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Personal control in future thermal comfort standards?

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Abstract

In this article 2 research questions are answered: Why should personal control be included in (future) thermal comfort standards? How could we include personal control in (future) thermal comfort standards?
An abundance of studies show that offering occupants control over their indoor climate results in less health symptoms, higher comfort satisfaction rates and improved performance. Therefore it seems very logical to include the aspect personal control over indoor climate in future (thermal) comfort standards. In this paper a suggestion is presented on how to include the aspect of personal control: see table 2 and 3. The class A requirements imply that building occupants have adequate possibilities for adjustment of the thermal environment at room level. The class A+ requirements imply that occupants have good personal control at workstation level (e.g. with a personal ventilation system). More research and discussion is needed before the proposal is implemented.

Key words

Adaptive thermal comfort, personal control, local climatisation, classification of thermal environment, standardisation.

Introduction

Many thermal comfort standards (e.g. EN-ISO 7730 and EN 15251) classify the thermal environment in 3 (indirectly 4) classes or categories. Varying from A to C (or ‘sub C’). The present classification approach (see table 1) suggests that buildings with tight, centralized temperature control (e.g. with summer temperatures between 23,5 and 25,5 ºC) are perceived as more satisfying than buildings with less tight temperature control (e.g. with summer temperatures between 22 and 27 ºC). While it seems obvious that it is not just the temperature design bandwidth that defines whether building occupants are satisfied. According to Fiala & Thomas (2001) access to environmental controls substantially changes building occupants’ attitudes and therefore alters the acceptability of their environments. Endravan, Thellier & Monchoux (2004) explain that human behaviour should be taken into account when assessing / prescribing thermal indoor environments. Where the 3 main issues to address are: 1. freedom for users to change heat production (change metabolism), 2. freedom to change heat loss (change clothing) and 3. freedom to change the thermal environment itself (use thermostats, use ventilators, open windows etc.)

Table 1: Standard thermal comfort criteria (source: EN-ISO 7730: 2005; example values for standard office work (1,2 met + 0,5 or 1,0 clo)

Category	PPD %	PMV	Operative temperature ºC	
			Summer (cooling season)	Winter (heating season)
A	< 6	- 0,2 < PMV < + 0,2	23,5 – 25,5	21,0 – 23,0
B	< 10	- 0,5 < PMV < + 0,5	23,0 – 26,0	20,0 – 24,0
C	< 15	- 0,7 < PMV < + 0,7	22,0 – 27,0	19,0 – 25,0

In the early 2000's Professor Ole Fanger (personal communication to author) put it as follows: '*Of course 100% satisfaction and a PD (Percentage of Dissatisfied) of 0% is possible, it just means that you have to offer effective personal control right there where people are*'. But then: where is the aspect of personal control in today's thermal comfort standards?

Two central questions will be answered in this paper:
1. Why should personal control be included in (future) thermal comfort standards? (What scientific evidence is there that personal control matters and therefore should be dealt with in guidelines for building and HVAC system design?)
2. How could we include personal control in (future) thermal comfort standards?

Methods

To answer the first research question ('Why should personal control be included in (future) thermal comfort standards?') a literature review was conducted. The review focused on 'landmark studies' of the last 20 years.
The second research question ('How could we include personal control in (future) thermal comfort standards?') was dealt with in a different way. Based on an expert judgment by the author a suggestion is given for a methodology that relates to the layout and contents of present standards and includes the aspect of personal control.

Results: literature review outcome

The literature was reviewed on personal control over indoor climate and its impact on health, general wellbeing, comfort and performance. The outcome of the review is presented below.

Vroon (1990) studied the phenomenon of personal control over indoor climate from a psychology perspective. He concluded that having personal control over one's environment is a very effective way to limit the negative health effects of stress, since once can use external coping strategies. Leyten, Kurvers & Van den Eijnde (2009) state that effective occupant control over the indoor environment increases 'robustness' because it allows occupants to adapt the indoor environment to their specific personal preference and to the temporal variation of their personal preference. They even suggest that within certain limits adequate means for personal control allow occupants to compensate for inadequate functioning of buildings and HVAC systems.

Several field studies looked at the general importance of personal control. 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.

Others researched the comfort impact of personal control. Roulet et al (2006) conducted a field study in office buildings accross Europe. They concluded that building occupants with a higher degree of control over their thermal, visual and acoustical environment are much more satisfied with their environment. This finding is in line with another study that solely looked at the effect of (perceived) control over the visual environment: Vine et al (1998) found that people assess lighting as more comfortable when they have manual control over their visual environment (can turn on and switch off desk lamps etc.). Illustrative in this context is also the study of Huizinga et al (2006). They conducted a field study in over 200 buildings in North America and Finland and found that people with access to a thermostat and/or an operable window were statistically more satisfied with their workplace temperature.

From the early nineties many researchers have looked at thermal indoor environment and indoor air quality and their impact on building occupant performance and productivity. Some of these studies addressed the aspect of personal control. Kroner & Stark-Martin (1992) found an effect of personal control over IEQ on performance. They conducted some field studies with ‘environmentally responsive workstations’ that offer a high degree of personal control over the thermal conditions and local air quality at work station level. They concluded that introducing personal control over the local climate beneficially affected performance. Note that the study also found some positive effects on comfort and health. Studies into the effects of thermal environments show a complex relationship between temperature and mental work performance. It is often assumed that only temperature itself (e.g. during overheating periods in summer) has an effect on performance (see for example REHVA, 2006). However, also having or not having personal control over the temperature in ones microclimate has an effect. Wyon (2000) conducted several field and lab studies on IEQ and performance. One of his conclusions was that in modern office buildings, with their already restricted temperature range, the amount in which the workers can control the temperature in their own rooms is really the most decisive factor for productivity. Wyon’s conclusion is supported by others, for example Clements-Croome (2000). He analyzed several laboratory and field studies and concluded that providing effective temperature control increases the objectively measured productivity by 2 to 3 %.

The overall conclusion is that there are many studies available that show that offering occupants control over their indoor climate results in less health symptoms, higher comfort satisfaction rates and improved performance of building occupants. Therefore it seems very logical to include the aspect personal control over indoor climate in future (thermal) comfort standards. An interesting quote in this context comes from Van Hoof, Mazej and Hensen (2010): '*If each and everyone of us could freely adjust the air temperature and air velocity and his/her activity level or clothing, there would be no thermal discomfort in buildings to begin with…*'

Results: proposal for future standards

In table 2 and 3 a proposal for new thermal comfort criteria is presented. Unlike the present standards, this proposal does deal with the aspect of personal control. The main idea is: a higher quality or a higher category/class means that occupants have more freedom and more options to influence their thermal environment.
Some remarks on the contents of table 2 and 3:

- The values in the table are example values to be used for spaces with office work with a metabolism of 1,2 met and a clothing insulation of 0,5 clo in summer and 1,0 clo in winter.
- A new class/category has been defined; it is labelled 'A+'. This is in line with latest developments with energy label categorisation.
- The values in the second column ('Maximum indoor temperature under summer design situation' and 'Minimum indoor temperature under winter design situation') are based on the upper summer and lower winter limits described in standard EN-ISO 7730. The values describe the minimum performance of building and HVAC system with extreme summer and extreme winter weather. The upper summer limits in column table 2 are placed between parentheses because in some situations adaptation effects might occur which means that higher values can be used.
- The values in the third column ('standard set point summer' and 'standard set point winter') are also based on EN-ISO 7730. In fact these are the 'middle values' (neutral temperatures at which PMV = 0) as described in that standard. The values are the same for all classes and can be used as indication for the basic temperature that should be offered in spaces upon arrival of building occupants. Note that under warmer summer weather in certain situations a bit higher values can be used as set point if one takes adaptation effects into account.
- In the fourth column a description is given of the level of personal control that is offered. The class C requirements imply that building users have no possibilities for personal control. While for example the class A requirements imply that people have good options for personal control at room level. The class A+ requirements imply that occupants have access to personal control devices at workstation level. These are for example personal ventilation systems or radiant panels that are integrated in worktables or workplace partitionings. For summer situations, access to devices that allow for local air speed alteration are regarded as class A+ solutions. This is because in summer not just a lower operative temperature but also a higher air speed changes the heat exchange between the body and its environment.

- The fifth column describes what the temperature and airspeed range is that should be designed for. The values presented are estimates by the author for ranges that offer (at least at class A+ level) about 100% user satisfaction. In other words: if the devices allow building occupants to adjust their operative temperature and air speeds within the ranges that are indicated, not just ‘average people’ will have ‘the right temperature’, but also those that easily are warm or cold (atopic people).

Table 2: Proposal for new SUMMER criteria (example values for standard office work @ 1,2 met + 0,5 clo)

Class (category)	**Maximum indoor temperature (under summer design situation e.g. +30 ℃ outside)**	**Standard set point summer**	**Personal control?**	**Personal control bandwidth**
A+	‘25,5 ℃’	24,5 ℃	Yes, at *workstation* level e.g. with a Personal Ventilation system or table fan	22,5-28,5 ℃ (-2/+4 ℃ around s.p.) OR airspeed adjustable between 0 and 1,5 m/s
A	‘25,5 ℃’	24,5 ℃	Yes, at *room* level with (easy to use) operable windows and/or ceiling fans	22,5-28,5 ℃ (-2/+4 ℃ around s.p.) OR airspeed adjustable between 0 and 1,5 m/s
B	’26 ℃’	24,5 ℃	Yes, at *room* level with operable windows	23,5-27,5 ℃ (-1/+3 ℃ around s.p.) OR airspeed adjustable between 0 and 0,4 m/s
C	’27 ℃’	24,5 ℃	No	-

Table 3: Proposal for new WINTER criteria (example values for standard office work @ 1,2 met + 1,0 clo)

Class (category)	**Minimum indoor temperature (under winter design condition e.g. -10 ˚C outside)**	**Standard set point winter**	**Personal control?**	**Personal control bandwidth**
A+	21 ˚C	22 ˚C	Yes, at *workstation* level e.g. with hand/feet warmers or radiant table top	18-24 ˚C (-4/+2 ˚C around set point)
A	21 ˚C	22 ˚C	Yes, at *room* level e.g. with radiators with thermostatic knobs	18-24 ˚C (-4/+2 ˚C around set point)
B	20 ˚C	22 ˚C	Yes, at *room* level e.g. with radiators with thermostatic knobs	19-23 ˚C (-3/+1 ˚C around set point)
C	19 ˚C	22 ˚C	No	-

Please note that the tables are primarily meant to communicate how personal control could be integrated in future thermal comfort standards. The exact wording within the table and e.g. the temperature levels mentioned of course can be adjusted when new insights tell us to do so.

Discussion

Before we actually change the present thermal comfort standards on the aspect of personal control more research and development is needed. A couple of important questions should be answered first:

- Should we think in terms of classes of buildings or classes of environment? And in this context: how to deal with aspects of personal control (like clothing adjustements and work station layout) that can not be influenced by architects and HVAC system designers?
- Should we develop a new, separate thermal comfort standard specifically for situations with above average access to personal control devices (e.g. to be used in spaces with personal ventilation or local climatisation systems)? Or is it better to include the aspect of personal control in present classification schemes as suggested in table 2 and 3)?
- Are the temperature ranges that are suggested in table 2 and 3 for class A and class A+ temperature control wide enough to allow for 100% user satisfaction (a PPD of 0%)?
- How to address the aspect of clothing insulation changes? Should we include clothing policy freedom in future standards? Or do we assume a standard clothing value (0,5 clo in summer and 1,0 clo) which means that we disregard the fact that in some buildings people will often make clothing adjustments during the day?
- How to integrate the latest (more relaxed) guidelines for summer comfort in ‘free running’ buildings as described for example in EN 15251 (Annex A2) with the approach as presented in this paper?
- What if in summer one can not control operative temperature but one can control air speed (e.g. with table fans or personal ventilation systems)? Will building occupants perceive this also as a class A or A+ solution? What air speed ranges should be used as design value?
- How about the impact on energy use? Does allowing for more personal control over temperature always result in a higher energy bill? Or does it in fact lead to a spectacular decrease in energy use especially when personal control is included in building design and workplace design right from the beginning (as suggested by the study of Zhang et al, 2008)?
- How about personal control over fresh air supply (access to operable windows or for example access to control knobs that influence air supply through a mechanical ventilation system)? Should this be addressed in the thermal comfort standards or should it be addressed in standards that specifically deal with ventilation rates?
- Are low tech solutions like individual operable windows in 1- or 2-person offices perceived as ‘better’ than high tech solutions like personal ventilation systems?
- How about personal control and linked pair effects e.g. between thermal comfort and noise? For example when lowering the operative temperature leads to higher installation noise levels. How to address that in (future) standards?
- How should (good) personal control be described more in detail? Should some guidance be given in future standards on how quick personal control devices should

respond? For example: how much time do we allow for the operative temperature to be at the new, desired level after thermostat settings are changed?

- And how about the ergonomics of devices for personal control? What are the requirements for good, easy to understand control devices? When are control devices too complicated (and therefore counter-effective)? And should we describe those requirements as an integral part of the (future) standards? Or should other standards address this issue?

Questions like these have to be answered before a final version of an integral thermal comfort standard that addresses personal control can be introduced.

Conclusion

Many studies show that offering occupants control over their indoor climate results in less health symptoms, higher comfort satisfaction rates and improved performance. Therefore it seems very logical to include the aspect personal control over indoor climate in future (thermal) comfort standards. In this paper a suggestion is presented on how to include the aspect of personal control in future thermal comfort standards: see table 2 and 3.
More research and discussion is needed before the proposal is implemented.

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