Impact of Perceived Control on Comfort and Health in European Office Buildings

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SUMMARY

In this study the impact of perceived control on comfort and building related symptoms was investigated by reanalyzing the HOPE database (60 office buildings with over 6000 respondents).

Correlations were found between buildings with more perceived personal control on temperature and increased thermal comfort during winter. Also buildings with more personal control on temperature were found to correlate with more overall comfort during winter and summer. Buildings with more control on noise were found to correlate with more overall comfort during winter and less building related symptoms. Furthermore combinations of control options were found to be more effective at reducing the building related symptoms than single control options (except for control on noise).

Our findings suggest that more perceived control over indoor environment will improve comfort and health of the building occupants.

KEYWORDS


1 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, CO\textsubscript{2} concentration, etcetera) by definition assures the comfort and satisfaction of building occupants.

However, occupants in many of these new office buildings are not satisfied with the indoor climate (e.g. BOMA 1997). An often heard explanation is a ‘lack of options for personal control’ (Mendell & Smith, 1990). Several studies have shown that the amount of perceived personal control over the indoor climate positively relates to a decrease in complaints over the indoor climate. 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 air conditioned buildings without operable windows. One of the possible underlying causes that was identified by the authors was 'limited possibilities for personal control of temperature and fresh air supply'. Zweers et al (1992) conducted a large epidemiological study in 69 Dutch office buildings and came to comparable conclusion as Hedge et al (1989): less options for personal control leads to a higher risk for building related symptoms. Also a meta-analysis study 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.
It is clear that personal control is of great importance to obtain satisfaction with the indoor climate. However, little is known about which aspects are important to have personal control over. Is it more beneficial for overall satisfaction to only use a thermostat to control the temperature? Or do building occupants need full control over all aspects of the indoor environment?

Note that Paciuk (1990) points out that personal control actually can be three things: 1. Available control, 2. Exercised control and 3. Perceived control.

The objective of this study was to determine the impact of perceived personal control on comfort and health in office buildings.

2 METHODS
In this study data from the HOPE database (HODA, see http://hope.epfl.ch) has been re-analyzed. HODA contains data from the HOPE project (Health Optimisation Protocol for Energy-efficient Buildings) in which 60 European office buildings with over 6000 building occupants have been surveyed. The aim of the HOPE project was to derive and test new guidelines for energy-efficient and healthy buildings. Building occupants of the surveyed buildings were invited to participate in a questionnaire about their perception of the indoor environmental quality at their workspace. More information on the methods used in the HOPE study is presented by Roulet et al (2006).

First, relevant questions were selected from the general questionnaire (table 1). These specific questions were related to perceived personal control, thermal comfort, perceived air quality and building related symptoms.

Table 1. Selected questions from the HOPE Office Environment Survey questionnaire.

| Perceived personal control: Selected questions to determine personal control over the indoor environment. |
|---|---|---|---|---|---|---|---|
| Temperature | full control | 1 | 2 | 3 | 4 | 5 | 6 | 7 None at all |
| Ventilation | full control | 1 | 2 | 3 | 4 | 5 | 6 | 7 None at all |
| Shading from the sun | full control | 1 | 2 | 3 | 4 | 5 | 6 | 7 None at all |
| Lighting | full control | 1 | 2 | 3 | 4 | 5 | 6 | 7 None at all |
| Noise | full control | 1 | 2 | 3 | 4 | 5 | 6 | 7 None at all |

Selected questions to determine building related symptoms.

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

**Symptom**

If ‘Yes’ was this better on days away from the office?

| Perception: Selected questions to determine comfort. |
|---|---|---|---|---|---|---|---|---|
| How would you describe typical working conditions in the office in season? |
| Comfort overall in season | Satisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 Unsatisfactory |
| Temperature in season | Comfortable | 1 | 2 | 3 | 4 | 5 | 6 | 7 Uncomfortable |
| Air quality in season | Fresh | 1 | 2 | 3 | 4 | 5 | 6 | 7 Stuffy |
| Air quality in season | Satisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 Unsatisfactory |

The questions regarding building related symptoms were combined into the Building Symptom Index (BSI). The BSI is based on 5 core symptoms: dry eyes, blocked or stuffy

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1 In the HOPE questionnaire these three questions over building related symptoms were asked for 8 building related symptoms: dryness of the eyes, itchy or watery eyes, blocked or stuffy nose, runny nose, dry throat, lethargy or tiredness, headaches, dry, itching or irritated skin.

2 The same questions regarding comfort were asked specifically for the winter and summer situation (season).
nose, dry throat, headache and tiredness. Each symptom reported by the occupant scores 1. This means that every individual can score any value between 0 and 5 (his or her Personal Symptom Index). The average of the PSI for building occupants of a building is called the Building Symptom Index (BSI).

For each other dependent variable (e.g. comfort) and independent variable (e.g. perceived personal control) also an average score was derived for each building.

The Spearman’s rank correlation test (2-sided \( p<0.05 \)) was used to test for correlations between the independent variable perceived control and the dependent variables: overall comfort, perceived temperature, perceived air quality and building related symptoms.

To determine the effect of multiple control options, the average building scores for questions about perceived personal control were combined. When one building scored ‘3’ on the seven-point scale for perceived control on temperature and ‘5’ for perceived control on ventilation, the building scored ‘8’ on a 14-point scale for perceived control on ventilation and temperature.

3 RESULTS
The results of the analysis are grouped into three categories: results concerning the winter situation, results for the summer situation and results concerning building related symptoms. The most interesting results are presented in figure 1-8 (notice that the seven-point scales for perceived personal control and comfort are reversed for increased readability of the graphs).

Effect of perceived personal control on comfort during winter
For the winter situation the strongest correlation (figure 1) was found for control on temperature and perceived temperature during winter [comfortable – uncomfortable] (\( \rho_s=0.40 \); 2-sided \( p=0.00 \)). Perceived control on temperature also correlated with perceived overall comfort during winter (\( \rho_s=0.27 \); 2-sided \( p=0.03 \)). Perceived control on noise was found to correlate (figure 2) with perceived overall comfort during winter (\( \rho_s=0.34 \); 2-sided \( p=0.00 \)). Furthermore no significant correlations were found between single control options and comfort, perceived air quality and building related symptoms.

When the scores for perceived personal control were combined for the winter situation, the strongest correlation was found for perceived personal control on temperature + ventilation in relation to overall comfort during winter (\( \rho_s=0.32 \); 2-sided \( p=0.02 \)). Perceived control on temperature + shading from the sun and perceived control on temperature + ventilation + shading from the sun also were found to correlate with overall comfort during winter (\( \rho_s=0.31 \) / \( \rho_s=0.30 \); 2-sided \( p=0.02 \)). A correlation was found between perceived control on temperature + ventilation and the perceived air quality during winter [fresh – stuffy] (\( \rho_s=0.25 \); 2-sided \( p=0.04 \)).

Effect of perceived personal control on comfort during summer
For the summer situation the strongest correlation was found for control on temperature and overall comfort during summer (\( \rho_s=0.32 \); 2-sided \( p=0.01 \)). No correlation (figure 3) was found between perceived personal control on temperature and perceived temperature during summer [comfortable – uncomfortable] (2-sided \( p > 0.05 \)). Perceived control on temperature did however correlate (figure 4) with perceived air quality during summer [satisfactory – unsatisfactory] (\( \rho_s=0.27 \); 2-sided \( p=0.03 \)). Furthermore no significant correlations were found between single control options and comfort, perceived air quality and building related symptoms.

When the scores for perceived personal control were combined for the summer situation, a correlation was found for perceived control on temperature + ventilation in relation to overall comfort (\( \rho_s=0.30 \); 2-sided \( p=0.01 \)). Perceived control on temperature + shading from the sun
and perceived control on temperature + ventilation + shading from the sun also were found to correlate with overall comfort ($\rho_s=0.29$ / $\rho_s=0.30$ ; 2-sided $p=0.02$). An average correlation was found between perceived control on temperature + ventilation and the perceived air quality [satisfactory – unsatisfactory] ($\rho_s=0.28$; 2-sided $p=0.03$).

**Effect of perceived personal control on building related symptoms**

No correlation (figure 5) was found between perceived personal control on temperature and BSI$_5$ ($p>0.05$). Also no correlation (figure 6) was found between perceived personal control on ventilation ($p>0.05$). A correlation was found between perceived personal control on noise and BSI$_5$ ($\rho_s=-0.44$; 2-sided $p=0.00$). Furthermore an average correlation was found between perceived personal control on lighting and BSI$_5$ ($\rho_s=-0.27$; 2-sided $p=0.04$).

When single options for perceived personal control were combined, a strong correlation (figure 7) was found between perceived control on temperature + ventilation and BSI$_5$ ($\rho_s=-0.44$; 2-sided $p=0.00$). Perceived personal control on temperature + ventilation + shading from the sun + lighting (figure 8) and perceived personal control on temperature + ventilation + shading from the sun + lighting + noise also were found to correlate strongly with BSI$_5$ ($\rho_s=-0.37$ / $\rho_s=-0.43$ ; 2-sided $p=0.00$).

4 DISCUSSION

The range of perceived control between buildings in HODA is limited (all scores are in the range 1.5-5 on a seven point-scale). This can indicate that no buildings were included in the database in which the occupants perceived very good personal control or it indicates that people tend to not give extreme votes (i.e. ‘1’ or ‘7’).

For the winter situation only perceived control on temperature and noise seems to be important for comfort. All combinations of control options for which correlations were found are combinations including personal control on temperature. It is expected that these correlations are influenced by perceived control on temperature, or in other words, these correlations emphasize the assumption that personal control on temperature is the most important control aspect for (thermal) comfort during winter.

The same conclusion applies to the summer situation: perceived control on temperature is the most important control aspect for (thermal) comfort and influences the correlations found for combinations of control options. Surprisingly, between perceived control on temperature and the perceived air quality a positive correlation was found. An explanation for this relation might be that high air temperatures are known to contribute to air quality complaints (Fang et al, 1996).

When looking at the results regarding BSI$_5$, notice how the single control options (e.g. temperature and ventilation) do not provide correlations with comfort etc. but the combined options do. This indicates that an adequate combination of personal control options will decrease the amount of building symptoms.

Roulet et al (2006) also analysed HODA; they came to comparable but not exactly the same conclusions. Explanations for the differences are for example: the use of BSI$_5$ instead of BSI$_3$, the use of a combined summer/winter score for comfort and a different statistical analysis method. Also Bluyssen et al (2011) re-evaluated the HOPE database. They also found that in general: the more satisfied occupants are with control over thermal indoor environment, the more satisfied they are with their comfort. Bluyssen et al (2011) also found (like this study) that perceived control over noise had a positive impact on perceived overall comfort. Note that in both these studies the impact of combinations of perceived control was not investigated.
Perceived temperature in winter
Perceived air quality summer
Overall comfort winter
Building Symptom Index (BSI)
Perceived productivity
Building Symptom Index (BSI)

ρs = 0.15
2-sided p > 0.05
n = 60 buildings

ρs = 0.34
2-sided p = 0.00
n = 60 buildings

ρs = 0.20
2-sided p = 0.13
n = 60 buildings

ρs = 0.27
2-sided p = 0.03
n = 60 buildings

ρs = 0.15
2-sided p > 0.05
n = 60 buildings

ρs = -0.37
2-sided p = 0.00
n = 60 buildings

ρs = -0.44
2-sided p = 0.00
n = 60 buildings

ρs = -0.40
2-sided p = 0.00
n = 60 buildings

ρs = 0.15
2-sided p > 0.05
n = 60 buildings

ρs = 0.27
2-sided p = 0.03
n = 60 buildings

ρs = 0.34
2-sided p = 0.00
n = 60 buildings

ρs = 0.40
2-sided p = 0.00
n = 60 buildings

ρs = 0.44
2-sided p = 0.00
n = 60 buildings

Perceived control on temperature and ventilation (none 1-14 full)
Perceived control on ventilation (none 1-7 full)
Perceived control on noise (none 1-7 full)
Perceived control on temperature (none 1-7 full)
Perceived p
Perceived productivity
-3 too cold / +3 too hot
uncomfortable 1-7 comfortable
comfortable 1-7 comfortable

Thermal sensation during... p = 0.00
n = 60 buildings

Perceived p
c

Perceived p

Personal control on temperature, ventilation, lighting
and shading from the sun versus BSI5.

Figure 1. Perceived personal control on room temperature versus BSI5.
Figure 2. Perceived personal control on noise versus overall comfort during winter.
Figure 3. Perceived personal control on room temperature versus BSI5.
Figure 4. Perceived personal control on room temperature versus perceived air quality during summer.
Figure 5. Perceived personal control on room temperature versus BSI5.
Figure 6. Perceived personal control on ventilation versus BSI5.
Figure 7. Perceived personal control on room temperature and ventilation versus BSI5.
Figure 8. Perceived personal control on room temperature, ventilation, lighting and shading from the sun versus BSI5.
In this study the impact of perceived control on comfort and health was investigated. The impact of available control (e.g. availability of adjustable thermostats) on perceived control and comfort and health will be the objective of future studies. Also the impact of perceived control on productivity will be studied in a future research project.

5 CONCLUSIONS

Our findings suggest that buildings with a high degree of perceived control on temperature have significantly higher thermal comfort scores during winter. No significant correlation was found between perceived control on temperature in buildings and thermal comfort during summer. Buildings with a high degree of perceived control on temperature were found to have higher scores for overall comfort during summer and winter. For the summer situation, buildings with a high degree of perceived control were found to have better perceived air quality.

Furthermore our findings suggest that buildings with a high degree of perceived control on noise have higher overall comfort scores during winter and significantly less building related symptoms among their occupants. No significant correlation was found between buildings with a high degree of either perceived control on temperature or perceived control on ventilation and the amount of building related symptoms among occupants. Building occupants of buildings with a high degree of perceived control on ventilation and temperature were found to have significantly less building related symptoms. Moreover, in general occupants of buildings with a combination of control options were found to have less building related symptoms.

This indicates that new office buildings should be designed with at least adequate possibilities for control on temperature. If a low amount of building related symptoms is the goal, one should invest in adequate combinations of controls. For optimal overall comfort, also control on noise should be addressed.

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6 REFERENCES


HODA (Hope database) http://hope.epfl.ch.


