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User problems with individual temperature control in offices

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Abstract

Individual thermal control is important for handling personal differences in thermal preference. Several studies have shown that comfort, health and productivity in offices can be improved by individual thermal control. Local controls for temperature are commonly available in modern office buildings. However, office occupants are often still dissatisfied with the thermal environment and their control options. In this study we used contextual techniques to gain an understanding of the user problems with individual temperature control. A total of 27 office occupants in 13 Finnish buildings were interviewed in their offices. They were asked to show and tell us how they use the controls. The results show that the temperature controls were often not used in thermal discomfort. A diversity of problems with individual temperature control was identified and are listed with proposed solutions. The main reason for the many of the problems is that systems are planned and constructed without a realistic view of their users, and end users are presumed to have knowledge they don't have. The users should be studied and more effort should be put into user interface development.

Keywords: Thermal comfort; Individual control; Office; User interface; Usability; Thermostat

1. Introduction

According to a well-known study by Fanger [1], there are individual differences in experiencing thermal environments and no thermal environment can satisfy everybody. Nowadays the need for individual control of thermal environments is widely recognised. It is agreed that individual control of local thermal environments is needed from the standpoint of comfort and satisfaction [2]. Also Fanger [3] suggests individual thermal control for handling personal differences in thermal preference.

In addition to comfort, health and productivity reasons also support individual thermal control. It is generally agreed that improving the indoor environment increases productivity [4–9]. Individual control of room temperature is one of the central issues in improving working conditions and productivity [8–12]. It has also been found that individual control of room temperature in office buildings reduces sick building syndrome (SBS) symptoms [13] and sick leave days [14].

Local temperature controls are often available in modern offices. Every radiator or convector typically has a valve with which the user can adjust the room air temperature set point or water flow. Room thermostats are also common. For examples of temperature controls, see Fig. 1.

Thermal environments are often unsatisfactory, and several studies (Table 1) have shown that the perceived level of control is low. It is easy to suppose that giving people local temperature controls will improve thermal comfort. However, a survey of nine office buildings showed that thermal comfort was no better in the buildings equipped with room thermostats than in the buildings with more limited possibilities for temperature control [17]. The individual temperature control seemed not to fulfil the expectations. The reasons why the individual temperature control did not succeed remained unclear, although it was noted that room thermostats were often installed so high up on the wall that they could not be reached easily.

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The available information on usability problems of temperature controls is scattered and mostly concerns residential buildings. In one case the interface was so obscure that the control options were not understandable by most of the users [18]. If the interface lacks informative feedback, it is difficult to determine what actions are possible [19]. Problems with the terminology of temperature controls have also been recognised [20]. Kempton et al. [21] found that many air-conditioning users were not aware their units had thermostats.

This study concentrates on actual use of temperature controls in office rooms. We are interested in how people act regarding thermal discomfort and what kind of problems they have with room thermostats and thermostatic valves. Solutions for the problems discovered are suggested.

2. Method and material

2.1. Method

The main method in this study was interviews with office occupants. The interviews were performed in actual context, in the interviewees' offices. The main purposes of the interviews were to understand the ways of using the controls and, more widely, how people act when they feel cold or hot, and to discover the problems users have with the controls. These issues were discussed widely with open-ended questions. A pilot interview was prepared, and the questions in the final interview were slightly modified after the experiences from the pilot.

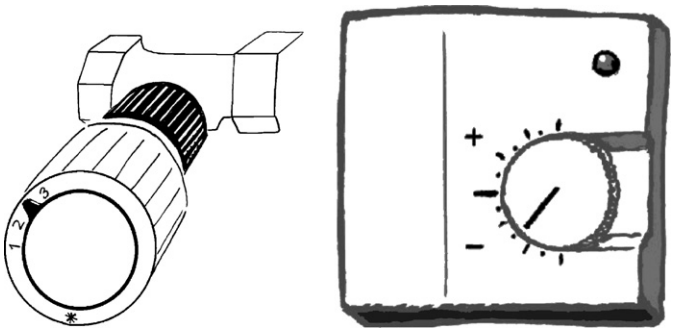

Fig. 1. Examples of temperature controls: a thermostatic valve (left) and a room thermostat.

An important part of the interviews was observation. We were interested in office environments as a whole, but especially the temperature controls and other controls the interviewees have for adjusting indoor environment. We asked them to show and tell us how they use the temperature controls. The research method was similar to contextual inquiry [22].

A total of 27 interviews were carried out. In the first part of the study we interviewed twelve persons (K1–12 in Table 2). The results were analysed before the second part of the study, in which fifteen persons (A1–5, B1–5, C1–5) were interviewed. The length of each interview averaged one and a half hours in the first part of the study. In the second part we concentrated on the main questions and the length of each interview was about half an hour. All interviews were taped and the first twelve interviews were transcribed.

All the interviews were conducted in Finland, the first part in February and March 2004, when the outdoor daytime temperature varied between −20 and +5 °C, and the second part in October 2004, when it was warmer, about +10 °C in the daytime. Although the interviews were carried out in winter and autumn, we asked also questions concerning the summer period.

2.2. Interviewees

We primarily interviewed people who work alone in an office, not in a shared working space, because they do not have to accommodate the thermal needs of others; 25 of the 27 interviewees work alone in an office. Two of them, K3 and C5 in Table 2, do not always work alone.

The interviewees were between 23 and 57 years of age. Fourteen women and thirteen men were interviewed. The educational level of the interviewees is high, which is typical for Finnish office workers. About half of the people have a university degree. Most of interviewees do typical office work with a computer. A dentist (K5) was an exception; she treats patients but also does office work. She has two rooms, one for patient work and one for office work, but only the office room is considered in this study.

Table 1
Satisfaction with room temperature control among office occupants

Respondents	Result	Refs.
Office occupants in Britain. 11 buildings	On a scale of 1 (low) – 7 (high), an average value of about 2 was given to the perceived level of control of room temperature	[15]
Office occupants in USA and Canada. 1829 respondents	Tenant control of temperature is important for 96% of respondents, but only 65% are satisfied	[16]
Office occupants in new Finnish offices. More than 500 respondents	On a scale of 4 (low) – 10 (high), an average value of 6.5 was given to the perceived level of control of room temperature and ventilation	[17]

Table 2
Interviewees

Person	Gender	Age	Occupation	Time worked in the building/room	Average part of working hours spent in own room (%)
K1	Female	54	Study advisor	5 years/2.5 years	75
K2	Male	52	Researcher	12 years/12 years	75
K3	Male	25	Researcher	2.5 years/2.5 years	50
K4	Female	45	Researcher	4 months/4 months	85
K5	Female	56	Dentist	>10 years/>10 years	30
K6	Female	28	Janitor/cleaner	4 years/4 years	70
K7	Male	36	Managing editor	4 years/2 years	10
K8	Female	25	Project co-ordinator	5 months/5 months	90
K9	Female	23	Office secretary	4 years/3.5 years	75
K10	Male	53	News editor	3 years/3 years	65
K11	Male	47	Development manager	5 years/5 years	80
K12	Male	49	Communications manager	14 years/3 months	75
A1	Female	28	Social worker	6 months/1.5 months	80
A2	Female	39	Social worker	2 years/2 years	80
A3	Female	33	Social worker	2 years/2 years	75
A4	Female	50	Social worker	2 years/2 years	35
A5	Female	43	Leading social worker	2 years/9 months	90
B1	Female	24	Accountant	3 months/3 months	90
B2	Female	47	Assistant accountant	3 months/3 months	90
B3	Male	57	Transportation chief	2 months/2 months	75
B4	Male	36	Financial manager	2 months/2 months	75
B5	Male	56	Cost accountant	2 months/2 months	95
C1	Male	31	System specialist	2 years/6 months	70
C2	Male	57	Group leader	2.5 years/2.5 years	60
C3	Male	32	Innovation consultant	7 months/6 months	60
C4	Female	27	Planner	4 months/4 months	75
C5	Male	40	IT developer	8 months/8 months	75

Most of interviewees spend at least half of their working hours in their own room. The interviewees had been working in their present rooms from 1.5 months to more than ten years, so not all of them have experienced winter and summer conditions. Further details regarding the interviewees are shown in Table 2.

2.3. Buildings and individual temperature controls

The interviewees work in the Helsinki area in total of thirteen commercial and governmental buildings. The first twelve interviews were conducted in ten buildings; only interviewees K1 & K9 and K4 & K8 have a room in the same building. The latter fifteen interviews were conducted in three buildings (A, B, and C); five people were interviewed in each of them.

The buildings are of different ages, but mostly new. Most interviewees work in high-quality office buildings that have been built within the past four years. These new buildings can be considered to represent the best current practice.

All the buildings are mechanically ventilated and heated by water radiators. In most of the buildings there is a cooling system in addition to heating. There are different kinds of cooling systems in the buildings: cooled beams, fan convectors, and centralised cooling of incoming air. A cooling system is only missing in the buildings of interviewees K2, K6, and K10.

The purpose of this work was not to study the systems and compare them but to understand the ways of using the controls, so the building services were generally not studied closely. We were mainly interested in the user controls the office occupants have for their personal use.

Out of 27 interviewees, 25 have a possibility to control room air temperature with a room thermostat or a thermostatic valve. In addition to thermostats, many of the interviewees have a ventilation window with which they can control their thermal environment. Closer details of the temperature controls and openable windows are shown in Table 3.

3. Thermal comfort and use of controls

3.1. Grouping of users

The interviewees were asked several questions about their thermal comfort and use of controls. The results were analysed and the users were divided into seven groups, as shown in Table 4. Seven people out of 27 are satisfied with their thermal environment, ten are mostly satisfied, and the remaining ten people are dissatisfied. In all of the three

Table 3
Temperature controls and openable windows in offices

Person	Room thermostat[a]	Radiator with adjustable thermostatic valve	Openable window or ventilation window
K1	Type A	Yes	Yes
K2	No	Yes	Yes
K3	Type A	No	No
K4	Type B	Yes (3 valves)	Yes
K5	No	Yes	Yes
K6	No	No	No
K7	Type B	Yes	No
K8	Type B	Yes (2 valves)	Yes
K9	Type A	Yes	Yes
K10	No	Yes	Yes
K11	Type C	No	Yes (only to roofed patio)
K12	Type A	No	Yes
A1	Type D	Yes	No
A2	Type D	Yes	No
A3	Type D	Yes	No
A4	Type D	Yes	No
A5	Type D	Yes	No
B1	Type E	No	No
B2	Type E, but it was not working	No	No
B3	Type E	No	No
B4	Type E	No	No
B5	Type E	No	No
C1	Type B	No	No
C2	Type B	No	No
C3	Type B	No	Yes
C4	Type B	No	Yes
C5	Type B	No	Yes

[a]Type A is shown in Fig. 1. To increase room temperature the dial should be turned upwards (+) and to decrease, downwards (–). The light symbol in the upper right corner is green when the room temperature is increasing and red when it is decreasing. In type B the temperature dial is coloured with red and blue, which refer to warmer and colder. In this thermostat there are texts "comfort", "economy" and "off", and a light symbol that denotes the active mode. The mode cannot be chosen by the user. Type C has a similar temperature dial to type A, and, additionally, a dial to control the fan speed of the fan convector. Type D has a similar temperature dial to type B, and a dial to control the fan speed of the fan convector. Type E has two push buttons, one for increasing and one for decreasing temperature. It has a line of lights for indicating the user's choice.

Table 4
Thermal comfort and use of temperature controls

Group	Thermal comfort	Use of individual temperature controls	Several buildings	Building A	Building B	Building C
1	Satisfied	Does not use	K7, K12		B3	
2		Uses	K11, K4[a]	A3, A5		
3	Mostly satisfied (temporal or small problems)	Does not use	K2, K3, K5, K10		B5, B4	C3, C5
4		Uses			B1	C2
5	Dissatisfied (feels cold or hot continuously or has major problems)	Does not have	K6		B2	
6		Does not use or is not able to use effectively	K1, K8	A4		
7		Uses	K9	A1, A2		C1, C4

[a]K4 had felt cold for a long time, but has recently started to use the controls and is now satisfied with the thermal environment.

groups there are people who do use the individual temperature controls and people who do not use them. In buildings A, B and C there are people who are satisfied and people who are dissatisfied with the thermal environment.

Out of 27, 25 users have individual temperature controls available (Table 3), but only eleven people have used them successfully. The people in group 1 (Table 4) are satisfied with their thermal environment and do not use

Table 5
Problems in different groups

Group	Thermal comfort	Use of individual temperature controls	Typical problem
1	Satisfied	Does not use	—
2		Uses	—
3	Mostly satisfied (temporal or small problems)	Does not use	User interface
4		Uses	System: not enough heating or cooling power available, fluctuating temperature or other problem with control system
5	Dissatisfied (feels cold or hot continuously or has major problems)	Does not have	No individual temperature control
6		Does not use or is not able to use effectively	User interface
7		Uses	System: not enough heating or cooling power available, fluctuating temperature or other problem with control system

Table 6
Actions taken by interviewees when feeling hot or cold. Actions in brackets are secondary; they will only be taken when feeling very hot or very cold

Action	Actions when feeling hot	Actions when feeling cold
Adjusts clothing	K1, K2, K7, K10, K11, A2, A3, B3, C2	K2, K4, K5, K6, (K10), K11, A1, A2, A4, B2, B5, C1, C4
Opens window	K1, K2, K5, K8, K9, K10, K11, K12	K4 (during cooling period)
Opens door to corridor	K1, K2, K11, A3, C1	
Uses temperature control (or checks the setting)	K9, A1, A2, A3, A4, A5, B1, C1, C2	K4, K5, (K11), A1, A2, A5, B1, C1, C4
Contacts building service personnel or management	(K12), (B4), (C3)	(K3), (K10), K12, A4, B3, (B4)
Takes a walk	K6, C5	K6
Gets a hot drink		K8, C4
Other	K3 (goes somewhere else to work)	K9 (warms fingers by sitting on them), C4 (uses additional heater she has brought)

controls—the automatic control seems to fulfil their needs. It is noteworthy that they are all males, and almost all of the non-users that are mostly satisfied with their thermal environment (group 1) are male.

The controls are not (successfully) used by group 6, although the people in this group are generally dissatisfied with their thermal environment. Group 3, the biggest group in Table 4, consists of people who do not use the controls but do have temporal or small problems with thermal environment.

The people in group 7 use the controls but are still dissatisfied with their thermal environment. It seems there are different kinds of problems to be solved. There are problems with the user interface and with the system itself, see Table 5.

The significance of user controls of temperature for thermal comfort is low. The only persons who profit or may profit from user controls belong to groups 2 and 4.

3.2. Actions in discomfort

The interviewees were asked how they act when they feel hot or cold in an office. The most typical action is to dress less or more, if the dress code allows that. If the windows can be opened, they are commonly opened to reduce the room temperature. The temperature controls are used in building A in particular.

It is typical that thermal discomfort leads to a multitude of actions. On the other hand, K7 and C5 reported that they do not do anything if they feel cold, they just tolerate it. Some people actively inform the building service personnel or management about discomfort. Personal fans are not common in Finnish offices, and none of our interviewees reported using one. The results are shown in more detail in Table 6.

4. User problems with temperature controls

As shown earlier in this paper, most of the people do not use the room thermostats and thermostatic valves they have in their rooms, and the significance of individual temperature control on thermal comfort is low. The reasons behind this lack of use were studied by interviewing the users and by examining the temperature controls with them. The problems detected are shown in Table 7, with suggested solutions.

Table 7
Problems with temperature controls and proposed solutions

Description of problem (persons[a])	Solution
It is not known that there is an adjustable thermostatic valve in a room (K4, K7, K9, K10) Thermostatic valve is located behind furniture so that it is impossible or awkward to use it (K1, K2, K5, K7, K9) Room thermostat is located too high on the wall or behind furniture so that it is impossible or awkward to use it (K12, B1, B2, B3, B4, B5, C2, C3, C4, C5) Temperature control is located behind a panel so that it is not found (K11)	Temperature controls should be installed so as to be clearly visible and easily reachable
The purpose of the room thermostat remains unclear. It is not recognised as being for temperature control (K3, B3, C5)	Temperature controls should be designed to take account of the conventions. For example, symbols that refer to temperature (degrees, red and blue denoting hot and cold, or thermometer) are recommended. Secondly, text can be used to describe the purpose of the equipment
It is not known that the room thermostat is for control of the heating or cooling system, or for both of them (Common problem) If there is both a room thermostat and a thermostatic valve in a room, the room thermostat is considered to be the only one (K4, K7, K9)	There should be only one temperature control in every office and it should adjust both heating and cooling
Does not dare to touch the temperature control because it is thought to be for service personnel only (K1, K5, K8, B2) Does not dare to touch the room thermostat because its effect is not known (K12)	After moving to a new office, users should be advised on the use of the controls and the effect controls give
Room thermostat does not give any feedback, or the feedback is not understood by users (K1, K3, K4, K7, K8, K9, A4, C2, C4) The meaning of lights and symbols in the room thermostat are misunderstood (K1, K3, K4, K7, K8, K9, A1, A4, C5)	The user interface should be tested with users in the product development phase to ensure usability The temperature control should give the user instant feedback after a control action, and inform the user that the system is working to fulfil the request.
The thermostatic valve is stiff and the user does not have enough physical power to turn it (K1) The dial in the room thermostat which is to be turned to set the temperature is not found (K7)	The temperature control should clearly indicate if it is not currently in use
Users don't know how much the dial should be turned to get the desired effect on room temperature (Common problem)	There is no easy solution. Further work is needed to study user preferences for different kinds of temperature scales, and other relevant issues

[a]The list of persons in brackets does not necessarily include all people with the specific problem because the temperature controls located too high on the wall or behind furniture could not be studied closely.

The problems with the user controls were found to be fundamental and diverse. Office occupants do not always know they have individual temperature control in a room, because the equipment is not recognised at all or the purpose of the equipment is unclear. If the temperature controls are inappropriately located, they are not always found, and they are impossible or awkward to use. Users may think that they are for service personnel only.

There are also problems with the use of temperature controls. It is not always known if the temperature control is operating or not. Although the room thermostats our interviewees have in their rooms are simple, the lights and other symbols in the user interface were often not understood correctly. None of those who have a room thermostat of type A or B correctly understood the meaning of the light symbols.

Because of the thermal inertia of the building materials and the heating (or cooling) system itself, the rate of room temperature change is slow. Users are not satisfied with the feedback they get from their control actions because they do not know whether the system is working to fulfil the request. Users also found that it is not easy to know how much to turn the dial to get the desired effect. The user controls of temperature were blameless in none of the buildings.

In building A the temperature controls were used more widely than in other buildings. Several reasons for that were recognised: (1) the room thermostats are big and located so that they are easily reachable, (2) the purpose of equipment is clear as the red and blue colours in the thermostat are understood to refer to temperature, (3) the control actions are followed by instant feedback as the fan convector starts to make a noise, (4) users have shared their knowledge about the room thermostat, and (5) the windows are not openable. However, three users out of five were dissatisfied with the thermal comfort in this building (Table 4). The discomfort partly results from not understanding the system. All users did not understand

that the room thermostat only affects the fan convector, which is part of the cooling system. It was thought that the fan convector also produces heat and blows fresh air, even though it just cools and circulates air. It was not understood that the heating and ventilation systems are separate from the cooling system in this building.

We asked the interviewees to describe their knowledge of the heating, cooling, and ventilation systems of the buildings they work in. Most of them reported very low knowledge. Discussions with them confirmed that knowledge of HVAC systems in office buildings is very low among office occupants. Users know that the radiators are full of water and emit heat, and the air terminal devices are part of the ventilation system, but otherwise their knowledge is very restricted. Only two of our interviewees (K2, C2) are more familiar with HVAC systems.

5. Discussion

User problems with temperature controls were identified in this field study by interviews and observation. By this research method we could gather data that revealed many reasons for the lack of use of temperature controls. The problems users have with temperature controls are numerous.

The current solutions for individual temperature control show that the systems are planned and constructed without a realistic view of their users. To control room temperature effectively and energy efficiently a user must (1) find the equipment for temperature control and understand its purpose, (2) know that the equipment is for the end user and not for service personnel, (3) become acquainted with the user interface, and (4) know the effect of the user control. The first two are very basic requirements, but often are not met (Table 7). The third requirement was also often not met, although the user interfaces were quite simple in the buildings studied compared with those we have seen elsewhere. To fulfil the fourth requirement the user must know whether the user control affects heating or cooling, and whether is the system currently active. This is not an easy task, even for an HVAC expert, because the systems give limited feedback on their operation. It is frequently the case that a user adjusts a system that is not currently active and gets frustrated when the thermal environment does not improve.

User problems with individual thermal control lead to thermal dissatisfaction, and also waste heating and cooling energy. If a user has separate controls for the cooling and heating system, it will easily lead to a situation where a room is cooled and heated at the same time. It is also common that windows are opened to cool room air during the heating period, although the most appropriate action would be to reduce the heating.

Wyon [11] has created a 3I-principle of user empowerment. This says that the user must be given Insight, Information, and Influence. Delegation of control means that user must understand the way building works and the consequences of actions (Insight), and to learn to use the control with help of feedback (Information). When the user has insight and information, they can be given individual choice (Influence). All the three Is must be provided.

The results of this study reveal remarkable problems in fulfilling Wyon's three Is. Interviews and observation showed that most of the users do not have enough insight and information. What should be done then? Three different strategies could be suggested to improve the situation: (1) individual temperature controls should not be provided for office occupants because they are not able to use them appropriately, (2) building systems and user controls should be extensively taught to office occupants, and (3) more effort should be taken in user interface development. Individual control of room temperature has been proved to have such advantages (see the introduction to this paper) that the alternative 1 is not an option. User training (alternative 2) is recommended but it is unrealistic to suppose that office occupants would be motivated to spend much of their valuable time on learning the way in which building works. User training is not the main solution for the problems.

Without doubt, the most efficient way to solve the problems is to put effort into user interface development and implementation of user controls in buildings. The proposed solutions for the problems of user temperature controls are shown in Table 7.

There is still a need for user studies. User needs, motivation, knowledge and ways of acting must be understood. The goal should be that user interfaces can be used by office occupants with effectiveness and satisfaction.

The study was carried out in Finland. It is clear that climate, HVAC systems and culture have an influence on the problems users have with individual temperature control, but the results are not specific for Finland alone. A literature survey (see the introduction to this paper) showed similarities with other developed countries. The user temperature controls are also basically similar. In addition, to our knowledge, we share the need for user studies.

6. Conclusion

The success of individual temperature control depends on the user controls, the heating and cooling system and the control strategy. In this study we concentrated on user controls. The problems with user controls were found to be fundamental and diverse. Room thermostats and thermostatic valves in offices are often not used at all by office occupants, and the significance of individual temperature control on thermal comfort is low. It is often not known that there is individual temperature control in a room. Lights and other symbols in the user interface are often not understood correctly, and it is not always known whether the temperature control is operating or not. In general, users are not satisfied with the feedback they get from the systems. Room thermostats were not found to be well designed in any of the buildings we studied.

Temperature controls should be installed so as to be clearly visible and easily reachable. There should only be one user control for temperature in every office and it should adjust both heating and cooling, if both systems exist. After moving to a new office, users should be advised on the use of the controls and the effect the controls give. The temperature control should clearly indicate whether it is currently in use or not, and give instant feedback after a user control action so that the user knows the system is working to fulfil the request (the rate of temperature change is slow because of the thermal inertia).

The main reason for the many of the problems is that the systems are planned and constructed without a realistic view of their users, and end users are supposed to have knowledge they don't have. Users should be studied and efforts should be taken in user interface development.

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