C: Behaviour & environmental psychology
C.1. Man-environment interactions

PERCEIVED CONTROL OVER INDOOR CLIMATE AND ITS IMPACT ON DUTCH OFFICE WORKERS

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SUMMARY

A field study was conducted in nine modern office buildings in the Netherlands. The study focused on perceived control over indoor climate and its impact on satisfaction of building occupants, the incidence of building related (SBS) symptoms and self-assessed performance.

The study involved a questionnaire amongst 236 office workers. Statistical analyses were conducted to investigate correlations between combined perceived control over temperature and ventilation on the one hand and satisfaction-, SBS- and productivity-indices on the other.

Individual perceived control over indoor climate scores were perfectly normally distributed (using a 7 point scale coded from 1 = no control at all to 7 = full control) with as mean value 3.1 (SD 1.4). Respondents that perceived to have a high amount of control over their indoor climate were considerably more satisfied with their indoor environment. High control respondents also had significant less building related symptoms (BSI(5) 0.94 vs. 0.61). And productivity scores were significantly higher (6.3 %point) in comparison with the low control respondents.

INTRODUCTION

Several theories and studies imply that having or not having control over one’s indoor climate affects how that indoor climate is perceived (e.g. Bell et al., 2002, Paciuk, 1990, Lee& Brand, 2005 and Hellwig, 2014). And there is growing evidence that human responses to sensory stimuli such as suboptimal temperatures modify when those exposed have control over these stimuli (Nicol & Humphreys, 1973; Brager & DeDear, 1998). Boerstra et al. (2013A) developed a provisional conceptual model based on this assumption, see Figure 1.

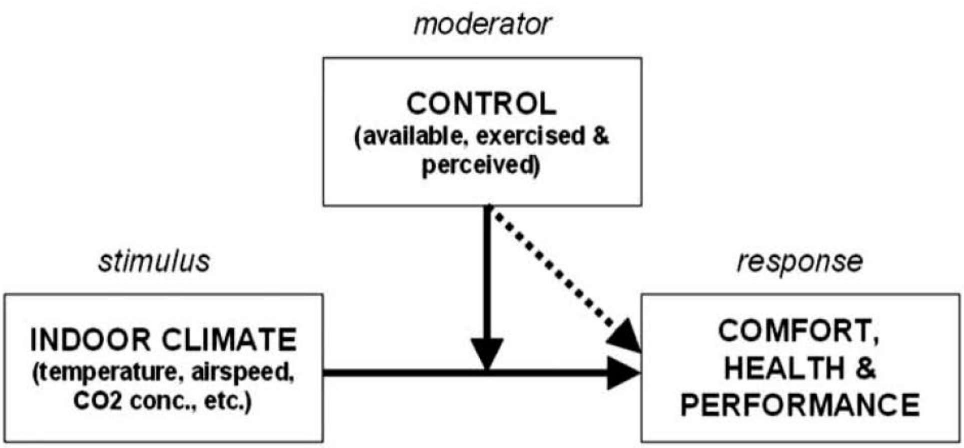

Figure 1. Conceptual model

A field study was designed to explore this conceptual model further. Central aspects that were investigated were (with reference to Paciuk (1990)): available control, exercised control and perceived control. In this paper the results related to perceived control and it's correlation with satisfaction, health and performance are presented. A previous paper by the same authors (see Boerstra, Loomans & Hensen, 2013B) describes other results of this field study, especially those related to available and exercised control over the thermal environment. This other paper also presents the outcomes of physical measurements (especially in relation to thermostat effectiveness) that were conducted during the field study.

The first objective of the present field study was to make an inventory of the status-quo in Dutch office buildings related to perceived control over thermal environment (temperature) and indoor air quality (ventilation). The second objective was to test the hypothesis that office workers that perceive to have a high amount of control over their thermal environment and (local) indoor air quality generally are i. more satisfied with their indoor climate, ii. have less building related (SBS) symptoms and iii. perceive to be more productive.

METHODOLOGIES

The field study was carried out in nine office buildings located in seven different cities spread out over the Netherlands. The buildings were selected based on 3 core criteria. The buildings had to have i. state-of-the art office work environments, ii. well-maintained building service systems and iii. a gross net floor surface of at least 2,000 m2. The buildings were visited at different times between November 2011 and March 2012. Relevant workplace, building and HVAC system characteristics were mapped using a dedicated checklist.

Building occupants' perceptions were the central focus during the survey. In each building the lead researcher asked between 20 and 30 people to manually fill in a questionnaire. The total number of respondents for the nine buildings was 236. The respondents were selected at random. Purposely we looked for respondents spread out over different floors, different departments, different facades etc. The response

rate was > 95%. More or less everybody that was approached agreed to participate. When people refused to participate this in all cases was because of lack of time.
After the respondents filled in the questionnaire they were asked to participate in an extra, 10 minute lasting, face-to-face interview. A total of 161 building occupants agreed to participate in this 2nd part of the survey.

Below, perceived control scores of the respondents are first presented at item-level, specifically for perceived control over temperature in winter, perceived control over temperature in summer and perceived control over ventilation. With as original questions (3 in total): ‘How much control do you have over temperature in winter / temperature in summer / ventilation?’. We know from other studies (e.g. Leaman & Bordass, 2001) that working with combined, aggregated scores often leads to better insight on how perceived control affects building occupants. So we constructed an aggregated indoor climate variable PC3, based on the 3 self-reported items referred to above. The mean score across the three items was used in the analysis.

During the further analysis ‘occupant type’ was used as the main independent variable. A distinction was made between two answering categories: i. occupants with Low Perceived Control (LowPC3 occupants) and ii. occupants with High Perceived Control over temperature in winter, temperature in summer and ventilation combined (HighPC3 occupants). An occupant ended up in the first category (i) if he/she voted less than 4 or 4 on the aggregated 7-point scale. To make category ii he/she had to vote higher than 4.

As far as the dependant variables are concerned: in line with the UK PROBE study approach described in Leaman & Bordass (2001), 3 indices were used:

- The Personal Satisfaction Index (measured at interval level on an scale from 1 to 7) gives an implication on how satisfied individual respondents were with the thermal environment in winter, the thermal environment in summer and the air quality throughout the year. This also is an aggregated variable that was constructed based on the 3 self-reported items (all with 7 point scale with answering categories: very dissatisfied to very satisfied): ‘In general, how satisfied are you in winter with the thermal environment at your workplace?’, ‘In general, how satisfied are you in summer with the thermal environment at your workplace?’ and: ‘In general, how satisfied are you with the air quality at your workplace?’. The Personal Satisfaction Index was calculated by taking the mean score across the 3 items.
- The Personal Symptom Index or PSI (5) (measured at ratio level on a scale from 0 to 5) communicates how many (with a maximum of 5) building related symptoms an individual occupant has; this is a predefined standard index also used in other studies (see e.g. Roulet et al., 2006). This 3rd output-index refers to the added incidence of the following symptoms: dry eyes, stuffy nose, dry throat, headache and tiredness. Respondents were specifically asked about ‘symptoms that they think are related to the indoor climate at their workplace’.
- The Personal Productivity Index (measured at ratio level on a scale from -30% to +30%); this index was based on the answers on a question that asked the respondents about how they estimate that the indoor climate at their workplace generally affects their performance.

The between-respondent differences were explored with the statistical program SPSS 20 (significance level: p=0.05). Chi-square tests and t-tests were used to analyze whether there were significant differences between the Low and High PC3 occupants. In all cases p=0.05 was used as the significance level.

RESULTS AND DISCUSSION

Figure 2 presents the perceived control scores of the respondents. The figure gives the histograms for the original items scores of i. perceived control over temperature in winter, ii. perceived control over temperature in summer and iii. perceived control over ventilation. The aggregated PC3 indoor climate scores of the respondents are presented in the histogram in the lower right. The PC3 indoor climate scores were near perfectly normally distributed (using a 7 point scale coded from 1 = no control at all to 7 = full control) with as mean PC3 value 3.1 (SD 1.4).

Figure 3 visualized how the Personal Satisfaction Index scores (rounded off to whole values) were within the two occupant groups (LowPC3 vs. HighPC3). The figure shows that those that perceived to have a low amount of control over their indoor climate more often indicated to be dissatisfied or very dissatisfied with their indoor climate than those that indicated to have a high amount of control. The LowPC3 mean value for the Personal Satisfaction Index was 4.04 (SD 1.24; SE 0.10), The HighPC3 mean value was 4.87 (SD 1.10; SE 0.14). The difference is highly significant (p<0.001).

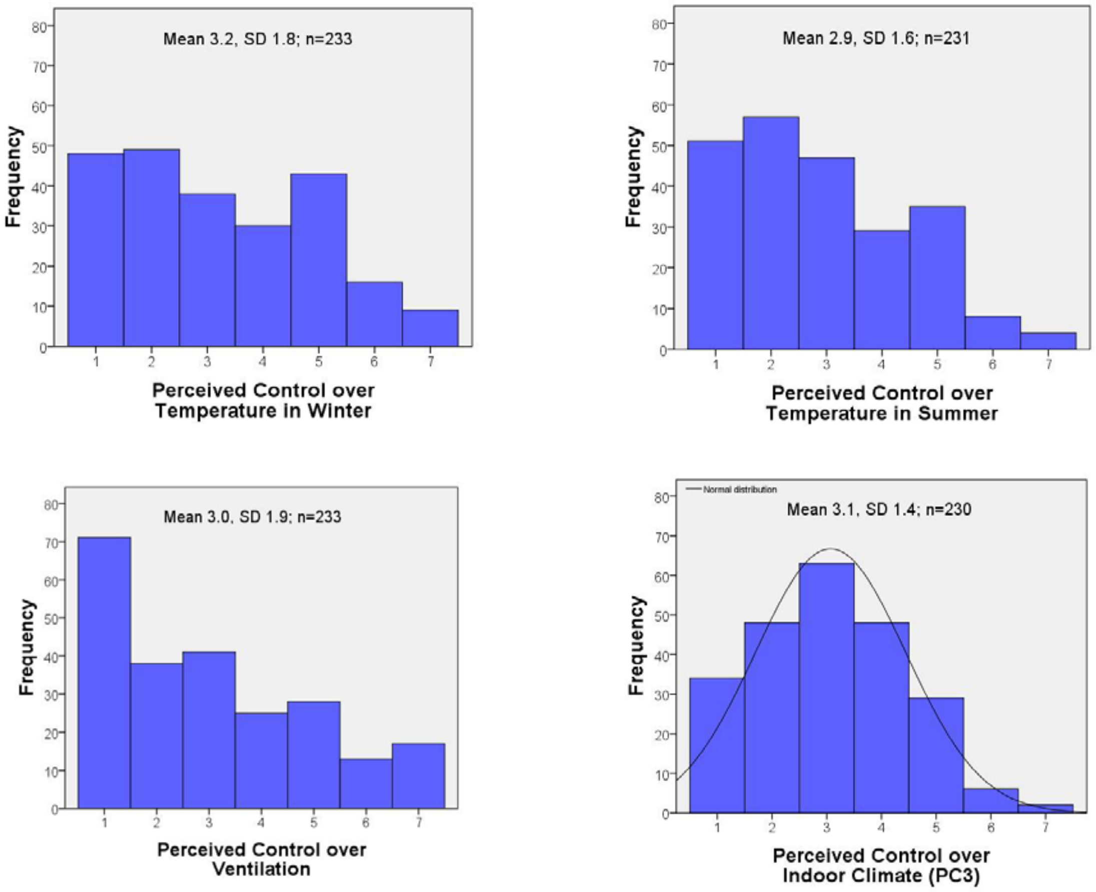

Figure 2. Distribution of perceived control scores

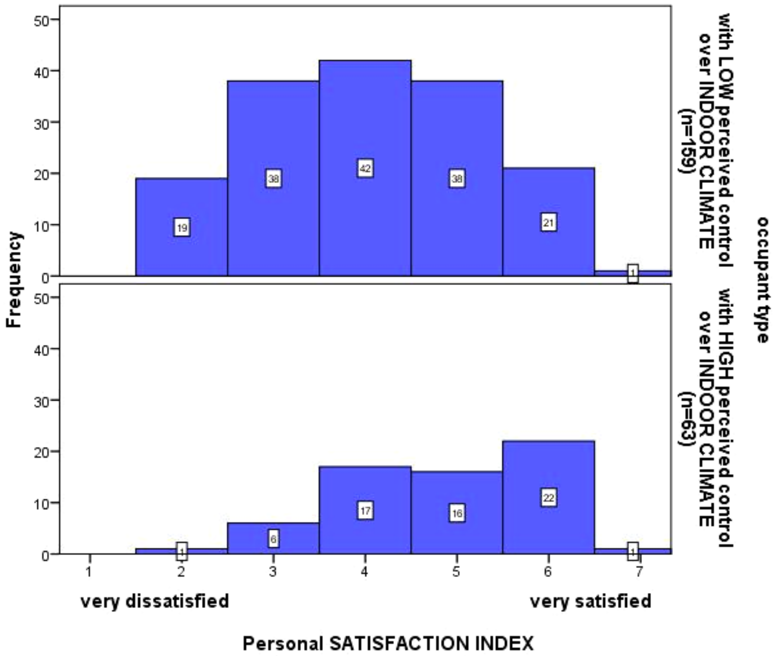

Figure 3. Difference in satisfaction scores between LowPC3 and HighPC3 occupants

There are also considerable differences when one compares the amount of occupants scoring dissatisfied (1, 2 or 3 on the 7 point scale)on one, two or all three of the satisfaction questions (satisfaction with temperature in winter, temperature in summer and ventilation overall). 66% of the respondents in the LowPC3 group are dissatisfied about at least one of the 3 indoor climate aspects, for the HighPC3 control group this is only 39%. Also this difference is highly significant (p<0.001).

The PSI(5) Mean and Standard Error (SE) for the 2 occupant groups are presented in figure 4. Note that the results from building X2 were disregarded for this specific analysis as a further exploration of the data showed that the symptom results from this building were unreliable due to an unusual control situation. Mean PSI(5) value for the LowPC3 respondents was 0.94 (SD 1.16; SE 0.10) and for the HighPC3 group this was 0.61 (SD 1.03; SE 0.13). This difference is (just) significant (p=0.044). The conclusion was that PSI (5) (symptom incidence) is a factor of 1.5 higher for those that perceive to have little control over their (combined) indoor climate.

In figure 5 the self-assessed productivity scores as communicated by the LowPC3 and the HigPC3 group are presented. The figure shows that self-assessed productivity is 6.3 %point higher for those that perceive to have a high amount of control over their indoor climate. Mean value for the LowPC3 group was -3.6% (SD 10.6, SE 0.84), for the HighPC3 group this was 2.7% (SD 11.4, SE 1.44). The difference is highly significant (p<0.001).

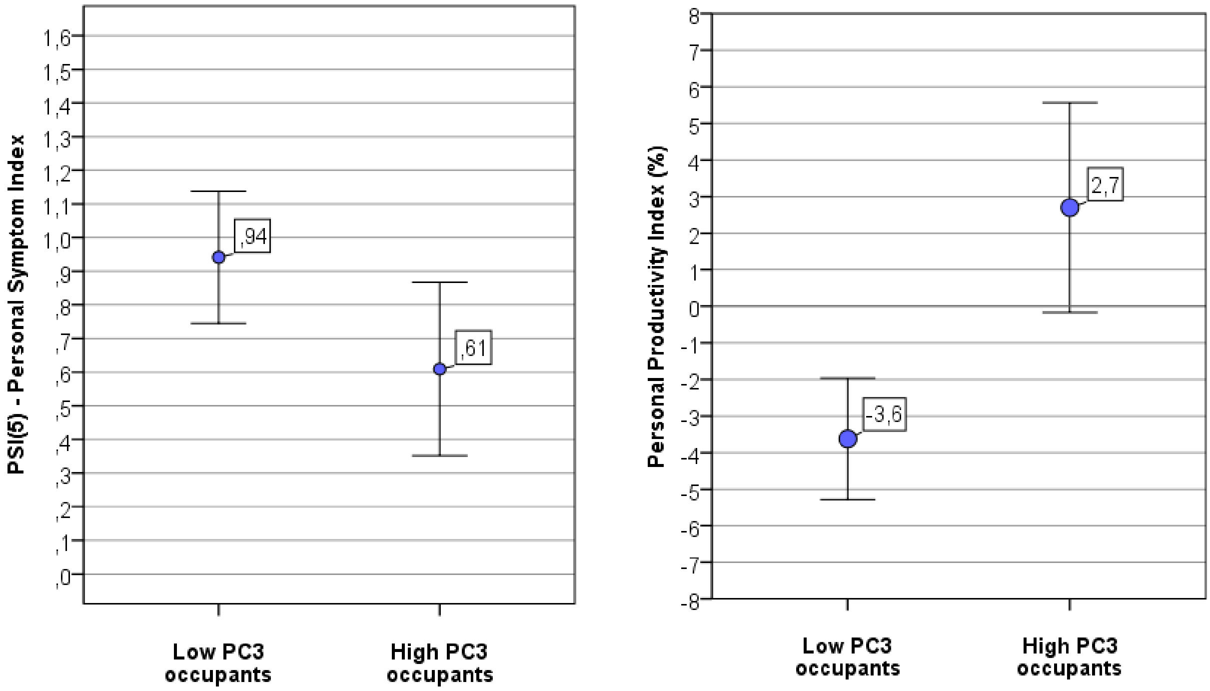

Figure 4 (left). Difference in PSI(5) scores between LowPC3 and HighPC3 occupants
Figure 5 (right). Difference in self-assessed productivity between the 2 (Mean + SE)

CONCLUSIONS

Analysis of the results from the Dutch office buildings showed that mean combined perceived control over the indoor climate per building (PC3 Mean) varied from 1.8 to 4.5 (using an aggregated 7-point scale from 1= no control at all to 7=full control).

Interpretation of the within-subjects results revealed that office workers that perceive to have a high amount of control over their indoor climate are considerably more satisfied (about 1 step on the satisfaction 7 point scale) with their indoor climate (highly significant difference). The incidence of building related symptoms is significant higher amongst occupants that perceive to have little control over their indoor climate: the Personal Symptom Index (5) amongst the low control respondents is a factor 1.5 higher compared to that of the high control respondents. Also self-assessed productivity differed considerably: self-assessed productivity is 6.3 %point higher for those that perceive to have a high amount of control over their indoor climate.

The outcomes of the present study are in line with the outcomes of the European HOPE study (see Roulet et al., 2006) and congruent with studies in other countries than the Netherlands (e.g. Raw, Roys & Leaman (1994), Toftum (2010), Leaman & Bordass (2001) and Schweiker et al. (2012)).

This article focused on perceived control over the indoor climate and how this impacts office workers. A further question could be what factors cause people to perceive to be (or not to be) in control over their indoor climate. Or in other words: how perceived control is related to available control and the presence or absence of controls. This partly has been explored in a previous article, see Boerstra, Loomans & Hensen, 2013B. The main conclusion in that article was that important aspects are access to adjustable thermostats, access to operable windows and absence of restrictions on control use (e.g. as set by facility manager).

This study resulted in new insights related to the importance and effects of perceived control over temperature and ventilation. Architects, HVAC consultants and other involved in office building and building service system design can use the study's output to better convince principals, developers and other key decision makers to invest in (adequate) options for manual control over indoor climate. Which in the end will result in more comfortable and more healthy offices that will be perceived as productivity enhancing by their end-users.

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