Personal control over indoor climate disentangled, Part 1

RUNA HELLWIG
PhD., Professor for Building Physics and Indoor Climate,
Augsburg University of Applied Sciences, Augsburg, Germany.
email: runa.hellwig@hs-augsburg.de

ATZE BOERSTRA
PhD, Managing director
BBA Indoor Environmental Consultancy and
REHVA Vice-president
email: ab-bba@binnenmilieu.nl

Most non-residential buildings that were built or retrofitted in the last 20 years use a Building Automation System (BAS). BASs are installed to efficiently operating buildings and reducing their energy usage and operating costs. At the same time BASs allow to tightly control the indoor climate in line with requirements as defined in guidelines, standards and building decrees. But this tight control does not necessarily lead to higher occupant satisfaction or lower complaint rates.

Keywords: Perceived Control, Occupant Behaviour, Indoor Environment Quality (IEQ), Integrated Design, Energy Efficiency, Smart Buildings, Building Automation System (BAS), Building Management System (BMS).

Introduction

Recent research shows that too much centralized control has drawbacks. Depriving building occupants of options to adjust their indoor climate in line with momentary needs is contra-productive. Personal control in indoor environments has been identified as playing a major role in the perception of the indoor environment. Leaman & Bordass (1999), for good reason, talk about personal control as one of the *'killer variables'* that determine a building's performance. This implies that HVAC system engineers, facade designers and facility managers should take personal control needs of building occupants into account when designing and operating buildings and their service systems. In this article we present answers to 10 frequently-asked-questions about control over the thermal environment and indoor air quality. The focus in this Part 1 article is on importance of control, effects of control and mechanisms involved. In a follow-up article (Part 2) additional control-related questions will be answered. The answers presented in this article are based upon our own research (as described in e.g. Boerstra, 2016, Hellwig, 2005 & Hellwig, 2015), the work of other researchers and the feedback from participants during workshops at Clima 2013 and Indoor Air 2016 conferences (reported in: Boerstra & Simone, 2013 and Hellwig & Boerstra, 2016).

Q1: What do we mean with personal control?

Personal control means that in the case of suddenly occurring discomfort an occupant has the opportunity to adjust their indoor climate according to his preference and momentary needs. Also in the case of comfort: the knowledge about the opportunity to be able to change the indoor climate if discomfort would occur

gives occupants more confidence in the comfort potential of their workplaces (Hellwig, 2015). Building occupants can exercise control by adjusting their physical environment (e.g. by adjusting a wall thermostat) or by adjusting themselves (e.g. by changing one's clothing insulation). Note that in the context of this article we look at personal control for all aspects affecting heat exchange of the body with the environment as well as control over the air quality in one's breathing zone. The latter implies that also adjustability of local fresh air supply is addressed (e.g. via an operable window).

Q2: Is control over indoor climate really an issue for the modern office worker?

International data, collected using identical methodology are not available. But a study conducted in 2011 and 2012 amongst 236 occupants working in a total of 9 modern office buildings in the Netherlands (Boerstra, 2016) revealed that only 31% of the Dutch respondents was satisfied with the amount of control that they had over their indoor climate. This shows that there is clearly room for improvement. One could argue in this context that maybe not every building occupant wants to be in control over his/her indoor climate at work. The results of a German field study (ProKlimA) contradict that view: this study revealed that 85% of German office workers (in total 4596 respondents) wish to have control over their indoor climate (Bischof et al. 2003).

Q3: What are the main problems with control over indoor climate in existing buildings?

This question was asked during a personal control workshop organized by the authors at the Indoor Air 2016 conference (Hellwig & Boerstra, 2016). One conclusion there was that one can distinguish between problems due to limited control options and problems due to mal-performing building service systems. Both can result in a perception of low personal control. More specific control problems reported by the workshop participants were the lack of openable windows and missing temperature knobs. The lack of information about control devices' functioning and lack of 'intrinsic logic' of interfaces were also reported as prevalent problems. A majority of workshop participants agreed that occupants often do not understand (or are not informed well on) how technical systems work and therefore do not know how to operate them. One example in this context are 'autonomously' operating sun blind systems, activating or deactivating venetian blinds at random (at least in the perception of building occupants).


Photo: J van Berkum

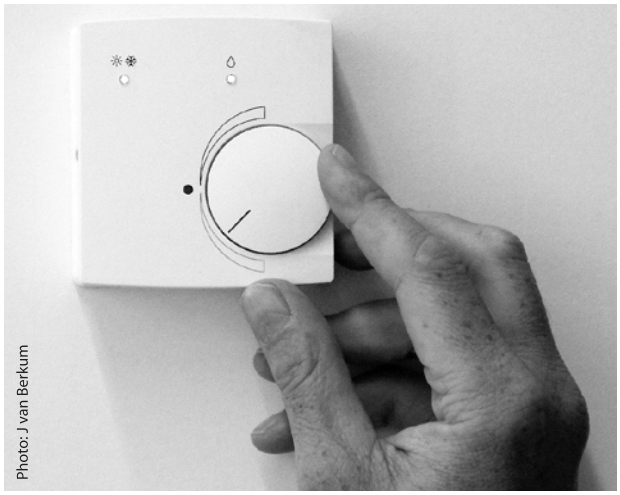
Photo: J van Berkum

Q4: How does control over indoor climate affect comfort and satisfaction in offices?

A number of studies have shown that personal control level is positively associated with wellbeing and occupant satisfaction (e.g. Leaman & Bordass 1999 and Ackerly, Brager & Arens 2012). An analysis of a database that consisted of data from 1612 respondents working in 21 Dutch buildings (Boerstra, 2016) revealed that those with adequate options for control over temperature and fresh air supply were significantly more comfortable. The previously mentioned Dutch field study (also described in Boerstra, 2016) revealed that high control respondents (those that perceive to be more in control over temperature and fresh air supply) are significantly more comfortable (about 1 scale unit on the 7 point scale used) than low control respondents. These results are in line with the outcomes from the EU HOPE study (Roulet et al. 2006). This field study, conducted in a total of 64 office buildings from 8 different European countries, found that a high degree of perceived control was positively associated with occupants' satisfaction with their environment.

Q5: Is there an impact of installation type?

Installation type seems to be a factor of importance. The above mentioned German field study ProKlimA revealed the following: In window ventilated offices with radiators, openable windows and light switch, 87% of the respondents feel they have control over temperature and air movement; meaning their office environment confirms their expectation towards control and hence they express satisfaction (Hellwig 2005). In the same study, offices with sealed facades and central air-conditioning lead to only 7% respondents saying they have control over the air-movement. For them, expectation towards control was not met and therefore they expressed more often dissatisfaction. Personal control and satisfaction with temperature showed a strong significant interrelation. A meta-analysis by Mendell & Smith (1990) too concluded that building related symptoms are more prevalent in buildings without operable windows and with more complicated HVAC systems. Mendell & Smith suggest that the more limited possibilities for personal control in more 'advanced' buildings explain this relation.

Q6: How about the effect of control on Sick Building Symptoms?

A study amongst 4596 German office workers in 14 buildings showed that a high perception of personal control is related to a lower prevalence of the Sick Building symptoms (Bischof et al. 2003). This result is in line with the outcomes of the Dutch database analysis (Boerstra, 2016) described before: the analysis revealed that occupants that perceive to have little or no control over their indoor climate are a factor 2,5 times more likely to have Sick Building symptoms than occupants that report optimal control over temperature and fresh air supply. A field study in 24 Danish office buildings (Toftum, 2010) lead to the conclusion that Sick Building Symptom prevalence was strongly correlated with occupants' satisfaction with control options.

Q7: How does control over indoor climate affect productivity?

Office workers that have access to adequate controls are more productive. Leaman & Bordass (2001) conducted a field study in 11 English office buildings and found that self-assessed productivity was significantly and positively associated with perceptions of control. Wyon (2000) re-analysed data of several lab and field experiments and determined that personal control over room temperature (with a ± 3 K bandwith) impacts objectively measured task performance of office workers positively. Also Boerstra (2016) found that high control occupants estimate themselves to be more productive than low control respondents.

Q8: How about sick leave effects?

The Netherlands database analysis described in Boerstra (2016) indicates that also self-reported sick leave is related to personal control: only 2% of the respondents that said to have access to (effective) operable windows and (effective) adjustable thermostats reported one or more days of sickness absence during the previous 12 months 'due to an adverse indoor climate'; for those that said not to have access to operable windows and not to have access to temperature controls this was 14%. Compare this to Zweers et al. (1992): they found that office workers that indicate to be in control over their indoor climate on average were 34% fewer days sick at home.

Q9: What do we know about the mechanism involved?

The core assumption is that it is not just the objective indoor climate (e.g. momentary temperature or indoor air quality in the breathing zone) that determines whether people feel warm or cold, or are satisfied or dissatisfied with the air quality. Instead, the hypothesis is (Hellwig, 2015 & Boerstra, 2016) that personal control also has an impact and in fact acts as a moderator in the indoor climate > comfort/health/performance relation that is depicted in **Figure 1**. The idea is that human responses to sensory stimuli are modified when those exposed have control over these stimuli (after Brager & de Dear, 1998).

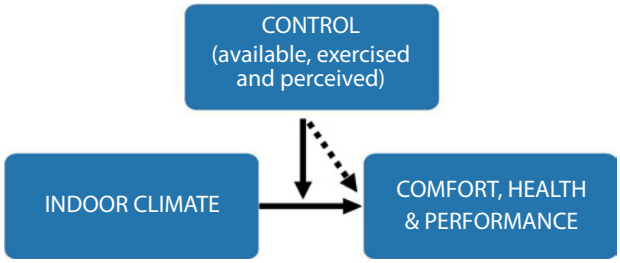

Figure 1. Conceptual model that describes how control acts as a moderator.

Q10: How about the difference between available, exercised and perceived control?

Personal control has been defined as the combination of available, exercised and perceived control as it is available to individual building occupants (Paciuk, 1990). Available control refers to the presence and effectiveness

of building controls like operable windows, adjustable thermostats, fans and blinds. Organisational aspects play a role too: available control is partly defined by e.g. dress codes and bans (if any) on control use. Exercised control refers to the use of controls and the relative frequency with which occupants engage in indoor climate related behaviour in order to regain comfort. Perceived control is defined as the degree to which building occupants perceive that they can change their local indoor climate. It refers to the confidence that individuals have in their ability to effectively influence their environment, in a desired direction (Boerstra, 2016 and Hellwig, 2015). ■

This is the end of part 1. In another issue of REHVA journal, the second and last part will be published. In this 2nd article we will explain more about the psychological factors involved. And we will focus on the design implications of the latest personal control findings. The 2nd article will end with some suggestions for future indoor climate guidelines and some general thoughts on further control studies.

References

Ackerly K, Brager G, Arens E, 2012. Data collection methods for assessing adaptive comfort in mixed-mode buildings and personal comfort systems. University of California. Berkeley: Centre for the Built Environment, Centre for Environmental Design Research. Retrieved from (21.1.2017): http://escholarship.org/uc/item/64p9111k.

Bischof W, Bullinger-Naber M, Kruppa B, Schwab R, Müller BH, 2003. Expositionen und gesundheitliche Beeinträchtigungen in Bürogebäuden – Ergebnisse des ProKlimA-Projektes. (Expositions and impairments of health in office buildings – Results of the Proclaim-project) Fraunhofer IRB Verlag, Stuttgart.

Brager G, de Dear R, 1998. Thermal adaptation in the built environment: a literature review. Energy & Buildings, 27 (1998): 83-96.

Boerstra A, Simone A, 2013. Personal Control Over Heating, Cooling and Ventilation: results of a workshop at Clima 2013 conference. REHVA Journal. 50(5). Available via (21.1.2017) from http://www.rehva.eu/publications-and-resources/rehva-journal/2013/052013/personal-control-over-heating-cooling-and-ventilation-results-of-a-workshop-at-clima-2013-conference.html.

Boerstra AC, 2016. Personal control over indoor climate in offices: impact on comfort, health and productivity. PhD thesis. Eindhoven: Eindhoven University of Technology. Available via: http://repository.tue.nl/850541.

Hellwig, RT, 2005. Thermische Behaglichkeit - Unterschiede zwischen frei und mechanisch belüfteten Gebäuden aus Nutzersicht (Thermal comfort - Natural ventilation versus air-conditioning in office buildings from the occupant's point of view). PhD Thesis, Munich University of Technology, Germany, November 2005.

Hellwig RT, 2015. Perceived control in indoor environments: a conceptual approach. Building Research & Information: 43 (3), 302-315. DOI: 10.1080/09613218.2015.1004150.

Hellwig RT, Boerstra AC, 2016. Workshop ID 37: Incorporating design for high perceived control into the design process. Indoor Air 2016, 3-8 July 2016, Gent, Belgium.

Leaman A & Bordass B, 1999. Productivity in buildings: The 'killer' variables. Building Research and Information, 27(1), 4–19. DOI:10.1080/096132199369615.

Leaman A & Bordass B, 2001. Assessing building performance in use 4: the Probe occupant surveys and their implications. Building Research and Information (2001); 29(2): 129-143.

Mendell MJ & Smith AH, 1990. Consistent pattern of elevated symptoms in air-conditioned office buildings: a re-analysis of epidemiological studies. American Journal of Public Health 80 (10): 1193-1199.

Paciuk M, 1990. Personal Control of the Workspace Environment as Affected by Changing Concepts in Office Design. Proceedings IAPS 11th International Conference. Ankara, July 8-12, 1990.

Roulet CA, Flourentzou F, Foradini F, Bluyssen P, Cox C & Aizlewood C, 2006. Multicriteria analysis of health, comfort and energy efficiency in building. Building Research and Information; 34 (5): 475-482.

Toftum J, 2010. Central automatic control or distributed occupant control for better indoor environmental quality in the future. Building & Environment 2010: 45: 23-26.

Wyon DP, 2000. Individual control at each workplace: the means and the potential benefits. In: Clements-Croome D (ed.), Creating the Productive Workplace. London (UK): E&F Spon 2000: 192-206.

Zweers TL, Preller L, Brunekreef B & Boleij JSM, 1992. Health and Indoor Climate Complaints of 7043 Office Workers in 61 Buildings in the Netherlands. Indoor Air journal; 2 (1): 127-136.