

Impact of Available and Perceived Control on Comfort and Health in European Offices

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ABSTRACT

The objective of this study was to find out how perceived control and access to control options like operable windows and thermostats affect comfort and health of European office workers. For this, the Health Optimisation Protocol for Energy-efficient Buildings (HOPE) database was re-analyzed. Statistical analyses were conducted to find out what the impact is of available controls on perceived control of building occupants. Furthermore the effect of perceived control on comfort and health (building related symptoms) of building occupants was determined.

Overall no significant correlations were found between available controls and perceived control. The one exception was solar shading.

On the other hand, between perceived control and comfort or health, multiple significant correlations were found. Occupants are more comfortable in buildings in which the amount of perceived control over temperature, ventilation and noise is high. Perceived control also has an impact on the incidence of building related symptoms, also if one looks at combinations of perceived control (e.g. control over temperature and ventilation).

KEYWORDS

Personal control, individual control, operable windows, adjustable thermostats, building related symptoms, adaptive opportunities

INTRODUCTION

The design of modern office buildings (often with relatively complex building service systems and sealed façades) seems to be based upon the assumption that maintaining a predefined set of environmental variables (temperature, CO₂ concentration, etc.) by definition assures the comfort and satisfaction of building occupants. However, occupants in many of these sealed office buildings with centrally controlled building service systems seem not to be satisfied with their indoor climate. For example, Hedge et al. (1989) conducted a large field study in 47 English office buildings. They

analysed their data to find out what factors cause 'Sick Building Syndrome' (building related symptoms). One of their main conclusions was that symptoms like dry eyes, dry throat, stuffy nose, itchy eyes and lethargy had the highest prevalence in centrally controlled air conditioned buildings without operable windows. One of the possible underlying causes that was identified by the authors was 'limited possibilities for personal control over temperature and fresh air supply'. Zweers et al. (1992) conducted a large epidemiological study in 69 Dutch office buildings and came to comparable conclusions as Hedge et al. (1989): less options for personal control leads to a higher risk for building related symptoms.

A meta-analysis by Mendell & Smith (1990) concluded that building related symptoms (and also occupant dissatisfaction) is more prevalent in buildings with complex HVAC systems. Also these authors concluded that limited possibilities for personal control might play an important role in reducing satisfaction.

There are many indications that it is of great importance to have options for personal control to obtain satisfaction with the indoor climate. However, little is known about which aspects are important to have personal control over. Is it primarily about offering the right amount of building controls to occupants (e.g. operable windows, adjustable thermostats) or is it also important to address the more psychological issue of perceived control? In this context, Paciuk (1990) points out that personal control actually can be three things: 1. Available control, 2. Exercised control and 3. Perceived control. She developed a conceptual model that explains how these phenomena interact. Within that model available control is defined as 'the degree and type of control made available by the environment (building, HVAC-system, etc.)'; it could also be described as access to building controls like operable windows, thermostats, fans etc.. Exercised control is defined as 'the relative frequency in which employees engage in several types of thermally-relegated behaviours in order to regain thermal comfort when needed'. Perceived control addresses the level of influence of building occupants. According to Paciuk the level of perceived control is dependent upon the availability of building controls (available control) and upon the use of those controls (exercised control).

For the study described in this paper we developed a simplified conceptual model partly based on the Paciuk model. Note that also interactive models of others were taken as a reference (Boerstra, Loomans and Hensen, 2012).

Our simplified conceptual model is presented in Figure 1. The hypotheses is that having or not having control over one's indoor climate influences how environmental parameters like temperature and CO₂-concentration impact comfort, health and performance. In fact, personal control is thought to act as a moderator.

Bordass, Leaman and Ruyssevelt (2001) in this context state that occupants like buildings that can respond to them (are responsive). Years of experience with (post) occupancy surveys have taught the authors that people who have control over their environment are more tolerant of that environment. They relate to this also as the 'forgiveness factor'.

Also Baker & Standeven (1996) are convinced of the moderator qualities of personal control. Based on results from multiple field studies these authors concluded that if there is little adaptive opportunity discomfort is always likely to occur.

The first objective of this study was to determine the impact of available controls (access to operable windows, thermostats etc.) on perceived control in office

buildings. The second objective was to determine the impact of perceived control on (self-assessed) comfort and health in office buildings.

Note that the role of exercised control was not researched as the database that was studied did not have any information about the actual use (frequency etc.) of building controls. The research project also did not investigate the impact of available and perceived control on productivity (performance).

METHODS

During this study data from the HOPE database have been re-analyzed (see <http://hope.epfl.ch> and Cox, 2005). The HOPE database contains data from the HOPE project where HOPE stands for Health Optimisation Protocol for Energy-efficient Buildings. As part of the HOPE project 64 European office buildings with over 6000 building occupants have been surveyed. The HOPE office buildings were located in the Czech republic, Denmark, Finland, Germany, Italy, the Netherlands, Portugal, Switzerland and the United Kingdom. Note that during the HOPE study also apartment buildings were studied, in this paper the apartment results are left out as the main focus here is on personal control over indoor climate in office buildings.

The aim of the HOPE project was to investigate whether and how buildings can be both energy-efficient and healthy (e.g. without indoor climate complaints). One of the objectives was to derive and test new guidelines for energy-efficient and healthy buildings.

The HOPE data were gathered as follows: first, the researchers inspected the office buildings to determine the building characteristics, the properties of the HVAC-system and the available building related control opportunities. Secondly, building occupants were invited to participate in a questionnaire. The questionnaire consisted of questions about for example building related symptoms, perception of the indoor environmental quality and comfort. Furthermore, measurements (of e.g. indoor air quality) were conducted. More information on the methods used in the HOPE study can be found in Roulet, Johner and Foradini (2006).

For the analysis described in this paper relevant questions were selected from the HOPE building checklist to determine the available controls for each office building (see appendix 1).

Also relevant questions were selected from the occupant questionnaire (see appendix 2). These were all questions that either related to perceived control over the indoor environment or to endpoint-effects like thermal comfort, perceived air quality and building related symptoms. For each building the occupant questionnaire answers were averaged to construct a control-score, comfort-score etc. at building level. The 'health score' for each building was calculated using the Building Symptom Index₅ (BSI₅), a performance indicator for the incidence of building related symptoms in a building. The BSI₅ for each building is calculated as follows: first for each occupant it is evaluated whether they suffer of one of the following 5 building related symptoms: dry eyes, blocked or stuffy nose, dry throat, headache and tiredness. Each symptom reported by the occupant scores 1. This means that every individual can score any value from 0 to 5 (his or her Personal Symptom Index 5, PSI₅). The average of the PSI₅ for all building occupants of a building is called the Building Symptom Index 5 (BSI₅) of that building. Note that in the HOPE study each individual building score was based on responses of about 100 building occupants. So when for example it is indicated that only 3 buildings had manual radiator valves ('n=3') we still dealt with a score based on the answers of around 3 x 100 respondents.

Two different statistical methods were used to identify any statistical associations. To investigate correlations between available control (access to building controls) and perceived control, the Kruskal–Wallis analysis of variance test ($p < 0.05$) was used. Since the Kruskal-Wallis analysis of variance becomes somewhat unreliable by small groups, groups with $n < 5$ buildings were excluded from the analysis. To investigate the correlations between perceived control and (self-assessed) health and comfort the Spearman's rank correlation test (2-tailed $p < 0.05$) was used. Note that for this second analysis we looked both at standard control scores (e.g. perceived control over temperature on the original 7 point scale) and combined control scores (e.g. combined perceived control score over temperature and ventilation on a totalled 2 to 14 point scale).

Note that Bluysen, Aries and van Dommelen (2011) also conducted a reanalysis of the HOPE database that also partly dealt with perceived control. The aim of that study was to get a better understanding of the relationships between building, social and personal factors (including personal control) and perceived health and comfort. The authors performed Principal Component Analysis (PCA), reliability analyses and linear regression analysis. If we compare the study of Bluysen, Aries and van Dommelen (2011) with ours we see a couple of differences: the Bluysen study had a wider scope but did for example not look at the relation between available and perceived control; furthermore they did not look at combined control scores and their impact on health and comfort as we did. Last but not least, they used other statistical techniques than we did (partly because their research scope was wider).

Below the results are presented separately for i) the impact of available control on perceived control and ii) the impact of perceived control on health and comfort.

RESULTS I: Impact of available control on perceived control

The most interesting results of our analysis are presented in Figures 1 to 6. Note that the original seven-point scales for perceived control and comfort are reversed for increased readability of the graphs.

As far as the availability of temperature controls is concerned: the analysis showed that there are no significant differences (Kruskal-Wallis: $p=0.70$) in perceived control over temperature if one compares the different types of temperature control (e.g. local thermostat vs. central sensor) (Figure 2). Mean and median perceived control scores (over temperature) for all types of temperature controls (for all buildings) lie at around 2.5 to 3 on the 7 point scale.

As far as availability of operable windows is concerned, scores for perceived control over temperature and scores for perceived control over ventilation did not differ significantly (Kruskal-Wallis: $p=0.09$ resp. $p=0.14$) between buildings with operable windows, with some operable windows, with operable windows that people are not allowed to use and with no operable windows (Figures 3 and 4).

Last but not least, as far as availability of solar shading is concerned, the type of control (e.g. individual control over solar shading vs automatic control) had no significant effect (Kruskal-Wallis: $p=0.25$) on perceived control over temperature (Figures 5 and 6). On the other hand, type of solar shading did have a significant effect (Kruskal-Wallis: $p=0.01$). In buildings with external solar shading mean occupant scores for control over temperature were around 0.6 point higher on the 7 point scale than in buildings with internal solar shading or with no shading at all.

RESULTS II: Impact of perceived control on health and comfort

The results of the analysis concerning the impact of perceived control on comfort and health are grouped into three categories: results concerning comfort in the winter situation, results concerning comfort in the summer and results concerning building related symptoms. The overall results are presented in Table 1. Some of the main findings furthermore are visualised in Figures 7 to 16.

Winter comfort

As far as perceived control and winter comfort is concerned: the strongest correlation was found for control over temperature and perceived temperature during winter (comfortable – uncomfortable) ($\rho_s=0.40$; 2-tailed $p < 0.01$) (Figure 7). This suggests that people who feel more in control over temperature, generally are more comfortable in winter. Perceived control over temperature also correlated positively with perceived overall comfort during winter ($\rho_s=0.31$; 2-tailed $p=0.01$). Perceived control over noise was also found to correlate with perceived overall comfort during winter ($\rho_s=0.33$; 2-tailed $p=0.01$). This indicates that people generally are more comfortable in buildings in which occupants perceive a high degree of control over noise (Figure 8). Furthermore perceived control over temperature was found to correlate positively with perceived air quality (both on the stuffy - fresh and the unsatisfactory - satisfactory scale) during winter ($\rho_s=0.28$; 2-tailed $p=0.03$ resp. $\rho_s=0.26$; 2-tailed $p=0.04$). Also perceived control over ventilation was found to correlate with perceived air quality (stuffy – fresh) during winter ($\rho_s=0.25$; 2-tailed $p=0.04$). This indicates that people who feel more in control over ventilation in their

office space regard the air in their office space as more fresh. No other significant 'winter comfort' correlations were found.

We also looked at the winter comfort impact of combined perceived control over the indoor environment (Table 1, lower half). When the scores for perceived control were combined for the winter situation, the strongest correlation was found for perceived control over temperature, ventilation and shading from the sun combined in relation to perceived air quality during winter (stuffy - fresh) ($\rho_s=0.34$; 2-tailed $p=0.01$). Note that this correlation is stronger than the correlations between the single perceived control variables and perceived air quality. This indicates that people who perceive more combined control over ventilation, temperature and shading from the sun perceive the air in their office as fresher. Other combinations of perceived control scores were found to correlate less strongly but still significant with perceived air quality during winter (stuffy - fresh) (see Table 1). Furthermore correlations were found for combinations of perceived control scores and perceived temperature in winter. However these correlations were all less strong than the correlation between perceived control over temperature and perceived temperature during winter (uncomfortable – comfortable). This suggests that for the winter situation control over temperature is the most important aspect when compared to e.g. control over ventilation and control over shading from the sun.

Summer comfort

For the summer situation the strongest correlation was found between control over temperature and overall comfort during summer ($\rho_s=0.35$; 2-tailed $p=0.01$; no Figure included). No correlation was found between perceived control over temperature and perceived temperature during summer (comfortable - uncomfortable) ($\rho_s=0.22$; 2-tailed $p=0.08$) (Figure 9). On the other hand, perceived control over temperature did correlate with perceived air quality during summer (satisfactory - unsatisfactory) ($\rho_s=0.30$; 2-tailed $p=0.02$) (Figure 10). Perceived control over ventilation in summer was also found to correlate with overall comfort (unsatisfactory - satisfactory) and perceived air quality (unsatisfactory - satisfactory) during summer (both $\rho_s=0.28$; 2-tailed $p=0.03$). No other significant 'summer comfort' correlations were found.

Also for the summer situation, correlations were found for combinations of perceived control scores and summer comfort (Table 1, lower half). For example, we found a positive correlation between perceived control over temperature, ventilation and shading from the sun combined and perceived overall comfort during summer (unsatisfactory - satisfactory) ($\rho_s=0.31$; 2-tailed $p=0.01$) (Figure 11).

Building related symptoms

As far as perceived control and the incidence of building related symptoms is concerned, a negative correlation was found between perceived control over temperature and BSI₅ ($\rho_s=-0.36$; 2-tailed $p<0.01$) (Figure 12). This implies that people who feel more in control over temperature have less building related symptoms. Also a negative correlation was found between perceived control over ventilation and BSI₅ ($\rho_s=-0.36$; 2-tailed $p<0.01$; Figure 13) and between perceived control over noise and BSI₅ ($\rho_s=-0.37$; 2-tailed $p<0.01$; no Figure included). Moreover a negative correlation was found between perceived control over lighting and BSI₅ ($\rho_s=-0.28$; 2-tailed $p=0.03$; no Figure included).

When the scores for perceived control were combined even stronger correlations were identified (Table 1, lower half). An example is the correlation between perceived control over temperature and ventilation combined and BSI₅ ($\rho_s=-0.42$; 2-tailed $p<0.01$) (Figure 14). Another example is the correlation between perceived control over temperature, ventilation, lighting, noise and shading from the sun combined versus BSI₅ ($\rho_s=-0.40$; 2-tailed $p<0.01$) (Figure 15).

DISCUSSION

This study did not find any significant correlations between available control and perceived control (with external sun shading as the exception). One might interpret this as proof that it does not matter whether occupants have access to e.g. operable windows and adjustable thermostats. Such a conclusion would be in contradiction with for example the findings of Brager & Baker (2009). They conducted occupant surveys in 12 mixed mode US office buildings (all with a space conditioning system that used a combination of natural ventilation and some form of mechanical ventilation and/or cooling) and compared the results with a benchmark database filled with survey data from 370 buildings. The main conclusion was that these mixed mode buildings performed exceptionally well compared to the average US office building (for example in terms of perceived thermal comfort and perceived air quality). According to Brager & Baker one of the explanations for this was access to building controls and a 'high degree of direct user control' (over temperature, ventilation etc.) in the mixed mode buildings.

As far as the available control related results are concerned, we did expect to find more significant correlations (e.g. a correlation between availability of operable windows and perceived control over ventilation). One explanation for the absence of a link between available control and perceived control might lie in limitations of the HOPE database itself. For example, data on temperature and ventilation controls were only available at building level and not at room level. While access to controls might differ significantly from room to room within a building.

Concerning the link between perceived control and comfort, these were the main conclusions (see Table 1):

- Perceived control over temperature is significantly (positively) correlated with overall comfort in winter and summer, perceived temperature in winter and perceived air quality in both winter and summer;
- Perceived control over ventilation is significantly (positively) correlated with perceived air quality in winter and summer and overall comfort in summer;
- Perceived control over noise is positively significantly (positively) correlated with overall comfort in winter (...);
- Combined scores of perceived control (e.g. perceived control over temperature, shading from the sun and ventilation combined) are significantly (positively) correlated with perceived temperature in winter, perceived air quality in winter and summer and overall comfort in summer.

These results imply that those that feel to be in control over their indoor climate generally are more comfortable and more satisfied with their indoor environment.

As far as the incidence of building related symptoms (more specifically BSI₅) was concerned (again, see Table 1): more or less all control scores (individual or combined) correlated negatively with 'health'. Those who feel more in control over

especially temperature, ventilation, lighting and noise (or combinations of these) have less 'sick building symptoms'.

The reanalysis of the HOPE database showed that personal control in office buildings matters. The results imply that people are more comfortable and healthy in buildings in which the occupants perceive to have a higher degree of control over e.g. temperature, ventilation and noise. This is in line with for example the findings of Bordass, Leaman and Ruyssevelt (2001). These researchers drew some general conclusions from the UK Probe study that are relevant in this context: high performance buildings - with above average occupant satisfaction scores and relatively low percentages of building related symptoms - in their eyes are those with characteristics like simplicity, usability, manageability and responsiveness. As concrete factors for success the authors identify access to operable windows and usable (simple) controls and interfaces of building service systems.

One other finding was that combined perceived control scores (for example for temperature and ventilation) correlated with summer and winter comfort and the incidence of building related symptoms. This combination of control scores into combined overall control scores, is a new approach (as far as the authors of this paper know). However, this approach has some relation to the combined exercised control concept as proposed by Haldi and Robinson (2008). These authors speak of the use of building controls in conjunction with other controls (for example simultaneous use of operable windows and blinds).

The study described in this article has a couple of constraints:

- The HOPE database provided us with a very rich and elaborate database (with over 6000 respondents) that would be very difficult to replicate. One disadvantage of working with such a database from a third party however is that it is more difficult to check the reliability of the core data.
- Another point with the database is that it consists of data from different countries with different cultures and maybe incomparable office layouts and building service systems. One could question whether results from one country can be compared with those from another country without correcting for such international differences.
- One important other limitation is that the quality and effectiveness of available controls was not described in detail in the database. For example, two distinct buildings can both have adjustable wall thermostats, while in one building these hardly work (temperature hardly changes when one turns the thermostat) while in the other building they are very fast and effective. Of course, the perceived control over temperature will be different in the two buildings.
- Also, exercised control (e.g. frequency of use of the available controls) was not described in the original database. Therefore interactions between available control, exercised control and perceived control as described e.g. by Paciuk (1990) could not be investigated.

Comparison of our results with those of Bluysen, Aries and van Dommelen (2011) shows similarities with their general findings. They also found that perceived control over sun shading and perceived control over noise are important aspects and that more control over temperature leads to more comfort. Interestingly, for some aspects they found a negative correlation, indicating that more perceived control leads to less

comfort. Note that Bluysen, Aries and van Dommelen (2011) used a different statistical method (see the Method section).

CONCLUSIONS

The first objective of this study was to determine the impact of available controls (access to control options like operable windows, thermostats etc.) on perceived control. The second objective was to determine the impact of perceived control on comfort and health.

The main findings are summarized below:

- Overall no significant correlations were found between available controls and perceived control. For example, surprisingly, no significant differences were found in the degree of perceived control over temperature in buildings with central control (central sensor) vs. buildings with manual radiator valves.
- The one available control exception was solar shading: occupants in buildings with external shading perceived themselves to have more control over temperature than occupants in buildings without solar shading or with only internal solar shading.
- We did find significant correlations between perceived control and comfort. Occupants were more comfortable and are more satisfied with the air quality in buildings in which the amount of perceived control over temperature, ventilation and noise was high.
- Combined control scores (for example perceived control over temperature and ventilation combined) positively correlated with overall comfort, perceived temperature and/or perceived air quality.
- The strongest correlations found were those between perceived control (and combined perceived control) and the incidence of building related symptoms (BSI₅). Office workers were more healthy (had less symptoms) in the buildings that had the best (highest) control scores.

Our findings imply that office buildings will be more comfortable and healthy if they are designed for a high degree of (combined) personal control over the indoor environment (are designed for optimum perceived control). Or in the words of Baker and Standeven (1996): 'Limit the extremes of (thermal) conditions by the inherent properties of the building and provide adaptive opportunity by environmental variety and user friendly building controls.'

Exactly what mix of building controls (type of available control) makes building occupants feel to be in control could not be concluded from our reanalyses of the HOPE study, with external sun shading as the exception.

This study showed that especially perceived control is important. Future studies should point out what kind of building controls (or building control combinations) are needed to help building occupants to perceive a sufficient degree of control over their indoor climate. Such new studies also should look at the link between exercised control, for example the frequency of use of operable windows, thermostats, etc. on the one hand and perceived and/or available control on the other hand. Another subject for a future study could be the effectiveness of different building controls, for example step responses and response times of different kinds of operable windows and adjustable thermostats.

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Figures and Tables

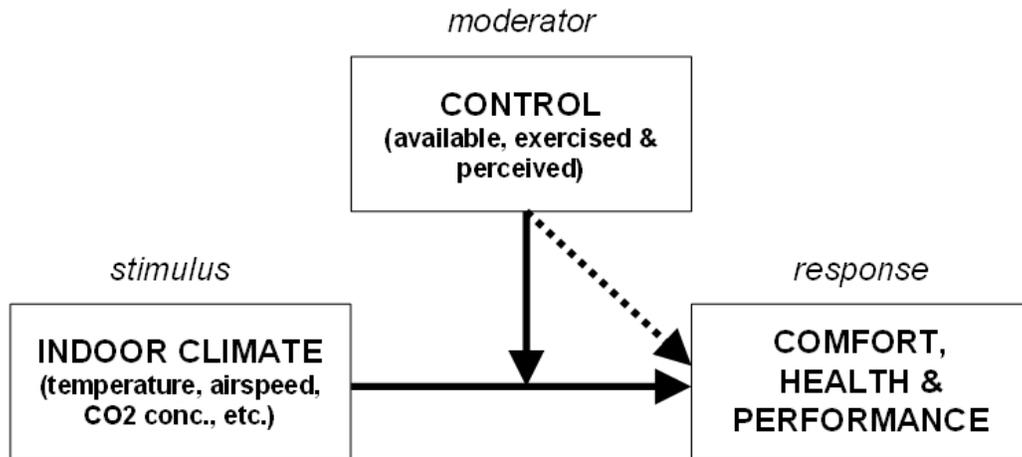


Figure 1. Conceptual model

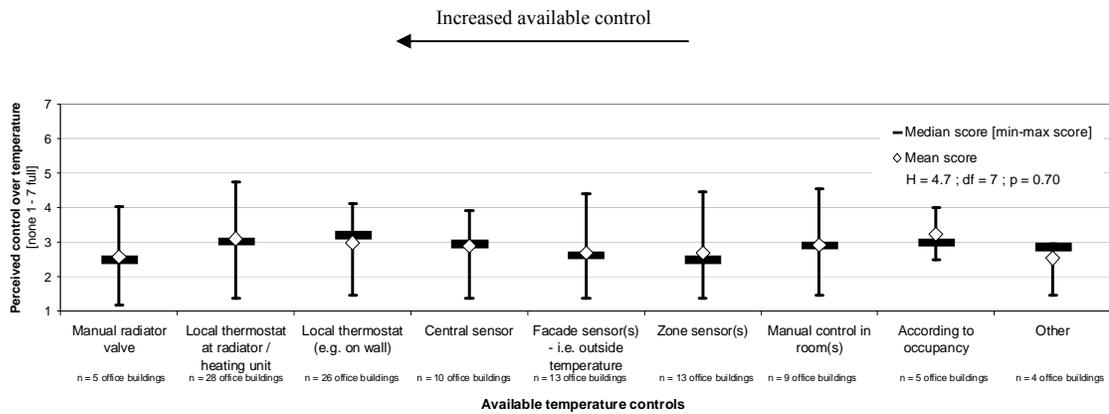


Figure 2. Availability of temperature controls versus perceived control over temperature (non significant difference). (Due to the low number of office buildings ($n < 5$) with 'Other' available temperature controls these buildings were excluded from the analysis)

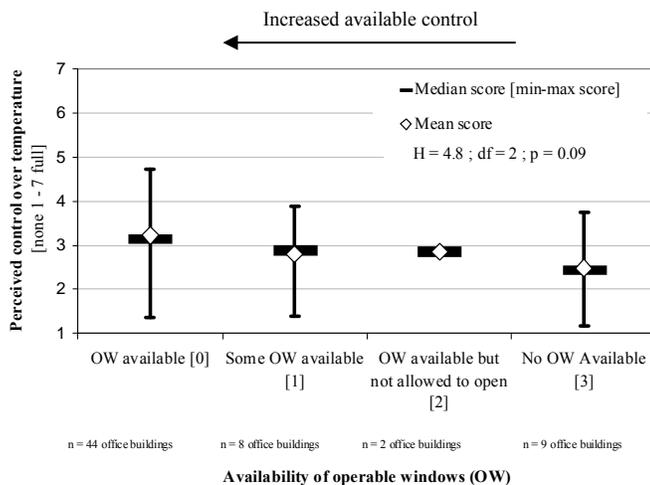


Figure 3. Availability of operable windows versus perceived control over temperature (non significant difference). (Due to the low number of office buildings ($n < 5$) with available operable windows that are not allowed to be opened these buildings were excluded from the analysis)

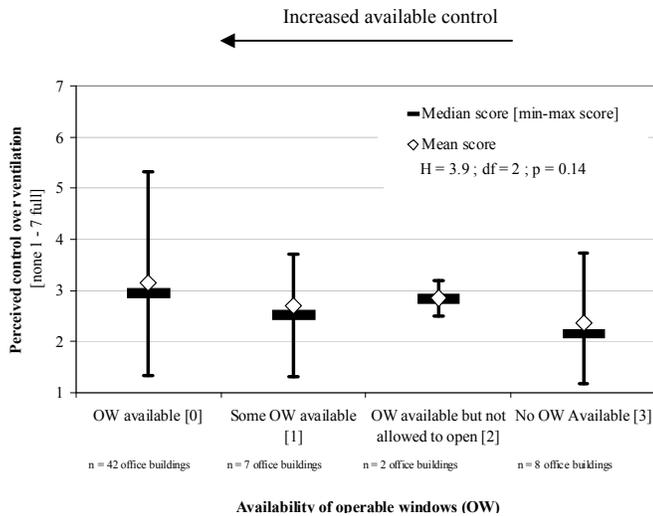


Figure 4. Availability of operable windows versus perceived control over ventilation (non significant difference). (Due to the low number of office buildings ($n < 5$) with available operable windows that are not allowed to be opened these buildings were excluded from the analysis)

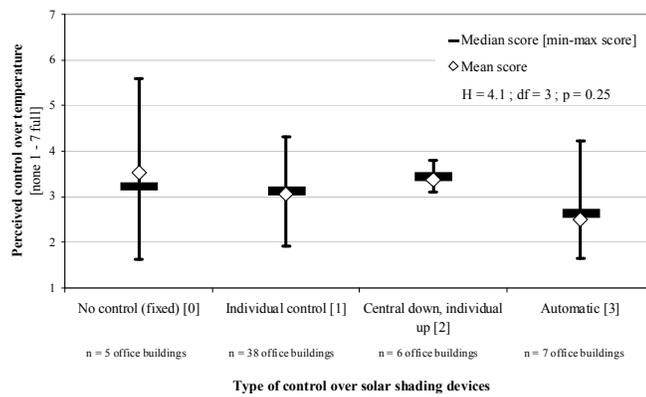


Figure 5. Availability of solar shading devices (no control, individual control, central up individual down, automatic) versus perceived control over temperature (non significant difference).

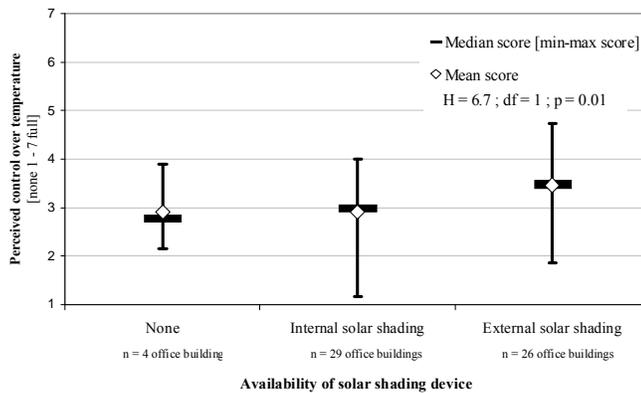


Figure 6. Availability of solar shading devices (internal / external / none) versus perceived control over temperature (significant difference). (Due to the low number of office buildings ($n < 5$) with no available solar shading devices these buildings were excluded from the analysis)

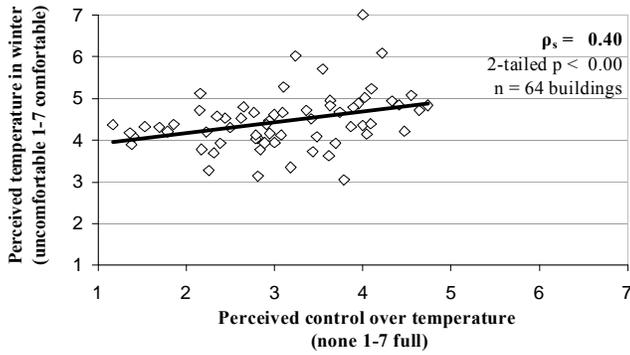


Figure 7. Perceived control over temperature versus perceived temperature (comfortable - uncomfortable) during winter (significant correlation).

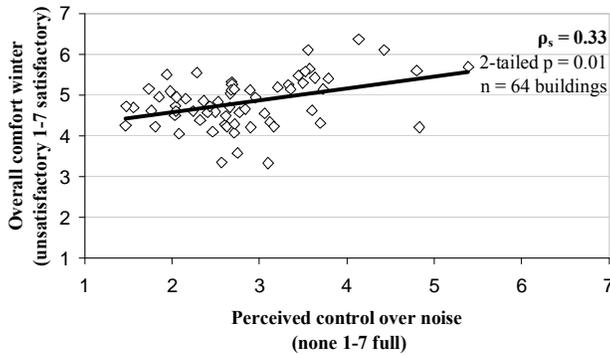


Figure 8. Perceived control over noise versus overall comfort (unsatisfactory - satisfactory) during winter (significant correlation).

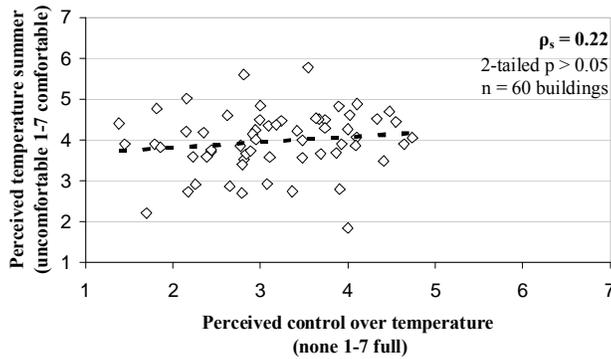


Figure 9. Perceived control over temperature versus perceived temperature (comfortable - uncomfortable) during summer (non significant correlation).

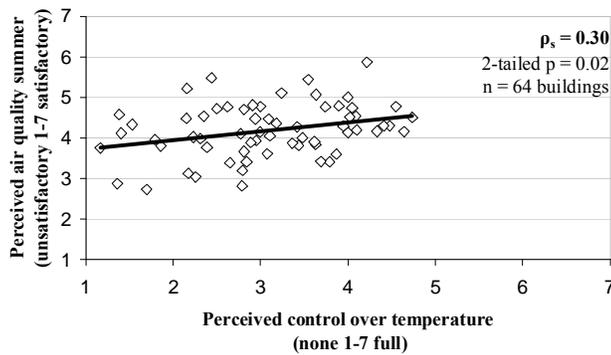


Figure 10. Perceived control over temperature versus perceived air quality (unsatisfactory - satisfactory) during summer (significant correlation).

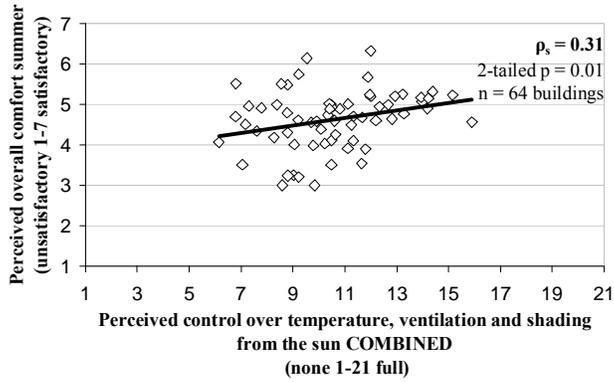


Figure 11. Perceived control over temperature, ventilation and shading from the sun combined versus overall comfort (unsatisfactory - satisfactory) during summer (significant correlation).

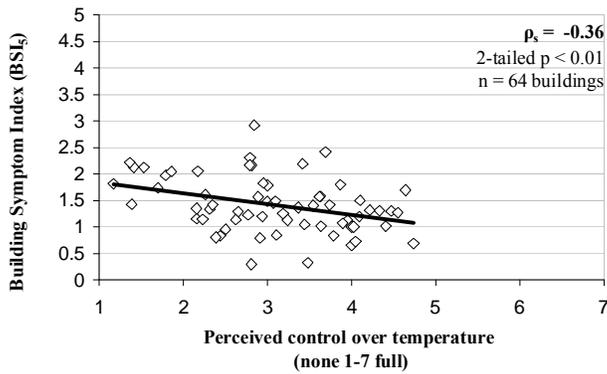


Figure 12. Perceived control over temperature versus BSI₅ (significant correlation).

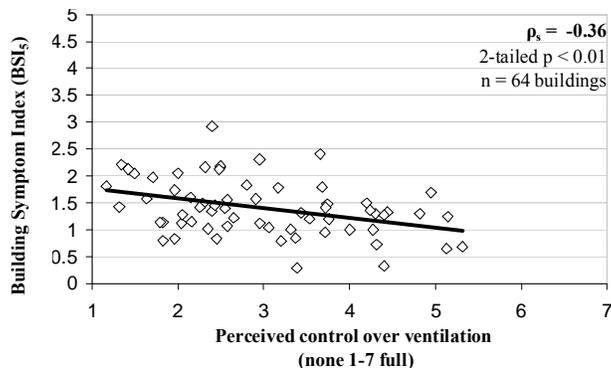


Figure 13. Perceived control over ventilation versus BSI₅ (significant correlation).

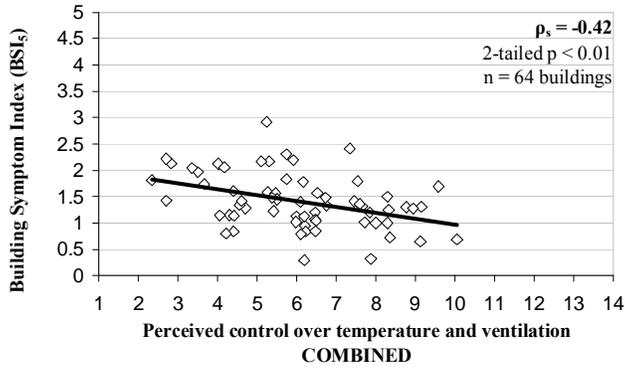


Figure 14. Perceived control over temperature and ventilation combined versus BSI₅ (significant correlation).

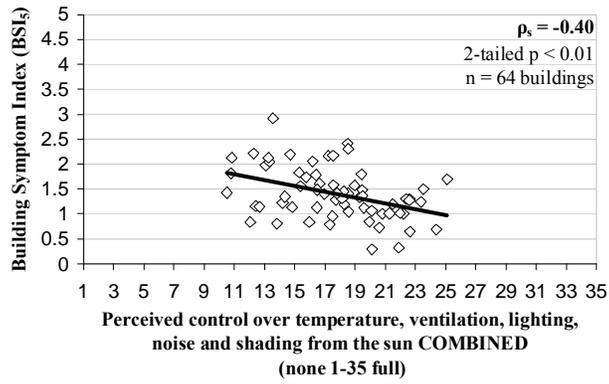


Figure 15. Perceived control over temperature, ventilation, lighting, noise and shading from the sun combined versus BSI₅ (significant correlation).

Table 1. Correlation Table. Spearmans rank correlations (ρ_s) between perceived control over the indoor environment and comfort and health (n = 64 office buildings). Significant correlations are indicated in bold. (Note that some of the noise and light correlations were not calculated because the main focus of this paper was on control over indoor climate (thermal environment and indoor air quality).)

	WINTER						SUMMER						ALL YEAR Building Symptom Index \leq (0 - 5)
	Overall comfort (Unsatisfactory 1 - 7 Satisfactory)	Perceived temperature (Uncomfortable 1 - 7 Comfortable)	Perceived air movement (Drafty 1 - 7 Still)	Perceived air quality (Stuffy 1 - 7 Fresh)	Perceived air quality (Smelly 1 - 7 Odourless)	Perceived air quality (Unsatisfactory 1 - 7 Satisfactory)	Overall comfort (Unsatisfactory 1 - 7 Satisfactory)	Perceived temperature (Uncomfortable 1 - 7 Comfortable)	Perceived air movement (Drafty 1 - 7 Still)	Perceived air quality (Stuffy 1 - 7 Fresh)	Perceived air quality (Smelly 1 - 7 Odourless)	Perceived air quality (Unsatisfactory 1 - 7 Satisfactory)	
Perceived control over temperature (None at all 1 - 7 Full control)	0.31*	0.40**	0.09	0.28*	0.09	0.26*	0.35**	0.22	0.03	0.14	0.08	0.30*	-0.36**
Perceived control over ventilation (None at all 1 - 7 Full control)	0.13	0.17	0.17	0.25*	-0.09	0.16	0.28*	0.20	-0.08	0.18	-0.05	0.28*	-0.36**
Perceived control over shading from the sun (None at all 1 - 7 Full control)	0.06	0.06	n.c.	n.c.	n.c.	n.c.	0.12	0.16	n.c.	n.c.	n.c.	n.c.	-0.05
Perceived control over lighting (None at all 1 - 7 Full control)	-0.43	n.c.	n.c.	n.c.	n.c.	n.c.	0.00	n.c.	n.c.	n.c.	n.c.	n.c.	-0.28*
Perceived control over noise (None at all 1 - 7 Full control)	0.33**	n.c.	n.c.	n.c.	n.c.	n.c.	0.24	n.c.	n.c.	n.c.	n.c.	n.c.	-0.37**
Perceived control over temperature and ventilation COMBINED (None at all 1 - 14 Full control)	0.21	0.27*	0.14	0.28*	-0.11	0.21	0.31*	0.21	-0.05	0.16	0.01	0.30*	-0.42**
Perceived control over temperature and shading from the sun COMBINED (None at all 1 - 14 Full control)	0.21	0.28*	-0.17	0.32*	-0.05	0.19	0.29*	0.23	-0.18	0.08	-0.11	0.20	-0.26*
Perceived control over temperature, shading from the sun and ventilation COMBINED (None at all 1 - 21 Full control)	0.21	0.27*	-0.20	0.34*	-0.06	0.21	0.31*	0.24	-0.15	0.14	-0.08	0.28*	-0.36**
Perceived control over temperature, shading from the sun, ventilation, lighting and noise COMBINED (None at all 1 - 35 Full control)	0.18	0.29*	-0.08	0.31*	-0.06	0.17	0.25	0.13	-0.13	0.07	-0.73	0.20	-0.40**

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

n.c. = not calculated (main focus of this paper is on control over the thermal environment and indoor air quality)

Appendix 1. Selected questions from the HOPE building checklist – offices

What solar shading devices are present?

- | | | |
|---|--|---|
| <input type="checkbox"/> None | <input type="checkbox"/> External vertical blinds | <input type="checkbox"/> External shutters |
| <input type="checkbox"/> External louvres | <input type="checkbox"/> External screens | <input type="checkbox"/> External window films |
| <input type="checkbox"/> External horizontal blinds | <input type="checkbox"/> External awnings / canopies | <input type="checkbox"/> External overhangs |
| <input type="checkbox"/> External vertical fins | <input type="checkbox"/> Blind between glazing | <input type="checkbox"/> Internal vertical blinds |
| <input type="checkbox"/> Internal louvres | <input type="checkbox"/> Atrium | <input type="checkbox"/> Double façade |
| <input type="checkbox"/> Other (specify) | | |

How are the solar shading devices controlled?

- | | |
|--|-------------------------------------|
| <input type="checkbox"/> No control (fixed) | <input type="checkbox"/> Individual |
| <input type="checkbox"/> Central down, individual up | <input type="checkbox"/> Automatic |

How is the room temperature controlled?

- | | | |
|--|--|--|
| <input type="checkbox"/> Manual radiator valve | <input type="checkbox"/> Local thermostat at radiator / heating unit | <input type="checkbox"/> Local thermostat (e.g. on wall) |
| <input type="checkbox"/> Central sensor | <input type="checkbox"/> Façade sensor(s) – i.e. outside Temperature | <input type="checkbox"/> Zone sensor(s) |
| <input type="checkbox"/> Manual control in room(s) | <input type="checkbox"/> According to occupancy | <input type="checkbox"/> Other |

Are the windows operable?

- | | |
|--|---|
| <input type="checkbox"/> Yes | <input type="checkbox"/> Yes, some (estimate % office area with operable windows) |
| <input type="checkbox"/> Yes, but occupants are not allowed to open them | <input type="checkbox"/> No |

Appendix 2. Selected questions from the HOPE occupant questionnaire

(Note that the scales for control over temperature, ventilation etc. were reversed in the original study (originally: 1 = full control; 7 = none at all); the same goes for the comfort scales (originally: 1 = satisfactory; 7 = unsatisfactory; 1 = comfortable; 7 = uncomfortable etc.). We reversed the scales to make Figures 7 to 16 more easy to interpret (left and low = negative; right and high = positive).)

Perceived control: Selected questions to determine control over the indoor environment

How much control do you personally have over the following aspects of your working environment?

Temperature	none at all	1	2	3	4	5	6	7	full control
Ventilation	none at all	1	2	3	4	5	6	7	full control
Shading from the sun	none at all	1	2	3	4	5	6	7	full control
Lighting	none at all	1	2	3	4	5	6	7	full control
Noise	none at all	1	2	3	4	5	6	7	full control

Health: Selected questions to determine building related symptoms

In the past 12 months have you had more than two episodes of:

Dryness of the eyes	Yes	No
If 'Yes' was this better on days away from the office?	Yes	No

Itchy or watery eyes	Yes	No
If 'Yes' was this better on days away from the office?	Yes	No

Blocked or stuffy nose	Yes	No
If 'Yes' was this better on days away from the office?	Yes	No

Runny nose	Yes	No
If 'Yes' was this better on days away from the office?	Yes	No

Dry throat	Yes	No
If 'Yes' was this better on days away from the office?	Yes	No

Lethargy or tiredness	Yes	No
If 'Yes' was this better on days away from the office?	Yes	No

Headache	Yes	No
If 'Yes' was this better on days away from the office?	Yes	No

Dry, itching or irritated skin	Yes	No
If 'Yes' was this better on days away from the office?	Yes	No

Comfort: Selected questions to determine perceived thermal and olfactory comfort

How would you describe typical working conditions in the office in winter?

Comfort overall in winter	unsatisfactory	1	2	3	4	5	6	7	satisfactory
Temperature in winter	uncomfortable	1	2	3	4	5	6	7	comfortable
Air quality in winter	stuffy	1	2	3	4	5	6	7	fresh
Air quality in winter	unsatisfactory	1	2	3	4	5	6	7	satisfactory

How would you describe typical working conditions in the office in summer?

Comfort overall in summer	unsatisfactory	1	2	3	4	5	6	7	satisfactory
Temperature in summer	uncomfortable	1	2	3	4	5	6	7	comfortable
Air quality in summer	stuffy	1	2	3	4	5	6	7	fresh
Air quality in summer	unsatisfactory	1	2	3	4	5	6	7	satisfactory