Building and Environment 87 (2015) 315–326

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Comfort and performance impact of personal control over thermal environment in summer: Results from a laboratory study

Atze C. Boerstra [a, b, *], Marije te Kulve [c], Jørn Toftum [d], Marcel G.L.C. Loomans [a], Bjarne W. Olesen [d], Jan L.M. Hensen [a]

[a] Unit Building Physics and Services, Department of the Built Environment, Eindhoven University of Technology, The Netherlands
[b] BBA Indoor Environmental Consultancy, The Hague, The Netherlands
[c] NUTRIM School for Nutrition Toxicology and Metabolism, Department of Health, Medicine and Life Sciences, Maastricht University, The Netherlands
[d] International Centre for Indoor Environment and Energy, Department of Civil Engineering, Technical University of Denmark, Denmark

ARTICLE INFO

Article history:
Received 13 October 2014
Received in revised form
26 December 2014
Accepted 26 December 2014
Available online 28 January 2015

Keywords:
Individual control
Thermal comfort
Fans
Productivity
Environmental psychology
Adaptive opportunities

ABSTRACT

Field studies suggest that the availability of adjustable thermostats, operable windows and other controls has a positive impact on comfort, the incidence of building related symptoms and productivity. This laboratory study was designed to further investigate how having or not having control over the thermal environment affects human responses to the indoor environment.

The study was conducted in summer in a field laboratory that was kept at 28 °C. A total of 23 subjects were exposed twice for about 2.5 h. During the first session (A) subjects were able to fine-tune their local thermal environment at any given time with a personal desk fan with continuous, stepless adjustable control. During the second session (B) subjects still had the desk fans, but this time the fans were controlled from an adjacent room by the researchers who adjusted the individual air speed profiles so they were identical to those recorded during the first session. Thus, each subject was exposed to two customized conditions with identical exposure, only different from a psychological point of view.

During the two sessions identical questionnaires and performance tests were used to evaluate subjects' comfort, SBS symptom incidence and performance. As expected, perceived control over the environment was significantly higher during session A, but there were no differences in perceived comfort and SBS symptom intensity. Both self-assessed and objectively measured performance was significantly better during session B. About two-thirds of the subjects indicated to prefer the situation as during the first session when they themselves controlled the air movement.

1. Introduction

The design of many modern office buildings seems to be based on the assumption that maintaining environmental variables at constant, predefined levels by definition assures comfort and satisfaction of building occupants (Boerstra and Beuker, 2011) [3]; (Boerstra, Loomans and Hensen, 2012) [4]. This assumption implies that people are better off with indoor climates that are centrally controlled within narrow ranges.

But many studies in fact imply that comfort, health and performance are better when occupants are provided with options for control over their indoor climate. For example, Humphreys, Nicol and Raja (2007) [38] and Brager et al. (2004) [35] interpreted field study outcomes and concluded that people are more tolerant of their thermal environment if they can control it. According to Leaman and Bordass (1999) [20] most people are satisfiers not optimizers and want conditions that are 'good enough' while tolerating offsets from the 'ideal' as long as they have adequate opportunities to make indoor climate interventions.

Psychologist Rohles (2007) [37] in this context stated that the ability of the individual to control his or her environment is a rather subtle but important aspect and one that affects our satisfaction with the surroundings to a large extent. Vroon (1990) [30], another psychologist involved in indoor climate research, came to the conclusion that allowing personal control over one's indoor

* Corresponding author. BBA Indoor Environmental Consultancy. P.O. Box 370, NL 2501 CJ The Hague, The Netherlands. Tel.: +31 88 2229494.
E-mail addresses: ab-bba@binnenmilieu.nl (A.C. Boerstra), m.tekulve@maastrichtuniversity.nl (M. Kulve), jt@byg.dtu.dk (J. Toftum), M.G.L.C.Loomans@tue.nl (M.G.L.C. Loomans), bwo@byg.dtu.dk (B.W. Olesen), j.l.m.hensen@bwk.tue.nl (J.L.M. Hensen).

http://dx.doi.org/10.1016/j.buildenv.2014.12.022
0360-1323/

environment is a very effective way to limit the negative health effects of stress (including stress induced by exposure to a suboptimal indoor environment).

In a Danish field study in 9 office buildings (5 mechanically ventilated and 4 naturally ventilated) Hummelgaard et al. (2007) [36] found that summer temperatures were higher in the naturally ventilated buildings. Nevertheless occupants in the naturally ventilated buildings were significantly more satisfied with the thermal environment and their perceived level of control over the indoor climate was higher. These findings were in line with those of Hellwig (2007). Hellwig studied indoor climate perceptions in 16 German office buildings (some of them naturally ventilated and others mechanically ventilated) and found a strong correlation between perceived control over temperature and air movement and the incidence of comfort complaints. This correlation was especially strong in the naturally ventilated buildings, and less so in the mechanically ventilated buildings.

Boerstra et al. (2013a) [5] conducted a reanalysis of the European HOPE database (that is further described in Roulet et al., 2006a [25] and Roulet et al., 2006b [26]) and found that availability of effective controls and high perceived levels of control over the indoor climate were positively correlated with occupant satisfaction. Furthermore, several studies showed that SBS symptom prevalence among occupants in naturally ventilated buildings was lower than in mechanically ventilated buildings (e.g. Burge et al., 1987 & Mendell, 1993). Lack of control opportunities in mechanically ventilated and air-conditioned buildings might be one of the explanations for this (Toftum, 2010) [28]. Jaakkola et al. (1989) [17] in this context came to the conclusion that 'individual control of room temperature in office buildings reduces sick building syndrome'.

Laboratory studies that looked at the impact of personal control on comfort, health and performance are scarce. Schweiker et al. (2012) designed a climate chamber study with one façade connected to the outside. During certain episodes people were exposed to relatively high indoor temperatures (>25 °C) while not being allowed to use available thermal controls (operable windows, ceiling fans, sun blinds). At other moments, they were allowed to use these controls at will. Indoor temperatures were slightly lower when subjects were allowed to use the controls (about 1–2 °C). At the same time comfort scores were much better than when control use was prohibited. And the comfort perception offset was much more than was expected just from the 1–2 °C lowered temperature and the locally elevated air speeds. One of the main conclusions of Schweiker et al. was that neither of the comfort models (the traditional model described in Fanger (1970) [8] nor the adaptive comfort model described in de Dear, Brager & Cooper (1997) [7]) was able to explain the much better comfort scores in situations where behavioral interventions were allowed. This led them to the hypothesis that just the permission to interact with the built environment in itself leads to a higher satisfaction and acceptance of (suboptimal) thermal conditions.

Having or not having access to controls also appears to have productivity effects. Kroner (2000) [19] performed field studies with 'environmentally responsive workstations' that offered a high degree of personal control over the thermal conditions and the local air quality at work station level. Productivity measurements showed that the introduction of personal control at workstation level significantly increased measured task performance. Wyon (2000) [32] estimated the task performance impacts of individual control based on the outcomes of several field and laboratory studies. His conclusion was that the provision of individual temperature control (±3 K adjustability around a group average (PMV = 0) neutral temperature) will increase group average performance, while the quantitative effect depends on the nature of the task. The mean performance improvement related to the provision of temperature control that Wyon found was 5.4%. Performance improvements for specific tasks were: thinking +2.7%, typing +7.0%, skilled work +3.4%, and speed +8.6% (Wyon, 2000) [32].

In line with the results of Kroner (2000) [19] and Wyon (2000) [32] also Fisk & Rosenfeld (1997) [11] came to a general conclusion that it is not just temperature in itself that has an impact on the performance of building occupants, but also the availability of adjustable thermostats and other controls. Zweers et al. (1992) [34] conducted a large field study in Dutch office buildings and found that offering adequate options for occupant control over temperature reduced sick leave days.

Some guidelines (e.g. Rehva, 2006 [24]) state that the provision of personal control options has a beneficiary effect on performance and sick leave. Fanger (2001) [9] even argued for a paradigm shift related to the design of building service systems and stated that the provision of adequate personal control over the thermal environment is a key measure to ensure comfort, health and performance of building occupants.

A drawback of many of the studies described above is that is difficult to unravel effects related to physical and physiological aspects on the one hand and psychological aspects on the other hand (with the study of Schweiker et al. (2012) as the possible exception). Therefore, a laboratory study about personal control was designed. The central idea was to compare comfort, health and performance responses in two situations that were the same from a physical and physiological point of view but different from a psychological point of view.

The objective of the study was to investigate how having or not having control over one's thermal environment (under warm summer conditions) affects end-user responses, in particular perceived comfort, the incidence of SBS symptoms and (self-assessed and objectively measured) task performance.

2. Methods

2.1. Overall research design

A conceptual model that envisions control as a moderator variable was the fundament for the present study.

This conceptual model was derived from the general environmental psychology literature (e.g. Bell et al., 2006 [2]) and interactive models developed by other indoor climate researchers (e.g. Paciuk, 1990 [23]). For a further description of these previously developed models see Boerstra & Beuker (2011) [3]; Boerstra et al., 2012 [4].

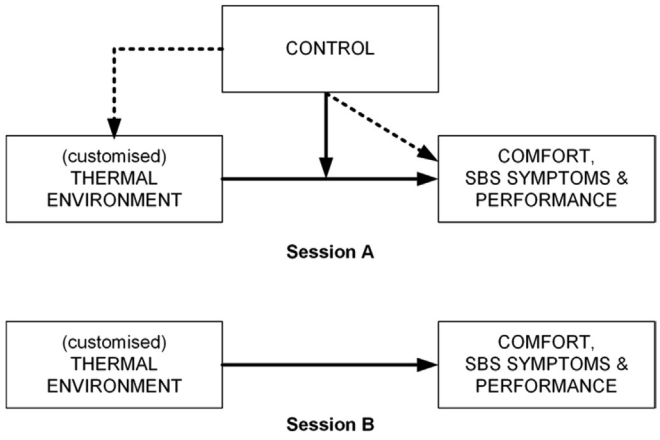

Fig. 1. Schematized research design (with reference to the conceptual 'control as a moderator' model presented in Boerstra et al (2013a) [5].