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Personal heating; energy use and effectiveness

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Abstract

Increasing personal comfort by heating office building occupants locally means that the lower setpoint for space heating. Less energy will be used when the total energy demand from all individual comfort systems together is lower than the energy saved by lowering the setpoint. The energy saving potential is dependent on the specific characteristics of the individual heating. The important performance characteristics are the energy used per unit of mitigated discomfort and the maximum discomfort that can be compensated for. A pilot study was conducted to investigate these performance indicators. Three methods for locally heating the hands were compared on effectiveness and energy use. The methods were a heated desk mat and two types of IR radiation lamps, all heating the hands. All were found to be effective, however, there was a clear difference in speed for compensating discomfort.

Keywords: personal comfort, thermal comfort, individual heating

1 Introduction

Comfort of all occupants in an office building can be improved using a small climate system at each desk that is able to heat or cool the individual occupant working there. Applying such a system has the potential to reduce the energy consumption of the whole building as well. Since an extra level of climate system is added, energy reduction is not a given.

In this paper, a strategy is presented that can be used to determine the energy saving potential of an Individual Comfort Systems (ICS) providing local heating, applied in a normal office building. A set of criteria can be formulated and performance indicators can be defined. That provides a guideline for the design of new ICSs and for the evaluation of these systems.

An ICS for heating consists of one or several small heaters that can heat specific parts of the body. That is enough to compensate for whole body discomfort and increase their overall thermal sensation (TS) (Watanabe, Melikov, & Knudsen, 2010). With the application of an ICS for all workplaces in an office building, the use of the central climate control system is partly replaced. When comfort can be provided for every person in the room individually, it provides each individual with influence on their environment and individual differences in preferences can be solved.

Earlier studies, (Boerstra, 2010) for example, have shown that the tolerance for environmental conditions in a room is strongly related to the amount of people in the room and the influence a person perceives to have on the environment. From a comfort perspective, applying an ICS is an improvement, however, adding an extra layer of system in a building could lead to extra energy use.

Using ICSs has to potential to reduce energy consumption. This is due to the following characteristics. The fact that the energy is used close to the person, so it affects a small area of the office, that the system is only used if someone is present and when this person is feeling uncomfortable.

The performance characteristics of an ICS determine the energy saving potential. The performance of an ICS is measured in the energy that is needed for the mitigation of a certain level of discomfort. An ICS has a limit in the level of discomfort that can be compensated for, because only parts of the body are heated. A large difference in temperature between body parts is also considered uncomfortable.

Methodology

Energy consumption can be reduced when the discomfort introduced by lowering the set point for heating can be compensated for by the ICSs more efficiently. As shown in formula (1), the energy use at the high set point of central heating (CH) should be higher than the energy use at lower set point plus the energy use of all ICSs that are turned on. The new set point of the central heating is highly dependent on the characteristics of the building itself, the climate system, the amount and density of the occupants and the performance characteristic of the ICS

$$E_{CH\ high\ setpoint} \geq E_{CH\ low\ setpoint} + \sum E_{ICS} \quad (1)$$

The strategy for finding the energy reduction potential of an ICS in a specific building starts with finding the ideal set point for the CH. Therefore, the energy use of the building is determined. The thermostat setting is connected to the room temperatures, than the Predicted Mean Vote (PMV) can be calculated. The Actual Mean Vote (AMV) can also be determined through questionnaires. The typical energy use of the CH is calculated from the measured energy use over a year and the degree days of the same year. This way, the energy reduction of lowering the thermostat setting can be calculated. The reduction of the PMV is to be determined as well.

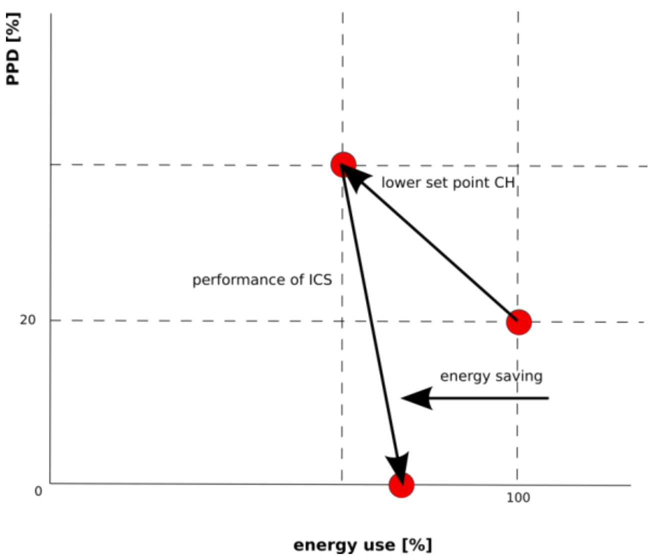

Figure 1: Strategy for reducing energy consumption and increasing comfort level in an office building: first lower setpoint of thermostat, reducing comfort level, then introduce ICS

The other factors determining the energy reduction potential are the performance characteristics of the ICS and the translation of the performance of one ICS to a whole building of ICSs. Lowering thermostat setting means reduction in PMV for the whole building and increase of

Predicted Percentage Dissatisfied (PPD). The PPD can be used as a measure for the number of people that turn on their ICS. The setting is harder to estimate, one only knows that there will be people who are dissatisfied, we don't yet know how much.

On an individual level, one can expect a dissatisfied person to turn on the ICS. The system will remain turned off for people that are not dissatisfied. The PMV/PPD relation shows that even with a PMV = 0, 5% of the building occupants can be expected to be dissatisfied with the local climatic conditions (Fanger, 1970). This means that in a neutral environment, one can expect that 2,5% of the people are too cold and have the ICS turned on.

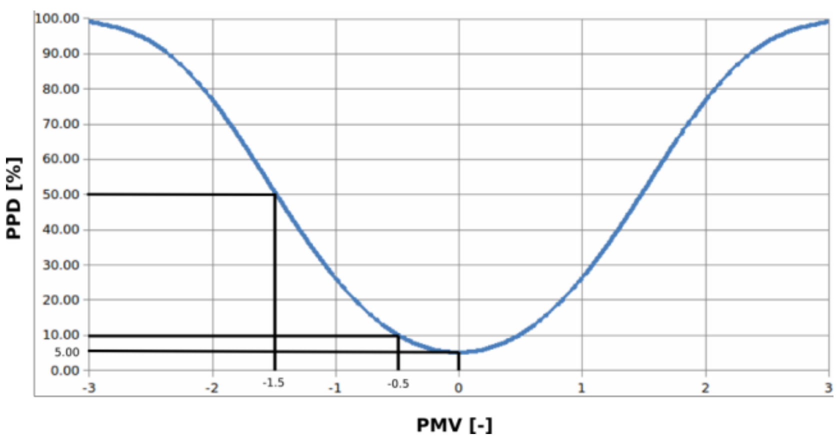

Figure 2: PMV/PPD curve, the PPD at PMV = 0 is still 5%, the PPD in a well-acclimatized building is between 5% and 10%. Experiments are conducted at PMV = 1.5 with expected PPD of 50% (Fanger, 1970)

A pilot study is done for determination of the performance and energy saving potential of several different parts of an ICS. For this pilot, four subjects were tested in the climate room. The room was set at a constant 18^{o}C (PMV = -1.5, PPD = 50% at 1.0 clo). Three different methods of local heating of the hands were compared. The three methods for heating were: contact heating by heating the desk (heating the hands from below), and heating the hands from above using two different IR lamps, one with a visible red glow and the other one with a ceramic housing that only emits heat in the invisible IR spectrum.

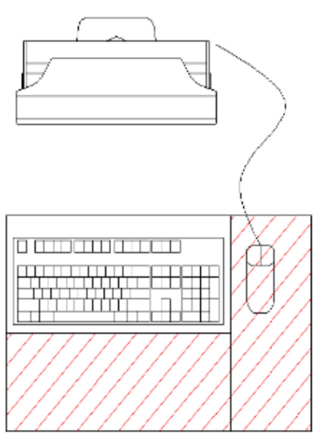

Figure 3: lay out of the heating panels around the keyboard of the computer

Figure 4: Two types of IR lamps used in the pilot experiment, White IR on the left, red IR on the right Table 1: Power of the heaters used in the pilot experiments

	Heater	Power
1	2 Desk heating panels	2x 12 W
2	2 IR heating red light (red IR)	2x 100 W
3	2 IR heating lamp (white IR)	2x 60 W

The tests lasted until all three heaters were tested. The test subjects were acclimatized to the cold, before each test. When people were reporting that they had reached a thermal sensation of -1.5, a hand heater was started. When the subject reported that he or she was neutral or comfortable again, the heater was turned off and the subject was left to cool again. This procedure was repeated for all heaters.

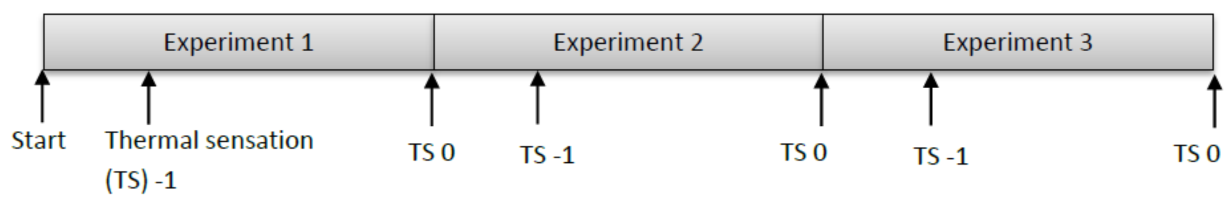

Figure 5: Experimental set up, timing is based on the thermal sensation of the test subjects.

During the test, the subjects wore 7 iButtons to measure the skin temperature. The iButtons were placed on the finger, wrist and lower arm, both left and right and one in the neck. A thermal camera is used to monitor the finger temperature. This way, the use of thermal images to determine comfort level based on fingertip temperature can be tested as well.

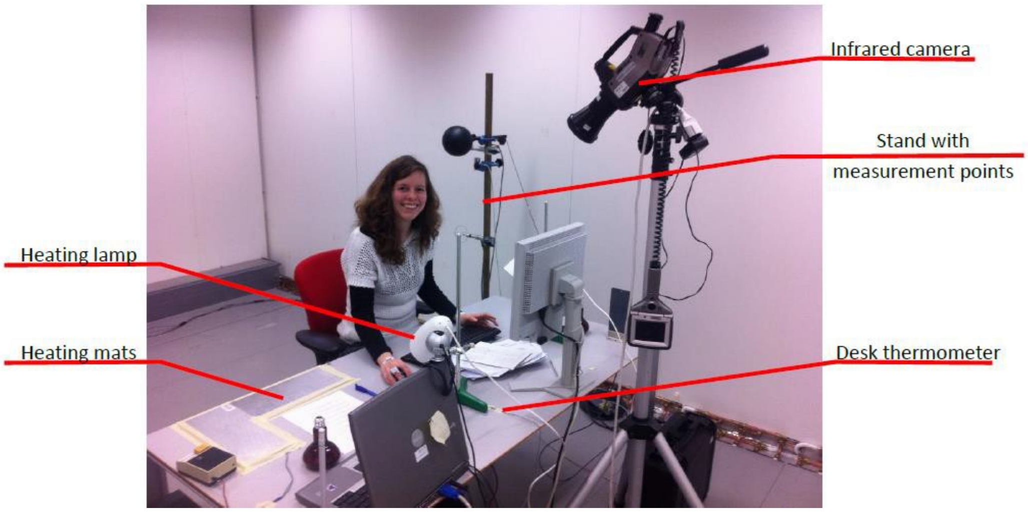

Figure 6: test set up in the climate chamber

Results

We have found that it is possible to increase the overall TS of an individual person using a local heating of the hands. All hand heaters managed to mitigate the discomfort within a relatively short time. The average recovery times are shown in Figure 7.

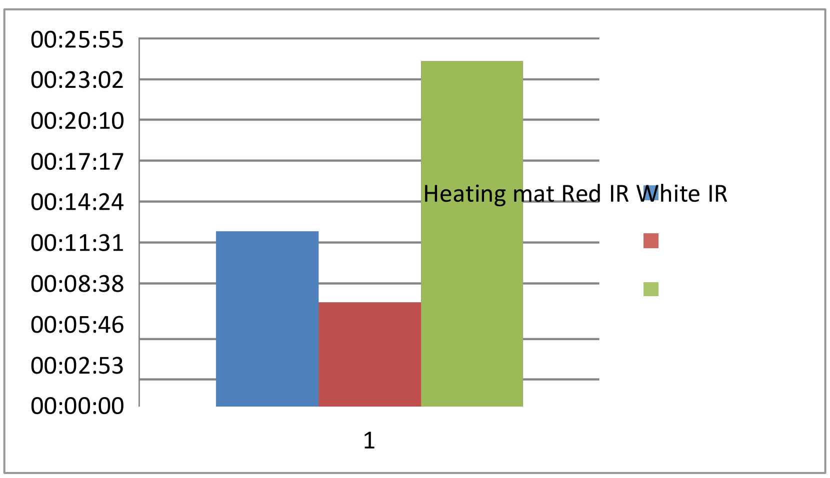

Figure 7: recovery times of different heating methods

The modes of heating have an impact on the possibility to track the fingers from the IR image. The finger is easier to track if the temperature difference is larger. On the images in Figures 8 through 10.

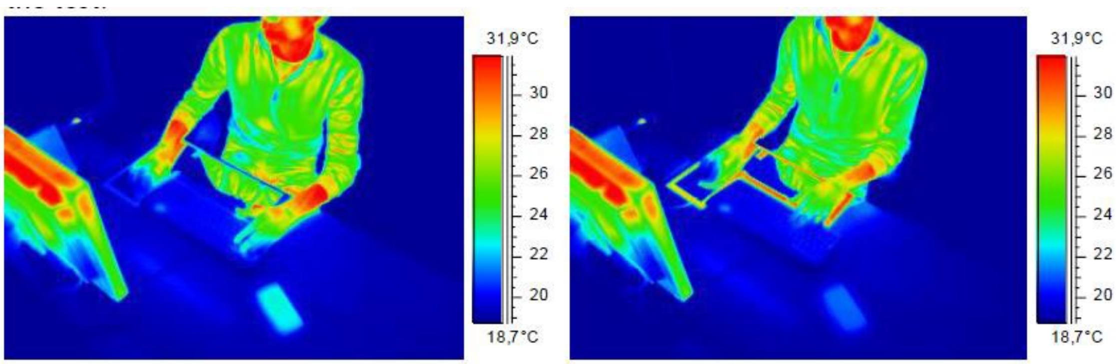

Figure 8: The desk heater tuned off (left) and on (right). The fingers are cold already, but wrist and arm still comfortable.

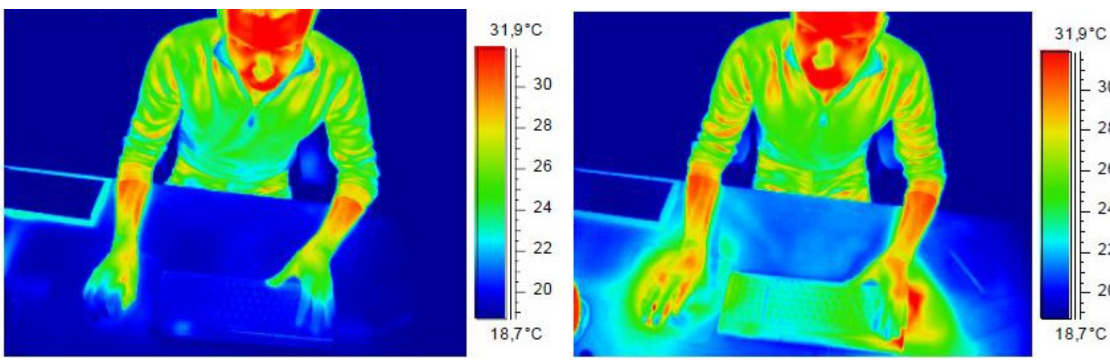

Figure 9: Effect of heating using the White IR lamps

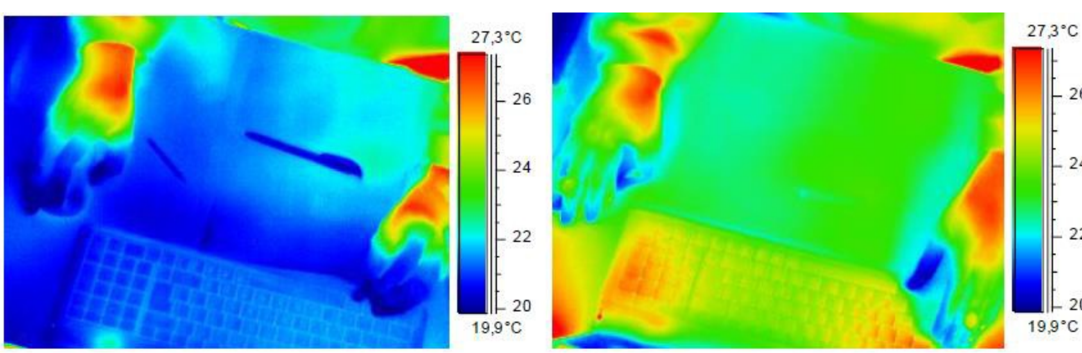

Figure 10: Effect of heating using the red IR lamps

Discussion

Even though during the experiments the focus was on removing existing discomfort, there was a clear distinction between the heating methods. The heaters used at maximum power when turned on, which would lead to a large overshoot in a real office environment. Ideally, the system would be turned on at emerging discomfort and the setting would be changed when needed. In later tests we found that people tend to be more cautious in choosing the setting and adjust the setting when comfort is reached.

Drawbacks come of the systems tested use direct electrical resistance heating. This choice is made because the devices are small, inexpensive, widely available en flexible. However, electricity is a high quality energy and has a high primary energy use. Higher than comparable room heating systems, usually based on gas fired boilers. The use of electricity could be compensated for by using Photo-Voltaic panels on the building.

Habituation to turning on the system is a risk. People could, after getting used to the system, dress for this extra heat provided by the system. Increased clothing level is still a more energy efficient method of increasing thermal sensation.

Further research

The energy saving potential of an office building equipped with ICSs can be further increased with a number of additional measures. Lower set points of the thermostat for the building climate system will reduce the required capacity of the heating system, which in turn would increase the systems efficiency.

The method of simply reducing the set point of the global heating system could be abandoned when the comfort level of individual users can be determined, either through combining the voting or through remote objective measurement. The global system would be engaged only when the energy use of all the local systems individually would exceed the energy use of the global system for increasing the room temperature or the discomfort that is to be mitigated is greater than the ICS is able to provide.

Even more energy can be saved when the global climate system in a building and the ICS fully cooperate with the local systems, when information is exchanged on the settings of the system, local environmental conditions and self-reported and possibly objective measured information on the comfort level of the individual workers.

The psychological effects of using local heating systems rather than what people are used to are not yet known. Before these systems become commonplace in the office, these factors are to be studied. As mentioned above, the effect of having direct influence on the climatic conditions on the workplace could be positive in that people become more tolerant compared to same size office spaces of the environmental conditions. This would allow a further increase in range of environmental conditions where the building can be kept free running.

Using an objective way of determining the comfort level of the occupants in addition to the user controls can lead to a reduction in energy use of the ICS, because it can start reducing power once comfort is restored and continuously adjust to stay within the TNZ in the most efficient manner. People are likely to wait before adjusting the system until it becomes uncomfortable on the other end of the TNZ. With the inclusion of comfort detection, the comfort level of the occupants and the energy use of all ICSs can be leading in controlling the ICS and the global climate system.

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