also, −80°C freezers were stored in a water-cooled storage facility.

The focus on the indoor climate, smart technology, and interior design led to the final:

> **Hypothesis 13:** The new buildings *are perceived as more sustainable* than the old buildings.

Setting

Tables 2 and 3 provide an overview of the main characteristics of the buildings in the old and new settings. A difference was made between offices (Table 2) and laboratories (Table 3). The old setting consisted of 11 different buildings, each building having its own characteristics. In the table, only the main buildings that housed most of the employees were included. Furthermore, the tables highlight differences in aspects between the old and new setting as described in the design objectives section.

Method

Participants

In the pre-occupancy evaluation 2,598 (Dutch and international) employees from the various diagnostic and research laboratories, pharmacy, central sterilization, rehabilitation medicine, rheumatology, and health science departments, received the survey. Twenty-eight percent of the surveys (729) were (partly) filled out and returned. Of the 729 employees who filled out the survey, 68% was female and 81% belonged to the age-group of 25–54 years.

In the post-occupancy evaluation 1,953 (Dutch and international) employees from the same departments that moved (intervention group) and that did not move (control group) received the survey. Thirty-four percent of the surveys (664) were (partly) filled out and returned. Of the 644 employees who filled out the survey, 71% were female and 74% belonged to the age-group of 25–54 years. Three hundred and seventy-two complete cases existed in the data set, meaning that these cases (employees) were included in both the pre- and the post-study.

Design

Type of building was the variable quasi-manipulated in the research. In the pre-occupancy evaluation, employees worked in more than 11 different old buildings. Thus, we assumed that employees coming from the same old building were more alike than employees from other old buildings and therefore nested employee groups

Table 2. Old Versus New Setting: Offices.

Old Setting			New Setting		
Offices	Main Characteristics of Old Buildings	Aspect	Offices	Main Characteristics of New Buildings	Aspect
A	Temporary modular building dating from the mid-90s		*F*	High rise office tower	
	Single corridor building with cell-type offices	Spacing		Offices around closed core (elevators/emergency stairs/ technical shafts)	Spacing, Fire safety
	Windows cannot be opened (proximity of helipad and busy road)	Indoor climate		Mix of open and closed office workspaces	Working environment
	Access via B building; no elevator, just (emergency) stairs	Accessibility		Glass partitions for orientation to/from the corridor	Transparency
	Hard flooring in the offices	Noise		Daylight adaptable lighting systems	Smart technology
	Four floors of offices			Standard zoning for pantry, supplies, toilets, etc.	Facilities
B	Typical commercial office building dating from the early 90s			Concrete core heating	Indoor climate
	Open plan floor, number of rooms	Spacing		Windows can be opened	Indoor climate
	Separate access from campus, elevators and (emergency) stairs	Accessibility		29 Floors of offices (2 technical floors), access by elevator bank from new public space	Accessibility
	Windows can be opened	Indoor climate		Direct connecting walkway/ corridor to adjacent laboratories (several floors)	Accessibility
	Carpets in the offices	Noise		Carpets in the offices	Noise
	13 Floors of offices				

existed in the research: the employees who worked in the same old building.

In the post-occupancy evaluation, the intervention group had moved to three new buildings, where only the laboratories (Buildings G and H) differed from the offices (Building F). The control group had not moved and still worked in their old environment (some of the old buildings). They evaluated their environment for the second time in the post-occupancy evaluation.

Survey

To evaluate the performance of the new and old buildings, an online survey was used. In accordance with the hypotheses, the survey covered items on the following aspects: Indoor climate, safety, working environment, well-being, physical activity, work performance, commitment to the organization, sustainability, orientation and routing, knowledge sharing, working atmosphere, facilities, and the overall satisfaction of the building. Furthermore, some open questions on building elements employees would like to keep or change and some demographical questions such as gender, age, and job were asked. At the start of the survey, respondents were asked to indicate the building they worked in. The survey was developed based on validated surveys used in office research on staff well-being, indoor climate, vitality, satisfaction, commitment, and performance (Blok, de Korte, Groenesteijn, Formanoy, & Vink, 2009; Koopmans et al., 2013; Leijten & Kurvers, 2007; Schauffeli, Salanova, Gonzaléz-Romá, & Bakker, 2002; Zweers, Preller, Brunekreef, & Boleij, 1992). Also, new questions were defined in cooperation with the hospital that fitted the purpose of

Table 3. Old Versus New Setting: Laboratories.

Old Setting			New Setting		
Labs	Main Characteristics of Old Building	Aspect	Labs	Main Characteristics of New Buildings	Aspect
C	High rise clinical research tower dating from the early 70s		G/H	Mid height building (10–14 floors, 2 technical floors)	
	Deep plan building, with laboratories/offices on the facades	Light, daylight, and view		Deep plan building, with laboratories/offices on the facades	
	Double corridor with mix of laboratories and offices	Spacing		Zoning for laboratories and offices (most offices in adjacent office tower)	Working environment
	Access with elevators from level 3, separate elevator for materials	Accessibility		Glass partitions to/from the corridor	Transparency
	Doors with windows to corridor	Transparency		Double corridor with auxiliary spaces in the inner core	Spacing
	Preclinical and clinical research laboratories (renovated where necessary)	Working environment		Separate elevators for people and materials	Spacing
	Auxiliary spaces in the deep inner core	Spacing		Access to elevators/stairs from new public space	Accessibility
	Windows cannot be opened, HVAC	Indoor climate		Large windows, that cannot be opened in laboratories, HVAC	Indoor climate
	4 × 6 Floors with labs and offices, 4 technical floors			Direct connecting walkway/corridor to adjacent offices tower	Accessibility
	(Diagnostic) laboratory wing of the old hospital (early 60s)				
D	Single corridor building with mix of laboratories and offices	Working environment, Spacing			
	Windows cannot be opened, HVAC	Indoor climate			
	Access from the adjacent old hospital building, just emergency stairs	Accessibility			
	Five floors of laboratories and pharmacy				
E	Fit for first purpose building for clinical pathology and oncology research				
	Built in the 90s with donated money				
	Access from 3rd floor of C building	Accessibility			
	Deep plan building, with laboratories/offices on the facades	Light, daylight and view			
	Windows cannot be opened, HVAC	Indoor climate			
	Three floors of laboratories and offices, separate technical floor				
	This building mainly housed the control group				

Note. HVAC = heating, ventilation, and air-conditioning.

the research. The survey was identical in the pre- and post-occupancy evaluation, except for the choice of the building respondents worked in, and at the end of the post-occupancy evaluation a control question was included to check whether employees had moved and if so, from which (old) building. This was done to ensure employees could be allocated to an old building, in case they had only filled out the post-occupancy evaluation.

Procedure

The employees received the pre-occupancy evaluation survey 3 to 7 months prior to the move to the new buildings by e-mail. The survey was voluntary. By participating in this survey, respondents gave permission to use their answers for scientific purposes. The data set was anonymous, and the Dutch Code of Conduct for Medical Research allows the use of anonymous data for research purposes, without an explicit informed consent (Federatie van Medisch Wetenschappelijke Verenigingen [FMWV], 2004). The employees had 3 weeks to complete the survey and were reminded after 2 weeks. In the post-occupancy evaluation, employees who moved (intervention group) and who had not moved (control group) received the survey 5–8 months after the ones who moved into the new buildings. This was done to ensure employees who moved were sufficiently familiarized with the new buildings, and because the survey was then filled out in the same month as the pre-occupancy evaluation. In this way, the results were controlled for seasonal influences on staff perceptions.

Measures

The different building aspects measured in the survey were used as performance measures. To determine the construct validity, that is, to confirm whether the items we believed belonged to an aspect, indeed belonged to that aspect, we conducted a confirmatory factor analysis (the oblique multiple group method, Holzinger, 1944; Stuive, Kiers, & Timmerman, 2009). We tested if the retrieved data fit the hypothesized structure. For each aspect (covering multiple items), we calculated the reliability statistic (i.e., Cronbach's α, 1951) and for each item, two types of correlations, namely the correlation with the aspect it is assumed to belong to (the corrected item-total correlation) and the correlations with the other aspects. If the first correlation was larger than the latter, and the Cronbach's α was higher than .65, the predefined structure was confirmed. Some of the items of the predefined structure did not fit. With the use of the iterative adjustment procedure (Stuive et al., 2009), some adjustments were made to the original structure. Items on the quality of knowledge sharing showed a better fit with the aspect-working atmosphere and were therefore moved to this aspect. Items that remained in the aspect, knowledge sharing included items on the frequency of knowledge sharing. The final structure explained 53.07% of the total variance. Furthermore, inter-aspect correlations were below $r = .5$ (except for the correlation between indoor climate—working environment, ($r = .56$), and facilities—working environment ($r = .54$)) and therefore, the aspects were assumed to be sufficiently distinctive. Ten multi-item aspects and two 1-item aspects were used as performance measures of the buildings. These performance measures were measured on a scale from 1 to 5 (5 being the maximum score). The overall satisfaction score of the building was an additional performance measure and was measured on a scale from 1 to 10 (10 being the maximum score). Table 4 shows the aspects with example items and the corresponding Cronbach's α.

Data Analysis

In order to test whether the new buildings significantly outperformed the old buildings (Hypotheses 1–13), a longitudinal multilevel regression analysis was conducted. The first level of the analysis was time (pre- and post-occupancy evaluation), Level 2 was the employee, and Level 3 was the old building. This indicates that time is nested in employees and employees are nested in an old building. This nested structure was taken into account in the multilevel analysis, meaning that the results were controlled for the dependencies that occur due to the nested structure. For each performance measure, we tested the effect of the intervention. We investigated whether the building performance measures rated by employees who moved to the new buildings (intervention group) improved more over time than the ratings of the control group. In case this intervention effect was significant ($p < .05$) and in favor of the new buildings, the hypothesis was accepted. Cohen's d (i.e., the standardized mean difference) was calculated with the method of Rosenthal, Rosnow, and Rubin (1999, p. 186) to report the strength of the effects. The guidelines of Cohen (1988) for the interpretation of the strength of an effect are as follows: $d = 0.20$ is considered as "small," $d = 0.50$ as "medium," and $d = 0.80$ as "large."

A complete case analysis was also conducted to check whether the results would vary if not (as the longitudinal multilevel analysis does) all data were taken into account (also the respondents that had only conducted the pre- or post-occupancy evaluation), but only the cases of employees who conducted both evaluations.

The open questions were analyzed as follows. First, comments were read and frequently mentioned themes were identified. Second, once the themes were identified the exact frequency was scored on how often the themes were mentioned positively or negatively. The comment "nothing" on the question what would you like to keep, was excluded from the positive comments. The top three was identified.

Results and Discussion

The aim of this research was to investigate the effects of the newly built nonpatient-related buildings of the medical center on staff perceptions and whether the design objectives were achieved. Table 5 shows the results of the longitudinal multilevel regression analysis. The average scores on the performance measures are indicated for the pre- and post-occupancy evaluation, for the control and intervention group (moved), the results of the intervention effect test and the effect sizes. As the table shows, performance of the buildings in the pre-evaluation for the control and intervention group is comparable. Compared with the post-evaluation of the control group, staff perceptions of the new buildings were significantly more positive than staff perceptions of the old buildings on indoor climate, perceived safety, well-being, work environment, sustainability, facilities, and the overall satisfaction score ($p < .05$). No effects were found for orientation, knowledge sharing, physical activity, work performance, working atmosphere, and commitment to the employer. The complete case analysis replicated the effects found with the full sample. No effect was found for the old building level. This means that the effects found apply to all (11) old buildings. If we had found an effect, this would mean that the effect was related to a specific building in the old setting.

The systematic changes among the movers compared with the staff that did not move to the new buildings indicate that the effects may be attributed to the new working environment and not to the passage of time, general hypes, or Hawthorne effect (which means that improvements in performance are the results of the simple fact that staff was asked to evaluate the building), as these would have affected both groups. However, causality between the design changes and the improvements cannot be demonstrated with certainty, as this would require an experiment with blinded participants, which is not possible in this type of pre-post research. Still, in order to better understand what design decisions could explain these results and learn from the evaluations, we related the results to the design decisions that were expected to have an effect on the performance measures (as described in the Introduction section). Based on this evaluation, we conclude whether the design team succeeded in creating a safe, pleasant, and sustainable building.

Safe

To create a safe environment efforts were put in a process supporting layout, spacing, and interior design (see working environment) and accessibility, transparency, and fire safety (see perceived safety). The efforts resulted in an improvement in the perception of the working environment, meaning that the new working environment better supports safe and comfortable working. Working environment was also relatively highly correlated with the overall satisfaction score ($r = .57$), indicating that the

Table 4. Example Items Belonging to the Defined Aspects.

Aspect	# Items	Example Items	Cronbach's α
Indoor climate	11	• There is sufficient daylight in the building • The view from my workplace is pleasant • The temperature in the building is comfortable • I do not experience problems with noise hinder •	.81
Perceived safety	7	• I feel safe on the campus of the medical center • I feel safe at my department • There is enough light in the corridors of the buildings on the campus • The escape routes are easily accessible • . . .	.83
Work environment	9	• This building supports me in doing my job • I have enough space to do my job • At my workplace, I can concentrate well • My workplace enables me to work according to the available protocols • . . .	.85
Well-being	13	• At the end of a normal workday, I am mentally tired • In the last month, I have suffered at work from my neck, back, and/or shoulders • In the last month, I have suffered at work from shortness of breath • In the last month, I have suffered at work from dry and/or irritated eyes • . . .	.86
Physical activity	1	• I like to use the stairs	NA
Work performance	4	• Compared to my average performance, I would rate my creativity at this time as • Compared to my average performance, I would rate the quality of my work at this time as • Compared to my average performance, I would rate my amount of work at this time as • . . .	.77
Commitment to the organization	4	• I would recommend the organization to others • I feel at home at the organization • I am proud of the organization • . . .	.82
Sustainability	1	• The building is sustainable (energy efficient and careful use of materials)	NA
Orientation and routing	9	• I can easily find my way around • Visitors can easily find their way around the campus • The signage is adequate • There are enough elevators • . . .	.68
Facilities	10	• There are enough spaces for formal meetings • There are enough spaces for informal meetings • There are enough spaces to meet colleagues • There is a good changing room • . . .	.76

(continued)

Table 4. (continued)

Aspect	# Items	Example Items	Cronbach's α
Knowledge sharing	4	• I frequently work together with others within the department • I frequently work together with others outside the department • I frequently share my knowledge with others within the department • . . .	.75
Working atmosphere	5	• The atmosphere within my department is good • Collaboration within the department is good • The knowledge sharing within my department is good • . . .	.78
Overall satisfaction	1	• Please score your general satisfaction with the building you work in on a scale from 1 (*very poor*) to 10 (*outstanding*)	NA

Note. NA = not applicable.

perception of the working environment is positively related to the overall satisfaction with the building. Other research that investigated determinants of positive workspace perceptions found that in U.S. office buildings amount of space is the greatest contributor (Frontczak et al., 2012). According to the results of the open questions shown in Table 6, a spacious working environment was the most mentioned positive comment in the old buildings. It seems, therefore, that especially the interventions done in the laboratories contributed to the effects observed.

Staff also felt safer in the new buildings, but the effect was small ($d = 0.21$). This could be influenced by the fact that the newly implemented access system did not work properly during an evacuation test in August 2013. Some people were not authorized to access or leave the building at certain floors. Furthermore, the connecting plaza was still a construction site with limited overview during the post-occupancy evaluation. Nevertheless, based on the significant improvements in the perceptions of the working environment and safety, we conclude that the design team succeeded in creating a safer buildings (safer than the old settings).

Pleasant

When judging the pleasantness of the new buildings based on the overall satisfaction score, it can be concluded that this second main objective was well achieved. A relatively large improvement in overall satisfaction was found ($d = 0.61$). This is supported by the significant improvement in perceived well-being, although the effect is small ($d = 0.12$). The number of comments that were made in the open questions also support an overall increased satisfaction with the new building. In the pre-occupancy evaluations, 350 positive and 711 negative comments were made on the old buildings. In the post-occupancy evaluations, 449 positive and 720 negative comments were made on the new buildings (excluding the control group). The results show that in the new buildings more comments were posted by fewer people and that they posted relatively more positive comments than in the pre-evaluation. Lee and Brand (2005) indicated that by conducting an evaluation, commitment to the building increases. This may explain the increased number of comments made.

Some may argue that the large increase in overall satisfaction is due to a so-called HALO effect, which implies that a change in the building as such may be the underlying reason for improved satisfaction rather than the specific design characteristics of the new building. When this is the case, improvements in all performance measures are likely. However, our results clearly show that some performance measures significantly increased but others did not, which is unlikely due to an HALO effect. For instance, when looking at the detailed aspects that

Table 5. Average Performance Scores in the Pre- and Post-Occupancy Evaluation for the Control and Intervention Group and Intervention Effect Results.

	Control Group				Moved				Intervention Effect			Effect Size
	Pre ($n \pm 82$)		Post ($n \pm 147$)		Pre ($n \pm 271$)		Post ($n \pm 454$)		Average Change Due to Occupancy of New Buildings			
Performance measure	Ave.	*SD*	Ave.	*SD*	Ave.	*SD*	Ave.	*SD*	*B*	*SE*	*p*	Cohen's *d*
Indoor climate	2.88	0.54	2.76	0.58	2.90	0.68	3.29	0.72	0.48	0.09	<.001	0.36
Perceived safety	3.59	0.58	3.57	0.67	3.50	0.55	3.74	0.61	0.22	0.08	.005	0.21
Work environment	3.59	0.66	3.48	0.70	3.51	0.60	3.82	0.57	0.42	0.08	<.001	0.34
Well-being	2.93	0.69	2.89	0.71	3.09	0.69	3.22	0.67	0.25	0.08	.002	0.12
Physical activity	4.01	0.75	3.81	1.04	3.86	0.95	3.76	1.04	0.08	0.12	.339	0.05
Work performance	3.34	0.52	3.26	0.51	3.30	0.48	3.29	0.47	0.07	0.07	.304	0.07
Commitment	3.63	0.59	3.56	0.59	3.71	0.53	3.67	0.60	0.10	0.06	.460	0.03
Sustainability	2.55	1.04	2.37	0.94	2.16	0.84	3.35	0.73	1.29	0.13	<.001	0.72
Orientation	3.01	0.50	3.10	0.63	2.99	0.48	3.04	0.54	0.02	0.08	.832	−0.04
Facilities	3.15	0.61	2.93	0.67	3.10	0.54	3.28	0.57	0.34	0.07	<.001	0.34
Knowledge sharing	3.85	0.54	3.86	0.59	3.75	0.68	3.74	0.60	0.01	0.08	.899	−0.02
Working atmosphere	3.49	0.65	3.43	0.63	3.51	0.61	3.48	0.60	0.03	0.07	.647	0.03
Overall score	6.13	1.62	5.58	1.71	5.66	1.66	7.07	1.30	1.98	0.21	<.001	0.61

Note. Ave. = average score; *SD* = standard deviation, *B* = regression coefficient, *SE* = standard error, *p* = *p* value.

Table 6. Top Three Positive and Negative Themes Reported in the Open Questions.

	Old Buildings	New Buildings
Top 3: Positive themes	Spacious working environment	Nice view
	Nice view	Good access to (day)light
	Good access to (day)light	Spacious working environment
Top 3: Negative themes	Indoor climate	Control of indoor climate
	Limited access to (day)light	Artificial light (sensor system)
	Inability to open a window	Elevator system

were expected to contribute to a pleasant building, some nuances should be highlighted. Investments were especially made to improve the indoor climate, orientation, knowledge sharing, and facilities, but these did not pay off for all aspects. To improve the indoor climate, effort was put into ventilation, temperature, (day)light, views, and noise reduction. As a result, indoor climate in the new buildings was rated as more comfortable and based on the open questions (Table 6) it seems that the nice view and the ability to open the window were especially valued. Various studies corroborate that aspects of the indoor climate (air quality, daylight, views, and noise) can improve satisfaction and well-being (Aries et al., 2010; Boubekri, Hulliv, & Boyer, 1991; Fisk & Rosenfeld, 1997; Heerwagen, 2000; Heerwagen & Wise, 1998; Holcomb & Pedelty, 1994; Kaplan, 1993; Klitzman & Stellman, 1989; Leather, Pyrgas, Beale, & Lawrence, 1998; Sensharma et al., 1998; Ulrich et al., 1991). We also found the highest correlation between indoor climate and overall satisfaction ($r = .64$), indicating a better perceived indoor climate relates to increased overall satisfaction with the new buildings. Also, a correlation with perceived well-being existed, although less strong ($r = .38$).

Interestingly, the control of the climate system and lighting system received the most negative feedback in the open questions (Table 6). Apparently, the output of the systems is comfortable; however, control of the system can be improved.

When talking to staff, it appeared that the light in the office annoyingly turned on and off when daylighting levels changed quickly and that people complained about the inability to switch the lights off. In the literature, the relation between perceived personal control over the physical environment and self-reported satisfaction is also stressed (Cole, Robinson, Brown, & O'Shea, 2008; Hauge, Thomsen, & Berker, 2010; Lee & Brand, 2005). However, although controllability can be improved, it did not diminish the overall perceived improvement of the indoor climate.

To improve the orientation in the new buildings, much effort was put in a clear infrastructure, lines of sight, and access to daylight in corridors and when exiting elevators, however perceived orientation did not improve. The fact that the post-evaluation was conducted in an interim setting in which the old buildings still function next to the new buildings might have negatively impacted the perceived orientation as travel distances were long (some people bring in scooters). Another item is the functioning of the elevator system that received negative feedback and might have decreased the overall orientation score. The fact that people had to indicate the required floor level outside the elevator was reported as confusing. Staff often entered the elevator in groups and only pressed the floor button once. This confused the elevator as it registered that there was only one person in the elevator and kept allocating people to this elevator even though the elevator was already fully occupied. Furthermore, the aspects indoor climate and perceived safety also cover items on daylight in the building. It could be argued that the daylight interventions to improve orientation have contributed to the improvement of these aspects and that the relation with orientation is less evident (staff know their way in the building) or perhaps the effect on orientation is more unconscious. As an effect of the methodology used (survey that measures conscious experiences), unconscious effects are missed (also see study Strengths and Limitations of the method used).

Special focus was on knowledge sharing in the creation of informal and formal meeting rooms and locating collaborating departments near each other. However, improvements in the frequency of knowledge sharing were not found. A reason could be the newly implemented access system, as departments could not be entered without the correct authorization. This might have felt as a barrier to cross departments and share knowledge. Furthermore, as opposed to the layout in the old buildings where offices were often located at the opposite side of each other, stimulating informal talks, in the new building offices were only located next to each other, which might have decreased informal knowledge sharing. Another explanation could be that the frequency of knowledge sharing is more influenced by its necessity and less by the building design. It should also be stressed that the aspect facilities (which included the perception of meeting rooms, coffee area, personal space, changing, and dinner facilities) were better appreciated ($d = 0.34$). Interestingly, at the time of the evaluation the central changing rooms and restaurant facilities were not operational yet. Furthermore, personal space was reduced as a result of paperless working. Therefore, the clear improvement in facilities seems mainly the result of the (informal) meeting rooms and coffee areas. Thus, the (in)formal meeting rooms are well valued, however there seems no direct relation to increased knowledge sharing.

Another aspect of a pleasant and healing building according to the project team was a building that stimulates the use of stairs. Therefore, the main stairs in the atrium were dominantly positioned and had access to daylight. Staff however did not report an increased use of the stairs. An explanation is that the atrium was not in the building where most staff was located. In the office towers, stair cases were not inviting and they also ended at the opposite side of the department from where one started. This might have resulted in staff in the office tower not increasing their use of the stairs even though related departments were close and complaints were reported on the elevator system. For the laboratories, related departments were often on the same floor, so there was less necessity to take the stairs, which also might have impacted the total results.

Improved perceived working performance, working atmosphere, and commitment to the employer were also expected as an outcome of a pleasant working environment. However, we found no improvement in the new buildings. It seems that these outcomes are more influenced by other factors than the building design. Other pre- and post-evaluations (but without control group or other methodological limitations) however, do report increases in perceived working performance, working attitude, pride (Heerwagen, 1998; Heerwagen & Wise, 1998; Heerwagen & Zagreus, 2005), and affective organization commitment (McElroy & Morrow, 2010). The study by Heerwagen was conducted in manufacturing environments, and the effects found were mainly the result of daylight interventions. Apparently in this environment daylight is more directly related to perceived work performance than in the nonpatient hospital environment. Thereby, also the explicit aim of the redesign is important. For instance, in the research of McElroy and Morrow (2010) one objective of the redesign was to change the organizational culture by creating open workspaces to break down hierarchical or bureaucratic attitudes. This indicates that aspects like organization commitment can be influenced by the building design, when there is a special focus in creating a change but seems not to be influenced in general when the working environment is improved for other purposes.

Sustainable

Due to efforts in the indoor climate, technical solutions, and interior design, the final main objective to create a sustainable building was convincingly achieved in the eyes of employees ($d = 0.72$). Interestingly, the smart lighting and elevator system implemented for sustainability reasons, received much negative feedback as well as the lack of temperature control which is a result of the concrete core heating. Therefore, it seems that sustainable solutions can occur at the expense of user comfort. Additionally, employees who moved to the new buildings received a leaflet with the house rules of the new building. Although facilities such as the water-free urinals and elevator system were mentioned because of their different use and not in relation to sustainability, it could have affected the perceived sustainability. Instructions on how to use the building, however, were only limitedly addressed. Lesson learned, therefore, is to better inform and instruct users how to use a "sustainable" building (indoor climate, lights, and elevators), in order to reduce negative experiences as a result of improper use. This is also supported by literature, according to Nicol and Roaf (2005) and Leaman and Bordass (2007) users of buildings are much less satisfied when they cannot understand how things work or how to control for instance temperature and ventilation. Information on use and operation of technical facilities is therefore crucial.

Study Strengths and Limitations

Investigating the effects of a new building is not trivial. A new building is a complex intervention as many aspects are changed simultaneously, which makes it difficult to directly relate changes in design aspects to performance outcomes. According to Craig et al. (2008) in their guidance for complex interventions in public health, researchers, therefore, need to carefully consider the method used and the value of the evidence that can be gathered in complex interventions, given these constraints.

Strengths of the method used in this research are the pre-post design, the inclusion of a control group, and a statistical technique that can deal with nested structures and missing cases. We showed that with this method it is possible to measure the performance improvements of a new building design. Important for this method to succeed, is to clearly document the objectives that were aimed for, the performance measures used to measure whether the objectives are achieved, and what decisions were taken to achieve the objectives. Only when these parameters are clearly defined, this method can be used to investigate whether the effort that was put into the design of a new building paid off. Since pre-post evaluations of new buildings are rarely conducted, our study provides guidance for future evaluations of improvement in work environment through building characteristics.

It should be noted that the performance measures in our study were all subjective measures that could only be measured if respondents were consciously aware of the performance. Unconscious performances of the building could therefore be missed. For example, it could be the case that knowledge sharing was increased based on the number of informal meetings. However, employees might not have perceived this increase and believed knowledge sharing did not improve. In our design, we would measure the latter. Objective performance measures could therefore complement subjective findings but were not used in this research.

Another limitation is the relatively low response and the fact that due to the anonymity of the data set, nonresponse could not be analyzed. A potential bias therefore exists, but this bias exists in the intervention as well as in the control group. We controlled the effects found in the pre- and post-evaluation of the intervention group for the effects in the control group. The effects found are therefore at least valid for the "responders" group (whoever they are). The effect sizes are also based on the difference between these groups. We found no other pre- and post-occupancy evaluations that included similar effect sizes and as a result, we were unable to compare our results with previous studies.

Implications for Practice

- This study demonstrates that it is possible to measure the performance improvements of a complex intervention being a new building design and validate design decisions.
- Structural attention in the new building design to daylight, views, acoustics, temperature, ventilation, lighting, accessibility, spacing, layout, transparency, fire safety, (in)formal meeting areas, coffee areas, location of collaborating departments, interior design, and smart technology resulted in the improvement of overall staff satisfaction, perceived well-being, working environment, perceived safety, indoor climate, facilities, and sustainability.
- Performance measures that received less design focus did not increase such as work performance, physical activity, working atmosphere, and commitment to the employer. This should encourage designers to aim for specific goals when designing or redesigning and translate them into explicit and focused design choices to achieve these goals.
- Attention should be paid to communicating the use of the building to optimize perceived performance.
- Although, due to the complexity of the intervention, no clear cause and effect relations can be established between the design decisions and performance improvements, we hope we have illustrated that by a structured evaluation and inclusion of a control group valuable insights can be generated on: the realization of design objectives, design decisions that could be considered to increase the perceived performance of a building, and lessons learned for future designs.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

Aries, M. B., Veitch, J. A., & Newsham, G. R. (2010). Windows, view, and office characteristics predict physical and psychological discomfort. *Journal of Environmental Psychology*, *30*, 533–541.

Blok, M., de Korte, E., Groenesteijn, L., Formanoy, M., & Vink, P. (2009). The effects of a task facilitating working environment on office space use, communication, concentration, collaboration, privacy and distraction. *Proceedings IEA China*, August 9–14.

Bordass, W., & Leaman, A. (2005). Making feedback and post-occupancy evaluation routine 3: Case studies of the use of techniques in the feedback portfolio. *Building Research and Information*, *33*, 361–375.

Boubekri, M., Hulliv, R. B., & Boyer, L. L. (1991). Impact of window size and sunlight penetration on office workers' mood and satisfaction: A novel way of assessing sunlight. *Environment and Behavior*, *23*, 474–493.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Cole, R. J., Robinson, J., Brown, Z., & O'Shea, M. (2008). Re-contextualizing the notion of comfort. *Building Research and Information*, *36*, 323–336.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: The new Medical Research Council guidance. *British Medical Journal*, *337*, 979–983.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*, 297–334.

Federatie van Medisch Wetenschappelijke Verenigingen. (2004). *Gedragscode gezondheidsonderzoek*. Rotterdam, the Netherlands: Stichting Federatie van Medisch Wetenschappelijke Verenigingen.

Fisk, W. J., & Rosenfeld, A. H. (1997). Estimates of improved productivity and health from better indoor environments. *Indoor Air*, *7*, 158–172.

Frontczak, M., Schiavon, S., Goins, J., Arens, E. A., Zhang, H., & Wargocki, P. (2012). *Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design*. Berkeley: Center for the Built Environment, University of California. Retrieved July 2014, from http://escholarship.org/uc/item/1wc7t219

Guinther, L., Carll-White, A., & Real, K. (2014). One size does not fit all: A diagnostic post-occupancy evaluation model for an emergency department. *Health Environments Research & Design Journal*, *7*, 15–37.

Hauge, A. L., Thomsen, J., & Berker, T. (2010). User evaluations of energy efficient buildings—Literature review and further research. *Zero emission buildings—Proceedings of Renewable Energy Conference 2010*. Trondheim, Norway.

Heerwagen, J. (1998). *Of light, time and space: Lighting quality and green building Design*. Paper presented at the CIE Symposium on Lighting Quality, Ottawa, Canada, May 9-10, 1998.

Heerwagen, J. (2000). Green buildings, organizational success, and occupant productivity. *Building Research and Information*, *28*, 353–367.

Heerwagen, J., & Wise, J. (1998). Green buildings: Differences in perceptions and experiences across manufacturing shifts. *HPAC Engineering*, *70*, 57–63.

Heerwagen, J., & Zagreus, L. (2005). *The human factors of sustainable building design: Post occupancy evaluation of the Philip Merrill environmental center*. Berkeley: Center for the Built Environment, University of California. Retrieved July 2014, from http://escholarship.org/uc/item/67j1418w

Holcomb, L. C., & Pedelty, J. F. (1994). Comparison of employee upper respiratory absenteeism costs with costs associated with improved ventilation. *ASHRAE Transactions*, *100*, 914–921.

Holzinger, K. J. (1944). A simple method of factor analysis. *Psychometrika*, *9*(4), 257–262.

Kaplan, R. (1993). The role of nature in the context of the workplace. *Landscape and Urban Planning*, *26*, 193–201.

Klitzman, S., & Stellman, J. (1989). The impact of the physical environment of the psychological well-being of office workers. *Social Science and Medicine*, *29*, 733–742.

Koopmans, L., Bernaards, C. B., Hildebrandt, V. H., Van Buuren, S., Van der Beek, A. J., & De Vet, H. C. W. (2013). Development of an individual work performance questionnaire. *International Journal of Productivity and Performance Management*, *62*, 6–28.

Leather, P., Pyrgas, M., Beale, D., & Lawrence, C. (1998). Windows in the workplace: Sunlight, view, and occupational stress. *Environment and Behavior*, *30*, 739–762.

Lee, S. Y., & Brand, J. L. (2005). Effects of control over office workspace on perceptions of the work environment and work outcomes. *Journal of Environmental Psychology*, *25*, 323–333.

Leaman, A., & Bordass, B. (2007). Are users more tolerant of 'green' buildings? *Building Research and Information*, *35*, 662–673.

Leijten, J. L., & Kurvers, S. R. (2007). *Praktijkgids arbeidshygiëne, binnenklimaat kantoorgebouwen. Onderzoek naar klachten*. Alphen aan den Rijn, the Netherlands: Kluwer.

McElroy, J. C., & Morrow, P. C. (2010). Employee reactions to office redesign: A naturally occurring quasi-field experiment in a multi-generational setting. *Human Relations*, *63*, 609. doi:10.1177/0018726709342932

Nicol, F., & Roaf, S. (2005). Post-occupancy evaluation and field studies of thermal comfort. *Building Research and Information*, *33*, 338–346.

Pati, D., & Pati, S. (2013). Methodological issues in conducting post-occupancy evaluations to support design decisions. *Health Environments Research & Design Journal*, *6*, 157–163.

Riley, M., Moody, C., & Pitt, M. (2009). *A review of the evolution of post-occupancy evaluation as a viable performance measurement tool*. BEAN Conference 2009, BEST Research Centre (Built Environment & Sustainable Technologies), Liverpool John Moores University, England.

Rosenthal, R., Rosnow, R. L., & Rubin, D. B. (1999). *Contrasts and effect sizes in behavioral research: A correlational approach*. Cambridge, England: Cambridge University Press.

Schauffeli, W. B., Salanova, M., Gonzaléz-Romá, V., & Bakker, A. B. (2002). The measurement of engagement and burnout: A two sample confirmatory factor analytic approach. *Journal of Happiness Studies*, *3*, 71–92.

Sensharma, N. P., Woods, J. E., & Goodwin, A. K. (1998). Relationships between the indoor environment and productivity: A literature review. *ASHRAE Transactions*, *104*, 686–701.

Stuive, I., Kiers, H. A. L., & Timmerman, E. (2009). Comparison of methods for adjusting incorrect assignments of items to subtests: Oblique multiple group method versus confirmatory common factor method. *Educational and Psychological Measurement*, *69*, 948. doi:10.1177/0013164409332226

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*, 201–230.

Zeisel, J. (2006). *Inquiry by design: Environment/behavior/neuroscience in architecture, interiors, landscape, and planning*. New York, NY: WW Norton & Co.

Zweers, T., Preller, L., Brunekreef, B., & Boleij, J. S. M. (1992). Health and indoor climate complaints of 7043 office workers in 61 buildings in the Netherlands. *Indoor Air*, *2*, 127–36.