Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design

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ABSTRACT
The paper examines which subjectively evaluated indoor environmental parameters and building features mostly affect occupants' satisfaction in mainly US office buildings. The study analyzed data from a web-based survey administered to 52,980 occupants in 351 office buildings over ten years by the Center for the Built Environment. The survey uses 7-point ordered scale questions pertaining to satisfaction with indoor environmental parameters, workspace and building features. The average building occupant was satisfied with his/her workspace and building. Proportional odds ordinal logistic regression shows that satisfaction with all 15 parameters listed in the survey contributed significantly to overall workspace satisfaction. The most important parameters were satisfaction with amount of space (odds ratio OR 1.57, CI: 1.55-1.59), noise level (OR 1.27, CI: 1.25-1.29) and visual privacy (OR 1.26, CI: 1.24-1.28). Satisfaction with amount of space was ranked to be the most important influence for workspace satisfaction, regardless of age group (below 30, 31-50 or over 50 years old), gender, type of office (single or shared offices, or cubicles), distance of workspace from a window (within 4.6 m or further) or satisfaction level with workspace (satisfied or dissatisfied). Satisfaction with amount of space was not related to the gross amount of space available per person.

KEYWORDS
Occupants' responses, office buildings, post-occupancy evaluation

PRACTICAL IMPLICATIONS
To maximize workspace satisfaction designer should invest in aspects which increase satisfaction with amount of space and storage, noise level and visual privacy. Office workers will be most satisfied with their workspace and building when located close to a window in a private office. This may affect job satisfaction, work performance and personal and company productivity.

INTRODUCTION
Occupants' satisfaction in office buildings is associated with indoor environmental quality (thermal, visual, acoustic environment and air quality) and workspace and building features including size, aesthetic appearance, furniture and cleanliness. The ten studies in Table 1 identified the parameters that contribute to building occupants' satisfaction (Marans and Yan, 1989; Humphreys, 2005; Veitch et al., 2007; Astolfi and Pellerey, 2008; Wong et al., 2008; Choi et al., 2009; Lai et al., 2009; Schakib-Ekbatan et al., 2010; Bluyssen et al., 2011; Bin et al., 2011). The definition of occupants' satisfaction was not consistent among the studies, but all of them defined occupants' satisfaction in a broad perspective and related it either to satisfaction/comfort with indoor environmental quality or satisfaction/comfort with the workspace. Five studies (Humphreys, 2005; Astolfi and Pellerey, 2008; Wong et al., 2008; Lai et al., 2009; Bin et al., 2011) focused only on the impact of indoor environmental quality on building occupants' satisfaction. They found that thermal, visual and acoustic environment and air quality contributed to building occupants' satisfaction. The importance of different indoor environmental parameters for building

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occupants' satisfaction varied slightly between studies but the importance of the thermal environment for building occupants' satisfaction was generally ranked slightly higher than the importance of air quality and acoustic environment and much higher than the importance of visual environment. A literature survey by Frontczak and Wargocki (2011) concluded that apart from indoor environmental parameters, there are other factors unrelated to the indoor environment that can influence satisfaction within the buildings, among others occupants' control over the indoor environment. In addition, the five studies presented in Table 1 (Marans and Yan, 1989; Veitch et al., 2007; Choi et al., 2009; Schakib-Ekbatan et al., 2010; Bluyssen et al., 2011) include effects of parameters unrelated to indoor environmental quality. These studies show that building occupants' satisfaction was also affected by satisfaction with the view, control over the indoor environment, amount of privacy as well as layout, size, cleanliness, aesthetics and furniture of office.

Table 1.Summary of studies investigating which parameters influence building occupants' satisfaction.

Study	Population	Data analysis	Results
Marans and Yan (1989)	Nearly 1000 occupants in 13 office buildings in US (RR* unknown)	Pearson correlation	Workspace satisfaction was correlated to satisfaction with lighting, noise, air quality, heating and drafts as well as amount of space, furniture quality, privacy, and color and area of walls and partitions
Humphreys (2005)	4655 responses** in 26 office buildings in 5 European countries (RR unknown)	Multiple linear regression	Overall comfort at workplace was affected by satisfaction with warmth, air quality, air movement, noise, humidity and light
Veitch et al. (2007)	779 occupants in 9 office buildings in Canada and US (RR~90%)	Exploratory and confirmatory factor analysis and structural equation modeling	Satisfaction with indoor environment at workstation was influenced by satisfaction with noise, air movement, air quality, temperature, lighting, privacy, view to outside as well as workspace's size, aesthetic appearance and degree of enclosure
Astolfi and Pellerey (2008)	852 students in a secondary school in Italy (RR=85%)	Pearson correlation	Satisfaction with indoor environment was correlated with satisfaction with acoustic, thermal, visual environment and air quality
Wong et al. (2008)	293 occupants of office buildings in Hong Kong	Multivariate logistic regression	Acceptability of overall indoor environment was

	(RR unknown)		affected by acceptability of thermal environment, air quality, noise level and illumination level
Choi et al. (2009)	492 occupants in 29 office buildings in US (RR unknown)	Pearson correlation	Satisfaction with indoor environment was correlated with satisfaction with air quality, thermal environment, lighting, acoustics and spatial conditions
Lai et al. (2009)	125 occupants in 32 residential apartments in Hong Kong (RR unknown)	Multivariate logistic regression	Acceptability of overall indoor environment was affected by acceptability of thermal environment, acoustics, lighting and air quality
Schakib-Ekbatan et al. (2010)	867 occupants in 14 office buildings (RR=79%)	Correspondence analysis and principal component analysis with optimal scaling	Workspace satisfaction was influenced by satisfaction with temperature, lighting conditions, air quality, acoustics, spatial conditions (privacy and individualization of workspace), office furniture and office layout
Bluyssen et al. (2011)	5732 occupants in 59 office buildings in 8 European countries (RR unknown)	Principal component analysis, Pearson correlation and linear regression	Overall satisfaction was affected by satisfaction with thermal, acoustic and luminous environment, air quality, control over indoor environment, amount of privacy as well as office layout, decoration and cleanliness
Bin et al. (2011)	500 occupants in 5 buildings in Beijing and Shanghai (RR unknown)	Multivariate linear regression	Overall satisfaction was influenced by satisfaction with thermal, acoustic and luminous environment and air quality

* RR – response rate;
** Number of filled out questionnaires; some of the building occupants gave their response more than once.

Occupants' satisfaction was shown to be positively correlated (linear model r: 0.74-0.8) to the self-estimated productivity of office workers (Leaman et al., 2007; Thomas, 2010). Occupants uncomfortable

with the overall environment reported much lower self-estimated productivity than those who felt comfortable with the overall environment (Leaman and Bordass, 2001). Occupants' satisfaction with workspace was also positively associated with job satisfaction (Oldham and Rotchford, 1983; Wells, 2000; Donald and Siu, 2001; Veitch et al., 2007). This may in turn have an impact on job performance: Judge et al. (2001) performed extensive meta-analysis of the relationship between job satisfaction and objective measures of job performance (mainly supervisory ratings) based on 54,417 responses from 312 independent samples and they concluded that the mean correlation between job satisfaction and job performance is 0.30. Job satisfaction was also related to frequency and duration of absenteeism (Sagie, 1998; Hardy et al., 2003) as well as intention to quit work (Hellman, 1997; Sagie, 1998; Shaw, 1999; Van Dick et al., 2004), issues which may have financial consequences for employers. Therefore there is much to gain from maximizing occupants' satisfaction.

Over a 10-year period the Center for the Built Environment (CBE) at the University of California Berkeley has conducted roughly 600 post occupancy evaluation surveys collecting information about satisfaction of building occupants in relation to several indoor environmental quality parameters and building features (Zagreus et al., 2004). The database created using these responses offers a unique opportunity to analyze specific contributors to building and workspace satisfaction from a broad perspective, providing input to a better understanding of occupants' satisfaction in the buildings. Such knowledge could guide investments in both new and retrofitted buildings to achieve the greatest increase in occupant satisfaction.
The aim of the present study is to investigate which subjectively evaluated indoor environmental quality parameters and building features (office type and distance from a window) most affect occupants' satisfaction in office buildings based on the data collected by CBE.

METHODS

Database description

The CBE occupant satisfaction survey is web-based, collecting information about occupants' evaluation of indoor environmental quality and building features (Zagreus et al., 2004). More information with demo version of the CBE occupant satisfaction survey can be found at http://www.cbe.berkeley.edu/research/survey.htm. A comparison of the CBE post occupancy evaluation survey and other available surveys is reported in Peretti and Schiavon (2011). The survey is comprised of a core survey and optional survey modules that are added depending on particular building's features and the building owner's interest. The present study focuses only on the core survey questions, which were asked in all surveyed buildings. The core survey measures occupant satisfaction in the following categories: office layout, office furnishings, thermal comfort, air quality, lighting, acoustic quality, cleanliness and maintenance as well as overall satisfaction with workspace and building. The list of parameters evaluated in each category is presented in Table 2. These parameters are not sufficient to fully describe occupant satisfaction in the buildings, but according to the CBE team that developed the survey, all are relevant. Questions about satisfaction have the following structure: "How satisfied are you with…". The satisfaction questions are answered using a 7-point scale ranging from "very satisfied" (+3) to "very dissatisfied" (-3) with a neutral midpoint (0). In case respondents vote "dissatisfied" (below the neutral midpoint) to a given satisfaction question, they are taken to a follow-up "branching" page containing further questions aimed at diagnosing the source of dissatisfaction. The present study focuses, however, on the satisfaction questions and contains no analysis of branching questions (which can be found in e.g. Moezzi and Goins, 2011). The CBE occupant satisfaction survey also collects background information about participants of the survey including gender, age group, type of work performed, office type, proximity of workstation to windows and external walls as well as duration of working in the present building and at the present workspace. In addition, a building facility manager fills out a building information form providing descriptive information about the building and its systems such as the

building's age, location and size, number of floors, number of occupants, type of HVAC system, solar shading and controls, buildings' LEED rating, energy use and cost of building construction, etc.

Table 2. List of parameters assessed by the CBE occupant satisfaction survey.

Category	Questionnaire item
Office layout	Amount of space available for individual work and storage
	Level of visual privacy
	Ease of interaction with co-workers
Office furnishing	Comfort of office furnishings (chair, desk, computer, equipment, etc.)
	Ability to adjust furniture to meet your needs
	Colors and textures of flooring, furniture and surface finishes
Thermal comfort	Temperature in your workspace
Air quality	Air quality in your workspace (i.e. stuffy/stale air, air cleanliness, odors)
Lighting	Amount of light in your workspace
	Visual comfort of the lighting (e.g., glare, reflections, contrast)
Acoustic quality	Noise level in your workspace
	Sound privacy in your workspace (ability to have conversations without neighbors overhearing and vice versa)
Cleanliness and maintenance	General cleanliness of the overall building
	Cleaning service provided to your workspace
	General maintenance of the building
General comments	Your personal workspace
	Building overall

For each of the above parameters, the occupant also rates its effect on their ability to perform their work, and at the end they also rate how the building affects their productivity. However, the responses regarding the self-rated productivity were not analyzed in the present study.

The buildings in which the survey was conducted were identified in one of the following ways: CBE researchers contacted a building representative to obtain permission to perform the survey in the building, or a building representative contacted CBE with a request to perform the survey in the building.

As of June 2010, the CBE occupant satisfaction survey has been conducted in more than 600 buildings including offices, hospitals, schools and universities, research centers, assembly halls, commercial, governmental, residential, industrial and public (e.g. libraries) and prisons. The buildings varied in relation to their location, size, age, design and HVAC system. In the present study only office buildings were of interest. The acceptance or rejection of each building to be included in the present study was done in multiple stages:

- Identification of office buildings based on reported descriptions of a building's purpose, provided by a building facility manager in the building characteristic form. Selected buildings were mainly governmental buildings, office buildings occupied by private companies, universities and research centers. The following buildings were rejected: day care centers and elementary schools, residential buildings, customs office and border stations, airport, museums and libraries, hospitals, sport facilities, buildings in industrial settings (refinery, depot, and warehouse), fire station and prisons. In some of the rejected buildings there may be offices as well. Due to the settings in which the buildings were situated, they were not considered as typical offices.
- Review of the workstation definition. Viewing the survey gave an understanding of how the workspace was defined in the particular building. Only the office-like workstations were of interest in the present study. For some research centers and universities it was not obvious whether the workspace corresponded to an office, lab or classroom as well as in some court

houses the workspace could be an office or a court room. In cases where definition of a workspace was ambiguous, the building was rejected.

- Review of the survey response rate. Surveys with a response rate above 5% were accepted. The minimum response rate was set low as responses of an individual were the focus of the present study. Despite low response rates in some buildings, those who responded are still a valuable source of information. One may fear that respondents in buildings with a low response rate may not be representative for the whole building and that they may have been more willing to fill out the survey than the other building occupants due to their high dissatisfaction in the building, but Zagreus et al. (2004) found no statistically significant relationship between response rate and occupant satisfaction levels (page 68) although statistical information on the applied tests was not reported.

The final dataset contains responses from 397 surveys performed in 351 different buildings. In 40 buildings the survey was conducted more than once (e.g. before and after renovation) and all surveys are included in the analysis. Additionally, the present study focuses on people performing office work. These people were identified based on the description of their personal workspace. Only responses of people working in offices (single offices, shared offices, cubicles and open-space offices) are included in the analysis. The final dataset contains responses from 52,980 building occupants. It was not possible to indentify people who participated in more than one survey and match their responses so their responses were treated as independent in the analysis.

Statistical methods

Proportional odds ordinal logistic regression was applied to investigate the relationship between satisfaction with the workspace (response variable) and satisfaction with indoor environmental quality and building features (predictor variables). This method is applicable when the response variable is an ordinal variable: it takes only values that have a natural ordering (-3, -2, -1, 0, 1, 2, 3) but are not continuous (Baayen, 2008). The results of the regression model are presented in the form of odds ratios; confidence intervals are reported at 95% level. In this paper, odds ratio (OR) describes the likelihood of increasing workspace satisfaction when one of the predictor variables is increased by one unit while the other variables are kept constant. The odds ratios were then used to rank the parameters regarding their importance for workspace satisfaction. The regression analysis was carried out with R software using the "Design" package (R Development Core Team, 2009). Only the responses of people who answered all satisfaction questions were considered in the regression analysis, resulting in a sample of 43,021 responses. Statistical significance of each predictor variable in the regression model was tested by the Wald test (Sheather, 2009).

The Spearman rank correlation was used to estimate the correlation between satisfaction with the workspace and satisfaction with the building, and the correlation between satisfaction with the amount of space and area per person. Spearman rank correlation was used as the satisfaction votes were measured in ordinal scale (Siegel, 1956). The mean and median values of satisfaction with different indoor environmental quality parameters and building features were calculated by averaging satisfaction votes of each occupant in the whole dataset (N=52,980). The statistical significance of differences in satisfaction with indoor environmental quality parameters and building features in different office types and for different distances from a window was tested by the Wilcoxon rank sum test (known also as Mann-Whitney test). Wilcoxon rank sum test is applicable when the variables have an ordinal character (Siegel, 1956). For all tests the results were considered statistically significant when $p<0.05$.

RESULTS

Table 3 summarizes personal characteristics of respondents of CBE occupant satisfaction survey and workspace and building characteristics. Respondents varied in relation to their age, performed job and duration of working in the building. The majority of respondents worked at their current workspace for

more than 12 months, full-time, in cubicles and close to a non-operable window. They mostly worked in air-conditioned buildings with no LEED rating, situated in the US.

Table 3. Characteristics of respondents, workspaces and buildings.

Parameter	Description					
Personal characteristics						
Gender	Female	Male	Unknown			
	47%	36%	17%			
Age	<30 years	31-50 years	>50 years	Unknown		
	7%	18%	10%	65%		
Job category	Admin.support	Technical	Professional	Managerial	Other	Unknown
	5%	5%	10%	4%	1%	75%
Duration of working in the building	<1 year	1-2 years	3-5 years	>5 years	Unknown	
	13%	16%	18%	34%	19%	
Duration of working at the present workspace	<3 months	4-6 months	7-12 months	>12 months	Unknown	
	8%	8%	12%	53%	19%	
Time spent at workspace per week	<10 hours	11-30 hours	>30 hours	Unknown		
	3%	14%	73%	10%		
Workspace characteristics						
Personal workspace	Private office	Shared office	Cubicles with high partitions*	Cubicles with low partitions	Other	
	26%	6%	39%	22%	7%	
Workstation's distance from a window	Within 4.6 m	Further than 4.6 m	Unknown			
	63%	34%	3%			
Building characteristics						
Country	Australia	Canada	Finland	Italy	US	Unknown
	7%	2%	6%	1%	78%	6%
Ventilation system	Air-conditioned	Non air-conditioned	Unknown			
	50%	1%	49%			
Operable windows	Yes	No	Unknown			
	8%	41%	51%			
LEED rating	None	Pending	Certified	Silver	Gold	Platinum
	86%	2%	1%	1%	8%	2%
Year of construction	Minimum	25^{th} percentile	Median	75^{th} percentile	Maximum	
	1907	1969	1982	2000	2009	
Gross building area (excluding parking), m^2	Minimum	25^{th} percentile	Median	75^{th} percentile	Maximum	
	232	15,487	30,463	52,397	233,744	

* higher than 1.5 m

Figure 1 shows the satisfaction levels with indoor environmental quality and building features assessed in the survey (Table 2). Statistics are based on responses from between 45,464 and 52,138 building occupants as some of the building occupants chose not to evaluate some of the parameters listed in the survey. The parameters are depicted in order from the highest to the lowest mean satisfaction. The extremities of the boxes are the 25th and 75th percentiles. Bold vertical lines indicate median values and empty dots represent mean values. Building occupants were generally satisfied with their workspace (mean M=0.84) and with the building overall (M=0.95). The highest satisfaction was observed for ease of interaction with co-workers (M=1.30) and amount of light (M=1.25). The highest dissatisfaction was observed for sound privacy (M=-0.82), temperature (M=-0.16), noise level (M=0.14) and air quality (M=0.31).

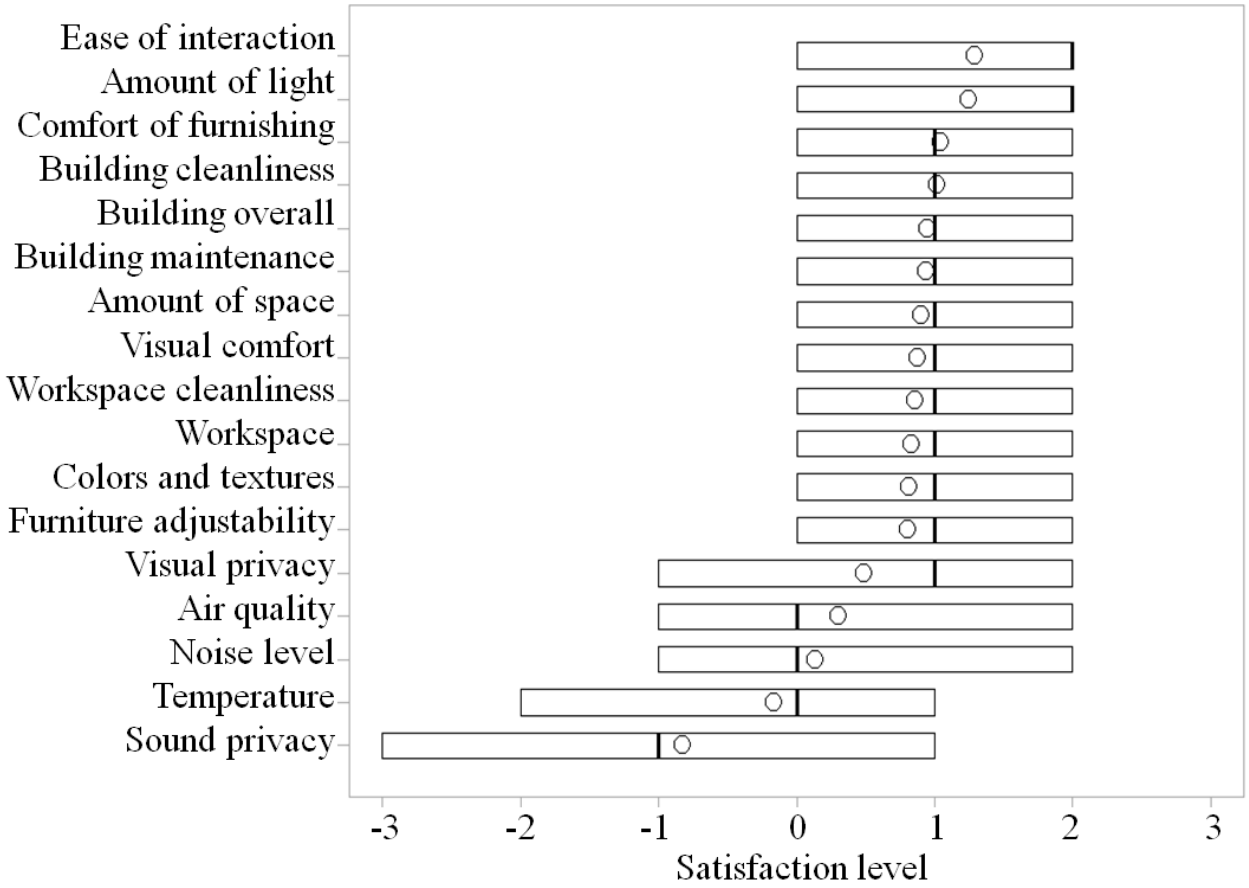

Figure 1. Box plots for satisfaction with parameters assessed in the CBE occupant satisfaction survey. The extremities of the boxes are the 25th and 75th percentiles. Bold vertical lines indicate median values and dots represent mean values. For all the parameters the minimum and maximum values are equal respectively -3 (very dissatisfied) and 3 (very satisfied).

Workspace satisfaction and satisfaction with the building were strongly correlated (Spearman rank correlation ρ=0.7, $p<0.001$) indicating that one could be used instead of the other. In the present study the workspace satisfaction was selected as the response (outcome) variable. Workspace satisfaction better represents and better describes the immediate surroundings of building occupants rather than building satisfaction, and is therefore more relevant for occupants' satisfaction.

Parameters affecting overall satisfaction

Proportional odds ordinal logistic regression was applied to investigate the relationship between the occupants' satisfaction with the workspace and satisfaction with indoor environmental parameters and building features. The results showed that satisfaction with all environmental parameters and building features listed in the CBE occupant satisfaction survey contributed significantly to workspace satisfaction ($p<0.001$). Figure 2 depicts values of odds ratios (OR) together with 95% confidence intervals (CI) for satisfaction with each indoor environmental parameter and building feature separately. The parameters are organized in order of decreasing value of the odds ratio. The results showed that satisfaction with the amount of space available for individual work and storage (OR=1.57, CI: 1.55-1.59) was the most important parameter for workspace satisfaction. Increasing satisfaction with the amount of space would increase 1.57 times the likelihood that workspace satisfaction is also increased compared to the case when satisfaction with the amount of space is not increased. The next most important parameters for workspace satisfaction were satisfaction with noise level (OR=1.27, CI: 1.25-1.29) and visual privacy (OR=1.26, CI: 1.24-1.28). From these results it seems that the satisfaction level with a particular parameter is not the strongest predictor of the relevance of this parameter to workspace satisfaction, i.e. even if occupants were very dissatisfied with sound privacy, temperature, noise level and air quality (see Figure 1), among those parameters only satisfaction with noise level was one of the most important parameters for workspace satisfaction.

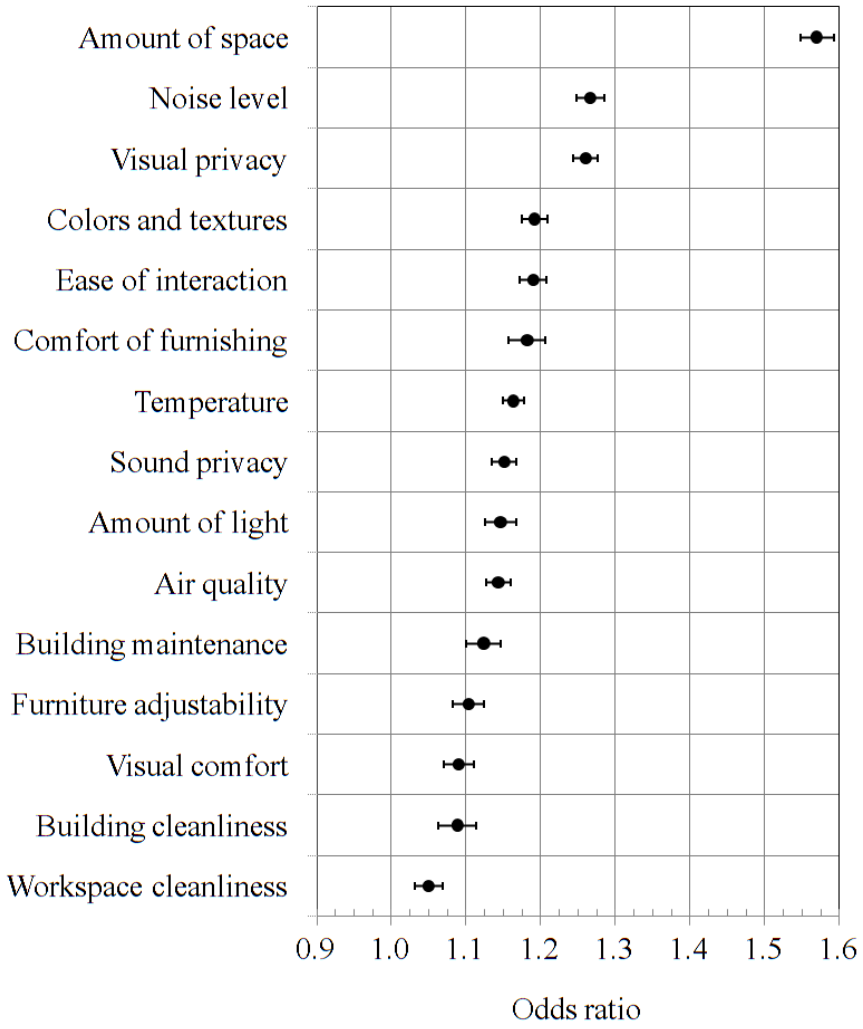

Figure 2. Odds ratios together with 95% confidence intervals for satisfaction with indoor environmental parameters and building features included in the CBE occupant satisfaction survey.

Personal factors and workspace features were examined to study their influence on the ranking of satisfaction with parameters presented in Figure 2. The following factors were examined: building occupants' age group and gender, type of office and distance of workstation from a window. The whole dataset was divided into smaller groups according to the considered personal factors and building features (e.g. when the effect of gender was examined, the separate subsets with female and male survey participants were created). Proportional odds ordinal logistic regression models were fitted separately for each subset of data.

Table 4 presents satisfaction with indoor environmental parameters and building features that most influenced the workspace satisfaction in each subset of data. The results showed that satisfaction with the amount of space had the highest importance for workspace satisfaction in all subsets of data, regardless of building occupants' age group (below 30, 31-50 or over 50 years old), gender, type of office (single or shared office, or cubicles with high or low partitions) or distance of workstation from a window (within 4.6 meters or further). The next most important parameters for workspace satisfaction in most of the data subsets were satisfaction with noise level and visual privacy. A similar analysis was performed for different satisfaction levels with the workspace. Respondents were divided into 2 groups: those satisfied with their workspace also including neutral responses (those who voted 0, 1, 2 or 3) and those dissatisfied with their workspace (those who voted -3, -2 or -1). Figure 3 and Figure 4 depict values of odds ratios together with 95% confidence intervals for satisfaction with each indoor environmental parameter and building feature for respondents satisfied and dissatisfied with workspace, respectively. The parameters are organized in order of decreasing value of odds ratios estimated based on the whole sample (as in Figure 2). In both groups satisfaction with the amount of space was the most important for workspace satisfaction. Among respondents dissatisfied with the workspace, satisfaction with building maintenance, visual comfort and building cleanliness did not contribute significantly to workspace satisfaction, while the order of importance of other parameters for workspace satisfaction was similar to the order in the whole sample. Among respondents satisfied with the workspace, the importance of satisfaction with ease of interaction and amount of light was much higher compared with its importance in the whole sample.

Table 4. Satisfaction with indoor environmental parameters and building features that influenced most the satisfaction with the workspace in each subset of data. In brackets are the number of responses in each group (N), odds ratios and 95% confidence intervals.

Subset of data	1st most important parameter	2nd most important parameter	3rd most important parameter
Age group			
Below 30 years old (N=2777)	Amount of space (1.49, 1.41-1.57)	Comfort of furnishing (1.31, 1.24-1.38)	Visual privacy (1.26, 1.20-1.33) Colors and textures (1.26, 1.19-1.34)
31-50 years old (N= 7714)	Amount of space (1.53, 1.48-1.58)	Ease of interaction (1.31, 1.27-1.36)	Visual privacy (1.30, 1.26-1.34) Noise level (1.30, 1.25-1.35)
Over 50 years old (N= 4397)	Amount of space (1.65, 1.57-1.73)	Noise level (1.33, 1.26-1.40)	Visual privacy (1.29, 1.24-1.35) Amount of light (1.29, 1.23-1.35)
Gender			
Female (N=21452)	Amount of space (1.54, 1.51-1.57)	Noise level (1.25, 1.22-1.27)	Visual privacy (1.24, 1.22-1.27)
Male (N=16805)	Amount of space (1.62, 1.58-1.66)	Visual privacy (1.29, 1.26-1.32)	Noise level (1.28, 1.25-1.31)

Type of office			
Single office (N= 11381)	Amount of space (1.62, 1.57-1.67)	Ease of interaction (1.30, 1.26-1.34)	Comfort of furnishing (1.28, 1.22-1.33)
Shared office (N= 2759)	Amount of space (1.58, 1.49-1.67)	Visual privacy (1.34, 1.27-1.42)	Amount of light (1.22, 1.15-1.29) Building maintenance (1.22, 1.14-1.30)
Cubicles with high partitions (N=16166)	Amount of space (1.56, 1.52-1.59)	Noise level (1.30, 1.27-1.33)	Visual privacy (1.27, 1.24-1.29)
Cubicles with low partitions (N= 9645)	Amount of space (1.57, 1.53-1.62)	Visual privacy (1.35, 1.31-1.39)	Noise level (1.30, 1.26-1.34)
Distance of workspace from a window			
Within 4.6 meters (N= 27175)	Amount of space (1.60, 1.57-1.63)	Noise level (1.26, 1.24-1.28)	Visual privacy (1.25, 1.23-1.28)
Further than 4.6 meters (N= 14638)	Amount of space (1.52, 1.49-1.56)	Noise level (1.29, 1.26-1.32)	Visual privacy (1.26, 1.23-1.28)

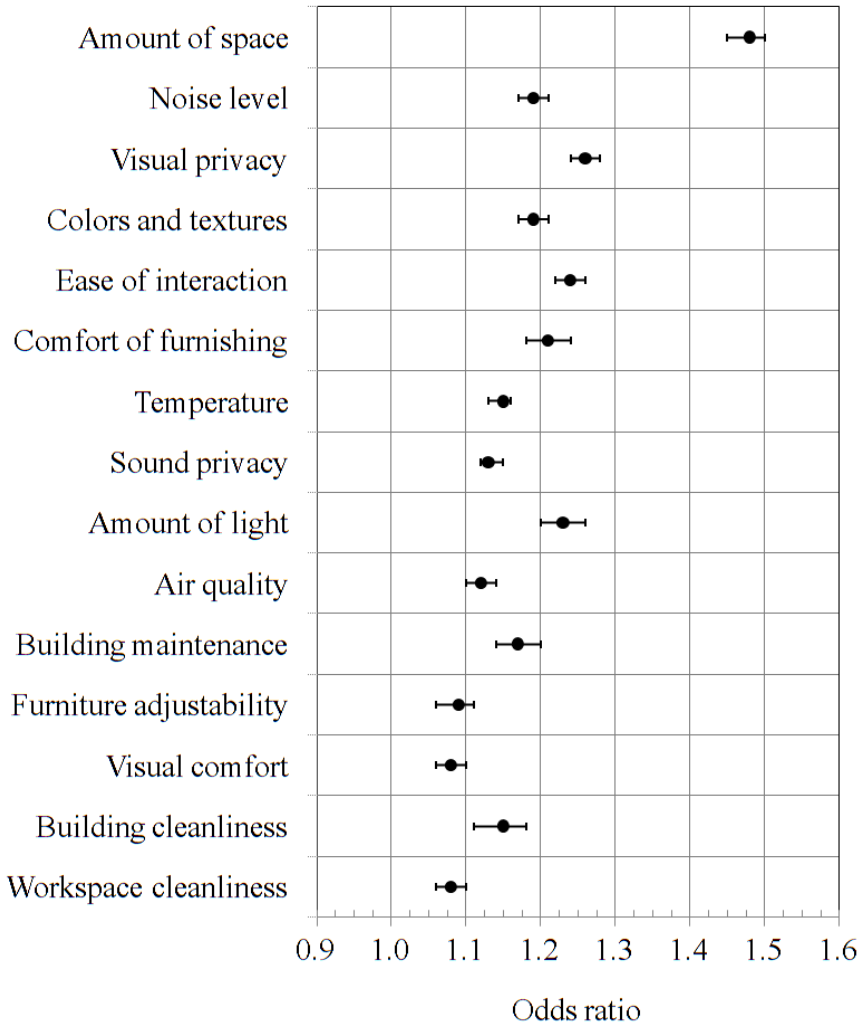

Figure 3. Odds ratios together with 95% confidence intervals for satisfaction with indoor environmental parameters and building features in the group of respondents who were satisfied with the workspace (N=34178).

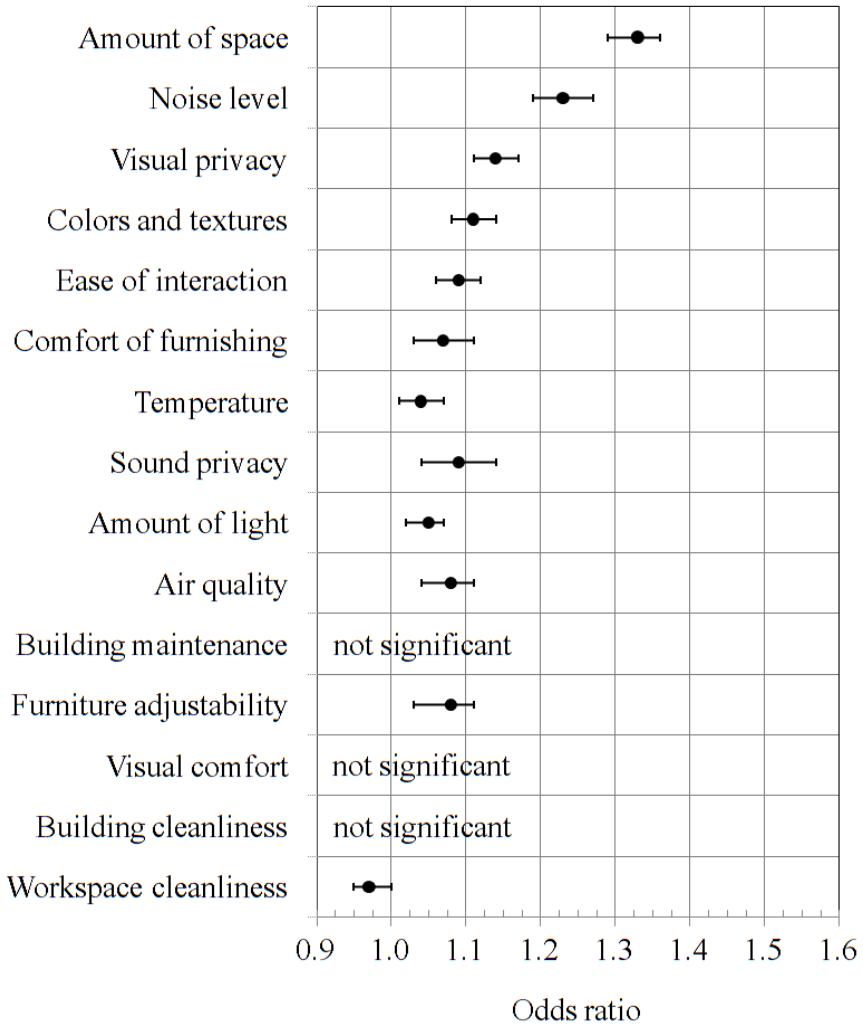

Figure 4. Odds ratios together with 95% confidence intervals for satisfaction with indoor environmental parameters and building features in the group of respondents who were dissatisfied with the workspace (N=8991).

The proportional odds assumption was verified for each regression model separately (Baayen, 2008). For each predictor variable two lines were plotted in one graph: a line representing the observed mean values of a predictor variable for each level of response variable and a line representing mean values of a predictor variable as they would be if the proportional assumption would be satisfied perfectly. Small discrepancies were observed for most predictor variables in the part of the scale representing dissatisfaction votes with the workspace (-3, -2 and -1). But since the means were still very close, it was concluded that the proportional odds assumption was satisfied and the regression models were justified.

Amount of space

Among the factors tested, satisfaction with amount of space was the most predictive of occupants' satisfaction. Here it is investigated whether a higher area available per person for work and storage

increases satisfaction with the amount of space. Area per person was calculated by dividing the building gross area (excluding parking) by the current number of occupants in a building. 26 buildings with extreme values of area per person were excluded from further analysis, resulting in a final sample of 35,704 responses. The gross area per person in the final sample varied between 8 and 86 m^2, with a median of 31 m^2. Correlation between satisfaction with the amount of space and gross area per person was almost negligible (Spearman rank correlation $\rho=0.03$, $p<0.001$). Despite statistical significance, the correlation is insignificant from an engineering point of view. Figure 5 confirms that satisfaction with the amount of space was almost independent of gross area per person.

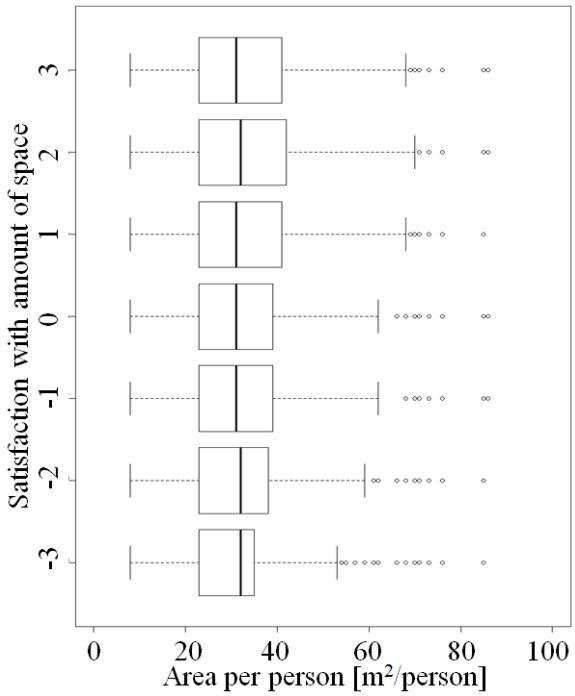

Figure 5. Boxplot showing values of gross area per person for each level of satisfaction with the amount of space.

Type of office and distance from a window

It was investigated if office type and distance of workstation from a window affected occupants' satisfaction in office buildings. These two workspace characteristics were selected as information about them was provided by respondents and not by building manager, who could not describe each workspace in details in the general building characteristics form. The results showed that the type of office had an influence on satisfaction with the amount of space available for work and storage (Figure 6). Satisfaction with the amount of space in private offices (mean M=1.62) was significantly higher ($p<0.001$) compared with shared offices (M=0.81) and cubicles with high (M=0.64) and low partitions (M=0.66). Satisfaction with the amount of space available for work and storage was also influenced by distance of workspace from a window (Figure 7). People sitting within 4.6 m from a window expressed significantly ($p<0.001$) higher satisfaction with the amount of space (M=1.06) than those sitting further from a window (M=0.62). The results show that occupants in private offices and close to a window (within 4.6 m) were more satisfied with the amount of space available for work and storage than people in shared offices or cubicles and far from a window. Similar results were observed in relation to workspace satisfaction. Workspace satisfaction was significantly higher ($p<0.001$) in private offices (M=1.45) and close to a window (M=1.01) than in shared offices (M=0.87) or cubicles with high (M=0.59) and low partitions (M=0.57) and far from a window (M=0.49) (Figure 8 and Figure 9). A difference in workspace satisfaction was observed also between shared offices and cubicles with high (higher than 1.5 m) or low partitions

($p<0.001$). Further analysis showed a similar trend for most indoor environmental parameters and building features (Table 5). Satisfaction with visual and sound privacy, ease of interaction with co-workers, furniture adjustability and comfort, colors and textures of surroundings, temperature, air quality, amount of light, visual comfort, noise level, building and workspace cleanliness was significantly higher ($p<0.02$) in private offices and workstations close to a window than in shared offices or cubicles and far from a window. Satisfaction with building maintenance was significantly higher ($p<0.001$) in private offices and close to a window compared with cubicles and far from a window. No difference in satisfaction with building maintenance was observed between private and shared offices. Most indoor environmental parameters and building features were also evaluated higher in offices shared with few people than in cubicles. Satisfaction with the amount of space, visual and sound privacy, ease of interaction, temperature, air quality, amount of light, visual comfort, noise level and workspace cleanliness were significantly higher ($p<0.05$) in shared offices than in cubicles with high or low partitions. People expressed higher ($p<0.001$) satisfaction with furniture comfort and adjustability and building cleanliness in shared offices compared to cubicles with high partitions.

Additional analysis showed that workspace satisfaction in LEED-rated buildings (including certified, gold, platinum, silver and pending; mean M=0.88) was significantly ($p=0.01$) higher than in buildings without any LEED-rating (M=0.83). The difference between buildings with and without LEED ratings although statistically significant was very small.

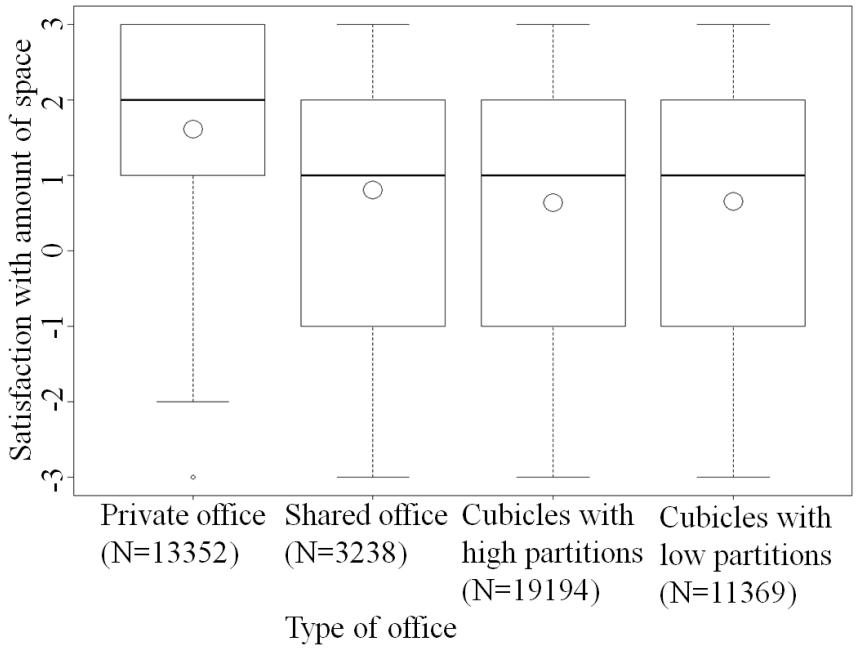

Figure 6. Boxplot showing values of satisfaction with the amount of space in offices of different types. Large dots represent mean values. Brackets indicate the number of responses in each category.

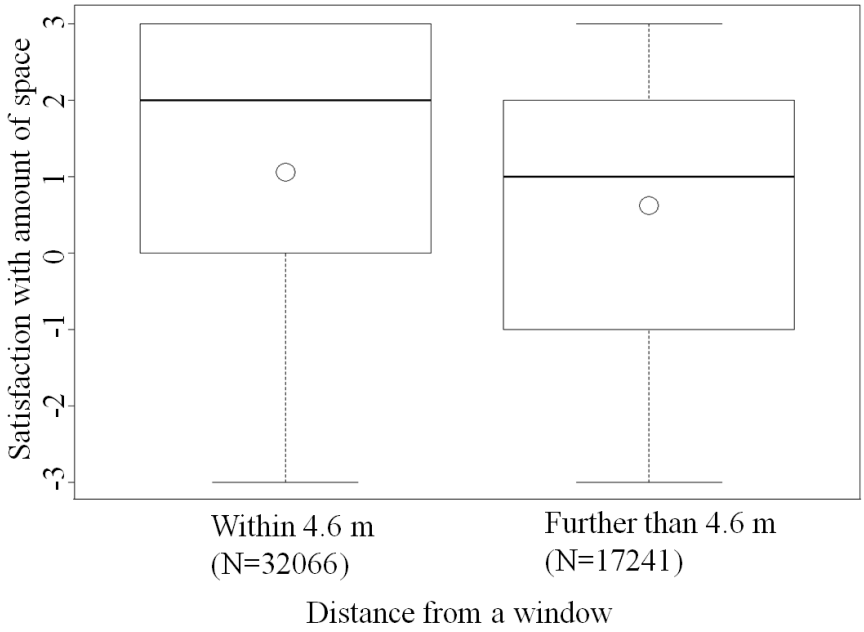

Figure 7. Boxplot showing values of satisfaction with the amount of space depending on the distance of a workspace from a window. Dots represent mean values. Brackets indicate the number of responses in each category.

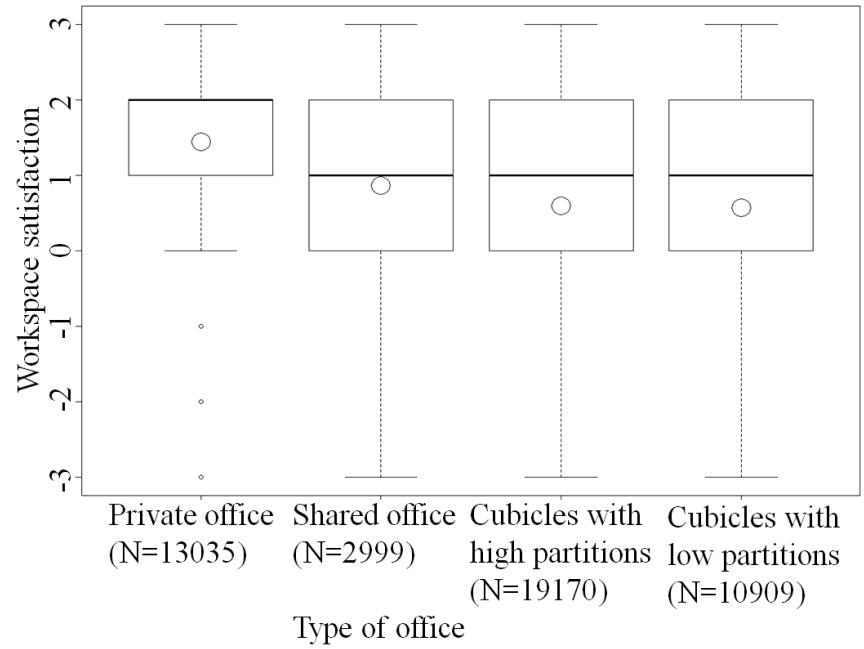

Figure 8. Boxplot showing values of workspace satisfaction in offices of different types. Large dots represent mean values. Brackets indicate the number of responses in each category.

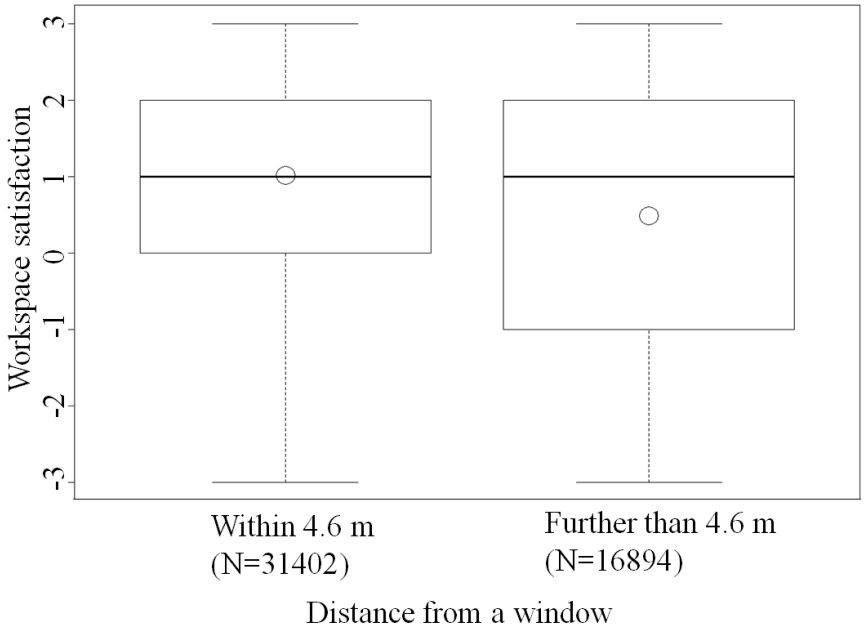

Figure 9. Boxplot showing values of workspace satisfaction depending on the distance of workspace from a window. Dots represent mean values. Brackets indicate the number of responses in each category.

Table 5. Mean values of satisfaction with indoor environmental parameters and building features assessed in the CBE occupant satisfaction survey in different office types and different distances from a window.

Satisfaction with parameter	Single offices	Shared offices	Cubicles with high partitions	Cubicles with low partitions	Close to a window	Far away from a window
Visual privacy	1.97	0.32[a]	0.15[a,c]	-0.26[a,c]	0.67	0.10[e]
Ease of interaction	1.67	1.37[a]	1.09[a,c]	1.19[a,c]	1.40	1.09[e]
Comfort of furnishing	1.34	0.99[a]	0.92[a,c]	0.97[a]	1.14	0.88[e]
Furniture adjustability	1.00	0.79[a]	0.68[a,c]	0.79[a]	0.89	0.65[e]
Colors and textures	0.94	0.70[a]	0.77[a]	0.78[a]	0.90	0.66[e]
Temperature	0.18	0.04[a]	-0.35[a,c]	-0.26[a,c]	-0.07	-0.34[e]
Air quality	0.55	0.32[a]	0.16[a,c]	0.25[a,d]	0.43	0.11[e]
Amount of light	1.66	1.41[a]	1.02[a,c]	1.12[a,c]	1.43	0.90[e]
Visual comfort	1.21	1.02[a]	0.71[a,c]	0.75[a,c]	1.01	0.64[e]
Noise level	0.95	0.63[a]	-0.23[a,c]	-0.28[a,c]	0.27	-0.13[e]
Sound privacy	0.63	-0.49[a]	-1.46[a,c]	-1.45[a,c]	-0.69	-1.10[e]
Building cleanliness	1.21	1.05[b]	0.95[a,c]	1.02[a]	1.03	0.97[e]
Workspace cleanliness	1.02	0.94[b]	0.75[a,c]	0.85[a,c]	0.88	0.79[e]
Building maintenance	1.02	1.02	0.89[a,c]	0.92[a,d]	0.96	0.90[e]

[a,b] statistically significant difference in satisfaction level compared with single offices when $p<0.001$ and $p<0.05$, respectively.

[c, d] statistically significant difference in satisfaction level compared with shared offices when $p<0.001$ and $p<0.05$, respectively.
[e] statistically significant difference in satisfaction level compared with workstations close to a window when $p<0.001$.

DISCUSSION

Building occupants are the best source of information as regards their needs and comfort requirements. Thanks to its large number of responses, the CBE database makes it possible to draw general conclusions about building occupants' needs and satisfaction in different settings, and enables identification of the enquired indoor environmental parameters and building features that cause the highest dissatisfaction. Occupants of the office buildings in which the CBE occupant satisfaction survey has been conducted are generally satisfied with their workspace and with the overall building, even if they register high dissatisfaction with sound privacy, temperature, noise level and air quality. The findings are consistent with earlier studies on smaller subsets of CBE data (Huizenga et al., 2006; Jensen et al., 2005), in which acoustics, thermal comfort and air quality received the lowest satisfaction ratings. In open-plan offices in Canada, building occupants expressed the lowest satisfaction with noise and conversational privacy (Veitch et al., 2002). Air quality, thermal comfort and privacy were identified as the areas of greatest complaint in university buildings in New Zealand (Leifer and Gumbaketi, 1999). In the present study, the lowest satisfaction level was observed for sound privacy. It may be caused by the fact that most of the responses were collected in open-plan offices. Earlier studies (Danielsson, 2008; Haapakangas et al., 2008; Jensen et al., 2005; Kaarlela-Tuomaala et al., 2009; Lee, 2010; Marans and Spreckelmeyer, 1982) indicated that satisfaction with acoustic privacy was much lower in open offices than in single offices. The present study supports these findings. Satisfaction with sound privacy was highest in single offices, slightly lower in offices shared with few people and the lowest in cubicles.

The present study attempts to identify which subjectively evaluated parameters play a major role when people evaluate the overall satisfaction with their workspace. Knowledge about people's priorities may be used as guidelines when constructing and renovating buildings so that building occupants' satisfaction can be maximized. This study of 43,021 office workers showed that satisfaction with the amount of space was the most important for workspace satisfaction. This was in agreement with earlier findings of Marans and Yan (1989) performed among nearly 1,000 office workers, but in contrast to the results of the study of Veitch et al. (2003) who carried out the study among 779 office workers in which parameters were ranked in the following order: air quality and ventilation, privacy, noise level, temperature, lighting, size of workstation and window access. The differences in importance of the amount of space may be due to differences in methodology of the studies. In the present study and the study of Marans and Yan (1989) statistical analyses were performed to estimate the extent of the relationship between workspace satisfaction and satisfaction with the amount of space. In the study of Veitch et al. (2003) office workers were asked to rank the parameters in order from the highest to the lowest importance.

Despite the large range of available area per person (8-86 m^2/person), surprisingly almost no effect of the available area per person was observed on satisfaction with the amount of space, which was not consistent with earlier findings of Marans and Spreckelmeyer (1982). One of the reasons for the lack of a stronger correlation between satisfaction with the amount of space and area per person may be that area per person was a rough estimation of real area per person in each building. The total building area used for calculating the area per person included not only the workstation area but also corridors and common areas like meeting rooms, copying rooms and restrooms. Secondly, the estimated area per person was common for the whole building and did not account for differences in size between different workstations within the building. Thirdly, we are not sure how reliable are the estimates of building gross area provided by the facility managers. It may also be that the way in which building occupants perceive their space is much more important than the actual amount of space. In the study of Marans and Yan (1989) the subjective assessment of amount of space was strongly correlated with workspace satisfaction, while

objective measures of amount of space influenced workspace satisfaction to only a small extent. The perceived amount of space for work and storage may also be influenced by storage space in a vertical direction which would not be noticed via estimated area per person. A study of Skov et al. (1990) showed that the shelf factor which approximates the amount of storage space was related to the sick building syndrome. More studies are needed on the relationship between amount of space and satisfaction with the amount of space. Knowledge about how to increase satisfaction with a given amount of space could lead to increased workspace satisfaction, job satisfaction and productivity.

The present study prioritized satisfaction with different indoor environmental parameters and building features in order of their importance for overall satisfaction with workspace, but it did not provide much information about physical characteristics of the workspace. More studies are needed on the link between satisfaction with a particular parameter and physical characteristics of the workspace. Such studies will supplement the present study and result in guidelines how to (re)design physical aspects of the workspace to maximize occupants' satisfaction.

Different office settings also have a major influence on occupants' satisfaction. Satisfaction with the workspace and with almost all indoor environmental parameters and building features was higher in private offices than in shared offices and cubicles, which is consistent with previous studies (Brennan et al., 2002; Haapakangas et al., 2008; Marans and Spreckelmeyer, 1982). A recent study showed that shared offices increased also the risk of sickness absence (Pejtersen et al., 2011). The findings suggest that building occupants favor private offices. Preference for private offices may partly be associated with greater freedom to organize the office space, ability to control the indoor environment to a greater extent in a private office and freedom from having to negotiate the conditions with co-workers. However, the present study does not offer the possibility of verifying this hypothesis.

It is estimated that for a typical office building 82% of all costs are associated with building occupants (employee salary and benefits) and the remaining costs cover building construction and arrangement, technology support, maintenance and operations (Brill et al., 2001). Thus it seems reasonable to take action to ensure high occupants' satisfaction. Despite this, a recent survey in Denmark showed that office workers think that their bosses do not prioritize high the good indoor environment (Camfil Farr, 2011). The present study determined subjectively evaluated parameters that play a major role when people evaluate satisfaction with their workspace. If one accepts that there is a positive link between occupants' satisfaction and productivity of office workers (Leaman and Bordass, 2001; Leaman et al., 2007; Thomas, 2010) the study's results may be used not only to increase occupants' satisfaction but also to promote higher productivity.

Apart from proportional odds logistic regression, multivariable linear regression and linear mixed-effects regression were applied to study the relationship between workspace satisfaction and satisfaction with indoor environmental quality parameters and building features. Both linear regression models confirmed that satisfaction with the amount of space was the most important for workspace satisfaction, followed by satisfaction with noise level and visual privacy. In the CBE database, the intraclass correlation coefficient showed that only 3.6% of total variability in responses was accounted for by the building in which people filled out the survey. The influence of the building itself on building occupants' responses was very small. The results of linear regression models were not reported extensively in the present paper, because proportional odds logistic regression was considered more relevant for the present data, and the results of proportional odds logistic regression and linear regressions were very similar.

Limitations

One of the limitations of the study is related to the selection of buildings. There was no systematic randomized approach in relation to building selection. Almost 80% of the surveyed buildings were situated in US so the results relate primarily to American settings.

The study considered only the influence of satisfaction with 15 different indoor environmental parameters and building features on workspace satisfaction. The study proved that all parameters listed in the CBE occupant satisfaction survey are relevant for workspace satisfaction. However, perception of other parameters, not included in the survey, may also be relevant for workspace satisfaction (e.g., outside view may be an important parameter but, up to now, it is not measured in the CBE core survey).

Another limitation of the study is absence of physical measurements. It would be preferable to relate subjective responses of building occupants to objective measures of indoor environmental quality parameters and building features.

CONCLUSIONS

- Occupants were generally satisfied with their workspace and with the overall building. The highest levels of satisfaction were observed for ease of interaction with co-workers and amount of light. The highest levels of dissatisfaction were observed for sound privacy and indoor environmental quality (temperature, noise level and air quality).
- The most important parameters for workspace satisfaction were satisfaction with the amount of space, noise level and visual privacy.
- Satisfaction level with a particular parameter did not influence the relevance of this parameter for workspace satisfaction.
- Satisfaction with the amount of space was ranked to be the most important for workspace satisfaction regardless of age group, gender, type of office, distance of workspace from a window or satisfaction level with workspace.
- Satisfaction with the amount of space was not related to an approximate evaluation of the amount of space available per person at the workspace.
- People sitting close to a window (within 4.6 m) and in single offices expressed significantly higher workspace satisfaction compared with those sitting further from a window and in shared offices and cubicles. Satisfaction with almost all indoor environmental parameters and building features was also higher in single offices and close to a window than in shared offices and cubicles and far from a window.

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