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*Published in:*  
10th International Conference on Healthy Buildings 2012

*Publication date:*  
2012

*Document Version*  
Peer reviewed version

[Link back to DTU Orbit](#)

*Citation (APA):*  
Wargocki, P., Frontczak, M., Schiavon, S., Goins, J., Arens, E., & Zhang, H. (2012). Satisfaction and self-estimated performance in relation to indoor environmental parameters and building features. In 10th International Conference on Healthy Buildings 2012 International Society of Indoor Air Quality and Climate.

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# **Satisfaction and self-estimated performance in relation to indoor environmental parameters and building features**

Pawel Wargocki<sup>1\*</sup>, Monika Frontczak<sup>1</sup>, Stefano Schiavon<sup>2</sup>, John Goins<sup>2</sup>, Ed Arens<sup>2</sup> and Hui Zhang<sup>2</sup>

<sup>1</sup> International Centre for Indoor Environment and Energy (ICIEE), DTU Civil Engineering, Technical University of Denmark (DTU)

<sup>2</sup> Center for the Built Environment (CBE), University of California (UC) Berkeley, USA

\* *Corresponding email: paw@byg.dtu.dk*

## **SUMMARY**

The paper examines how satisfaction with indoor environmental parameters and building features affects satisfaction and self-estimated job performance. The analyses used subjective responses from around 50,000 occupants collected mainly in US office buildings using a web-based survey administered by the Center for the Built Environment (CBE) over the period of ten years. Overall satisfaction with the workspace significantly improved self-estimated job performance; increased satisfaction with temperature was estimated to provide the greatest improvement in self-estimated job performance, followed by increase in satisfaction with noise and air quality. The improvement of building features such as amount of space, visual privacy and noise level offered the highest chance to improve satisfaction with workspace. The study implies that it should be carefully considered how investments to upgrade indoor environmental quality and building design are used, and that they should consider whether comfort or working morale are expected to be improved.

## **KEY WORDS**

Office buildings; Indoor environmental quality; Architectural and design features; Comfort; Self-estimated job performance

## **1 INTRODUCTION**

In the developed parts of the world people spend substantial part of their time indoors, at home, at work and/or in schools, and also when commuting. Indoor conditions have therefore far-reaching implications for their health, general well-being and performance. Numerous studies have explored how building users perceive the indoor environment and what conditions are considered by building occupants to be comfortable (Frontczak and Wargocki, 2011). In indoor environments, a number of physical and chemical parameters have been identified that influence the comfort of building occupants. Standards dealing with indoor environmental quality have been developed to define the acceptable ranges of these parameters. Even though the requirements of these standards are met, not all building occupants are satisfied with the indoor environment. One of the possible reasons could be that not only physical conditions but also other factors, unrelated to indoor environmental quality, such as personal characteristics of building occupants, building-related factors and the outdoor climate, influence whether indoor environment is considered to be comfortable or not.

Occupants in buildings are exposed to all indoor environmental parameters simultaneously and their evaluation of the indoor environment is most likely to be a combination of the evaluation of different environmental parameters. Still many studies which examined the issue of building occupant comfort in indoor environments were focused mostly on the effects of single environmental conditions on humans or factors, not related to the indoor environment such as

perceived control, adaptation, expectations and outdoor climate. Among others it was shown that workspace and building features such as view, control over the indoor environment, amount of privacy as well as layout, size, cleanliness, aesthetics and office furniture affect occupants' satisfaction.

Occupants' satisfaction was also shown to be positively correlated with the self-estimated performance of office workers. Occupants uncomfortable with the overall environment reported much lower self-estimated performance than those who felt comfortable with the overall environment. Occupants' satisfaction with the workspace was also positively associated with job satisfaction, which in turn had an impact on job and company performance. Job satisfaction was also related to frequency and duration of absenteeism as well as intention to quit work, issues which may affect working morale and consequently may have financial implications for employers.

The purpose of the present work was to investigate which subjectively evaluated indoor environmental quality parameters and building features mostly affect satisfaction and self-estimated job performance in office buildings, to examine the link between occupants' satisfaction with their personal workspace and self-estimated job performance, and to quantify the size of these effects.

## **2 METHODS**

Over a 10-year period CBE has conducted post-occupancy evaluation surveys in more than 600 buildings using a web-based CBE occupant satisfaction survey (Zagreus et al., 2004). The subset of the data collected by CBE was analyzed in the present work comprising only office buildings and resulting in a dataset containing responses from 52,980 building occupants from 397 surveys performed in 351 different buildings (Frontczak et al., 2011; Kim and De Dear, 2012).

CBE occupant satisfaction survey collects information about occupants' satisfaction and self-estimated performance in different categories related to indoor environment and building features (Table 1). Questions about satisfaction have the following structure: "How satisfied are you with (e.g., temperature in your workspace)?" The answers are given on a 7-point categorical scale and coded as follows: "very satisfied" =+3, "very dissatisfied" = -3; a neutral midpoint is coded as 0. Questions about performance are as follows: "Overall, does (e.g., thermal comfort) enhance or interfere with your ability to get your job done?". The answers are given on a 7-point categorical scale coded as follows: "enhances" =+3, "interferes" =-3; a neutral midpoint is coded as 0. There is also a summarizing performance question, as follows: "Please estimate how your job performance is increased or decreased by the environmental conditions in this building (e.g., thermal, lighting, acoustics, cleanliness)". An estimate is given on a 7-point categorical scale ranging from 'increased' to 'decreased' with each point defined as 20%, 10%, 5%, 0%, -5%, -10% and -20%. Respondents provide also information about their gender, age group, type of work performed, office type, proximity of workstation to a window and external walls as well as duration of working in the present building and at the present workspace. A building facility manager is also asked to provide 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.

Proportional odds ordinal logistic regression was applied to investigate the relationship between satisfaction with the workspace and satisfaction with indoor environmental quality and building features. Multivariate linear regression was applied to investigate the relationship between (1) self-estimated job performance and overall satisfaction with workspace and (2) self-estimated job performance and satisfaction with indoor environmental parameters and building features. The results were considered statistically significant when  $p < 0.05$ .

Table 1. List of parameters assessed by the CBE occupant satisfaction survey.

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

### 3 RESULTS

The levels of satisfaction with different indoor environmental parameters and building features are shown in Figure 1. The highest dissatisfaction was observed for indoor environmental factors such as sound privacy, temperature, noise level, air quality and visual privacy; building occupants were generally satisfied with their personal workspace and building features. Figure 2 summarizes the responses of occupants describing whether indoor environmental parameters and building features enhanced or interfered with getting their job done. Acoustic quality and thermal comfort were indicated by the occupants to interfere with their ability to get the job done, while the other parameters were indicated to enhance it; buildings' cleanliness and maintenance were considered to mostly enhance their ability to get the job done.

The results of proportional odds logistic regression showed that satisfaction with all 15 environmental parameters and building features listed in the CBE occupant satisfaction survey contributed significantly ( $p < 0.001$ ) to overall satisfaction with personal workspace (Figure 3). Modelling showed that there would be the highest chance to improve the overall workspace satisfaction if satisfaction with the amount of space available for work and storage were improved. The next parameters that would have the highest chance for improving the overall satisfaction with personal workspace were satisfaction with noise level and visual privacy. Increasing satisfaction with the amount of space would increase 1.57 times the likelihood that overall workspace satisfaction is also increased compared to the case when satisfaction with the amount of space is not increased. Satisfaction with the amount of space was slightly correlated to satisfaction with visual privacy, ease of interaction, noise and sound privacy. However, the variance inflation factor was below 3 indicating that there was no problem of multicollinearity between predictor variables.

Satisfaction with the amount of space for work and storage was ranked to be the most likely parameter for improving the overall satisfaction with the personal workspace, regardless of respondents' 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), distance of workstation from a window (within 4.6 meters or further) or satisfaction level with personal workspace (satisfied including neutral responses or dissatisfied). A preliminary and rough estimation showed that satisfaction with the amount of space for work is probably also independent of gross area per person.

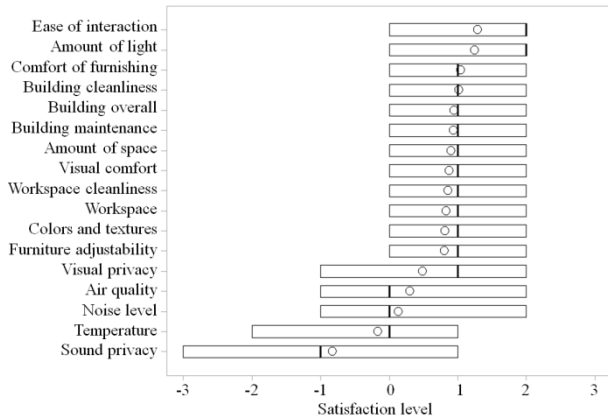


Figure 1. Satisfaction with parameters assessed in the CBE occupant satisfaction survey. The extremities of the boxes are the 25th and 75th percentiles. Bold vertical lines indicate median values and dots represent mean values

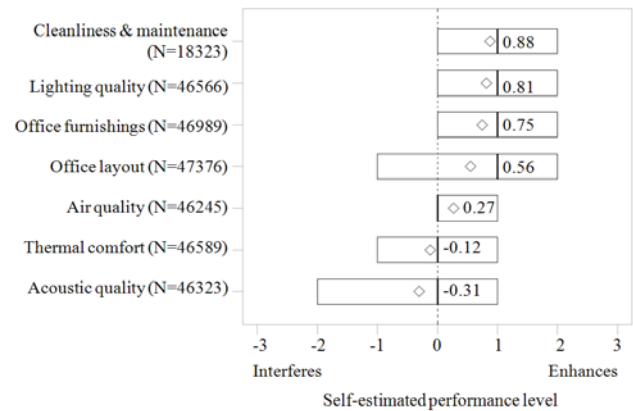


Figure 2. Ratings on whether indoor environmental parameters and building features enhanced or interfered with getting job done. Bold vertical lines show median values and diamonds represent mean values. The extremities of the boxes are the 25<sup>th</sup> and 75<sup>th</sup> percentiles. Numbers in the figure indicate mean values. N shows the number of responses

Simple linear regression showed that overall satisfaction with personal workspace correlated significantly with the self-estimated job performance ( $p < 0.001$ ). Increasing overall satisfaction with personal workspace by one unit on a 7-point scale would correspond to increasing self-estimated job performance by 3.7%. Among indoor environmental parameters and building features listed in the CBE occupant satisfaction survey, satisfaction with cleanliness of workspace, amount of light and comfort of furnishings were not statistically significant ( $p > 0.05$ ) in the multivariate linear regression model (Figure 4), indicating that their changes would not influence self-estimated job performance. The model showed that the highest increase in self-estimated job performance would be caused by improving satisfaction with temperature. Improving satisfaction with temperature by 1 unit on a 7-point scale would increase the self-estimated job performance by about 1% while the satisfaction with all other parameters was kept constant. Next highest increments of self-estimated job performance would be obtained by improving satisfaction with noise level and air quality; they would increase the self-estimated job performance by about 0.8%. Assuming fully additive effect, the combined effect of improving satisfaction with all indoor environmental parameters and building features examined in the present analysis by one unit on a 7-point scale would yield 5.67% increase in the self-estimated job performance. This is higher than 3.7%, as reported above, suggesting a hypo-additive effect which nature should be examined in the future studies.

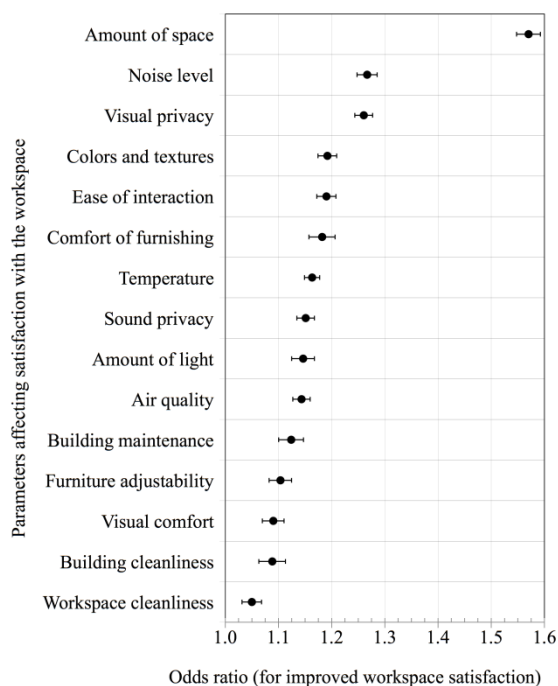


Figure 3. Odds ratios together with 95% confidence intervals indicating which changes to indoor environmental parameters and building features would have the highest effect on satisfaction with personal workspace

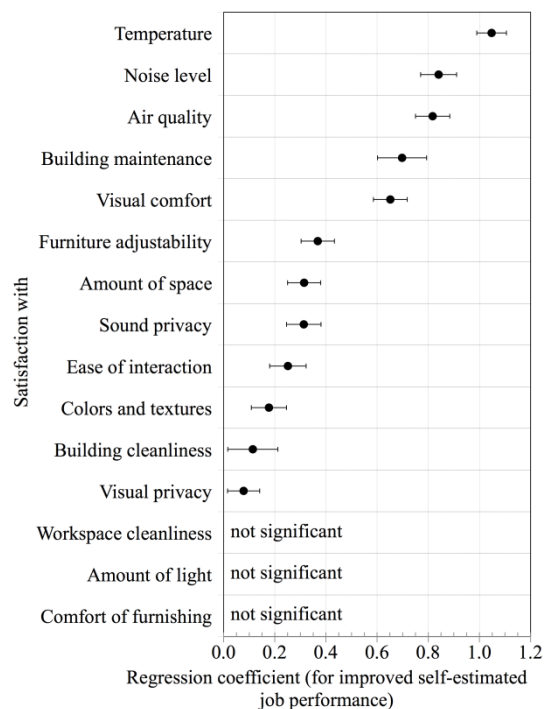


Figure 4. Regression coefficients together with 95% confidence intervals indicating how much self-estimated job performance will be improved when satisfaction with indoor environmental parameters and building features is increased

#### 4 DISCUSSION

Present results showed that in order to maximize overall satisfaction with one's personal workspace, investments should first be made that lead to increasing satisfaction with the amount of space, noise level and visual privacy. If on the other hand self-estimated job performance is considered, then satisfaction with temperature, noise level and air quality should be first improved as they have the highest effect on self-estimated job performance. Satisfaction with the amount of space and visual privacy (parameters highly important for overall workspace satisfaction) were of much lower importance for self-estimated job performance. The discrepancy between ranking of indoor environmental parameters and building features regarding their importance for overall workspace satisfaction and self-estimated job performance implies that the investments in improving conditions in indoor environments should be well targeted in order to obtain the expected benefits. We do not have clear explanation of the reason of this discrepancy. It is however likely that the amount of space is related by building users to the status and position at work, the higher status the higher satisfaction. The improved status may not however necessarily be considered by an individual to have direct effect on job performance. On the other hand, changes to temperature, air quality and other indoor environmental factors can be much easily considered to affect performance as an individual can perceive whether he/she works effectively on days with, e.g. elevated temperatures, though more likely that they would be perceived to affect job performance stronger when the changes are in the negative direction (Fig.1). They can thus be much more easily "correlated" with job performance than can building factors such as amount of space or ease of interaction which are more or less constant. This could explain why increasing satisfaction with changes to temperature would be expected to improve the self-estimated job performance to a

higher degree (Fig. 4), even though amount of space and other building factors have higher effect on satisfaction (Fig. 3). The observed discrepancy may have psychological, psychophysical and/or physiological origin, and its nature should be investigated further in future studies.

Self-estimated job performance in the present study may not necessarily reflect the actual performance and/or productivity of workers and probably was only a good marker of working morale, inclination and/or enthusiasm to perform the job well, etc. Productivity of office workers was not measured objectively and it is not known to what extent self-estimated job performance represents actual changes in workers' productivity. Consequently the obtained quantitative figures between satisfaction and self-estimated job performance should be treated with caution and cannot be directly used as a measure of productivity. As there is no clear reference level to which respondents estimated the effect on their job performance, the change (% decrease or % increase) in job performance as indicated by the respondents is somewhat ambiguous. Among other limitations of the present analysis is the lack of the systematic randomized selection of buildings in which the survey was conducted. Almost 80% of the surveyed buildings were situated in the USA, so the results relate primarily to American settings. Since the data were collected over 10-year period the changes in building design and regulations could affect outcomes and were not controlled for in the present analyses. The survey considered only the influence of satisfaction with 15 different indoor environmental parameters and building features on overall satisfaction with personal workspace and self-estimated job performance; there may be other parameters that affect overall workspace satisfaction or self-estimated job performance. Another limitation is the absence of physical measurements. It would be preferable to relate subjective responses of building occupants to objective measures of indoor environmental parameters and building features.

## **5 CONCLUSIONS**

Present results can guide building users, operators and employers in making decisions on how working indoor environment can be improved most effectively by selecting these parameters which promote comfort and working morale at the most. The tool to perform such selection is described..

## **ACKNOWLEDGEMENTS**

The research was partially supported by (a) the project "Indoor Climate and Quality of Life" granted by the Danish Enterprise and Construction Authority (EBST), grant no. 07/08368; (b) Center for the Built Environment, University of California, Berkeley; (c) International Centre for Indoor Environment and Energy (ICIEE), Technical University of Denmark; (d) partnership agreement between the Danish Agency for Science, Technology and Innovation (DASTI) and Center for Information Technology Research in the Interest of Society (CITRIS) at the University of California Berkeley. Present paper is part of the Ph.D. Thesis by Monika Frontczak defended at ICIEE, DTU in December 2011.

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