IMPACT OF ACTIVITY LEVEL AND THERMAL SENSATION ON HUMAN RESPONSE TO AIR MOVEMENTS

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INTRODUCTION

The influence of thermal parameters (air velocity, air velocity fluctuations, and air temperature) on draught discomfort has been studied extensively in office environments with sedentary, thermally neutral subjects. However, in cool industrial spaces the occupants perform physical work, and they often feel cool or cold during working hours. In cool industrial spaces, in which draught often causes discomfort problems, the influence of thermal parameters, activity level, and thermal sensation on human perception of draught has been studied only briefly. Thus, the purpose of this study was to investigate the impact of activity level and thermal sensation on human sensitivity to draught for persons performing physical work in a cool environment.

MATERIALS AND METHODS

Two separate studies were carried out. In the first experimental series (study 1), conducted with thermally neutral subjects, two different workloads were employed, corresponding to the metabolic rates 104 $W\cdot m^{-2}$ (s.d. 20 $W\cdot m^{-2}$) and 129 $W\cdot m^{-2}$ (s.d. 19 $W\cdot m^{-2}$). These experiments were conducted at air temperatures of 11, 14, 17 and 20°C. At each temperature level, the clothing insulation was adjusted to the activity level to attain a neutral thermal sensation.

In the second series of experiments (study 2), two different levels of thermal sensation were aimed at at each temperature level (11°C and 17°C). The planned thermal sensations corresponded to -0.5 (between slightly cool and neutral) and -1 (slightly cool) on a 7-point thermal sensation scale. In these experiments, the subjects performed work at one workload corresponding to a metabolic rate of 76 $W\cdot m^{-2}$ (s.d. 10 $W\cdot m^{-2}$).

In both experimental series ten male subjects participated. During the experiments, the subjects worked with their arms on a braked ergometer placed on a table. An additional experiment was conducted with sedentary subjects at 20°C. After 45 minutes of adaptation to the experimental conditions, the subjects, in five consecutive 15-minute periods, were exposed to stepwise increased mean air velocities 0.05 $m\cdot s^{-1}$, 0.10 $m\cdot s^{-1}$, 0.20 $m\cdot s^{-1}$, 0.30 $m\cdot s^{-1}$ and 0.40 $m\cdot s^{-1}$ directed towards their rear.

At each level of air velocity, a subject was asked three times to assess ***whether he had sensed an air movement during the last five minutes and, if so, whether the air movement was uncomfortable and where it was felt.***

RESULTS

Study 1: In Figure 1, the percentage of subjects dissatisfied due to draught as a function of the mean air velocity is shown at different activity levels. Only data for 20°C are included in the chart, but similar images were seen at the other temperature levels applied.

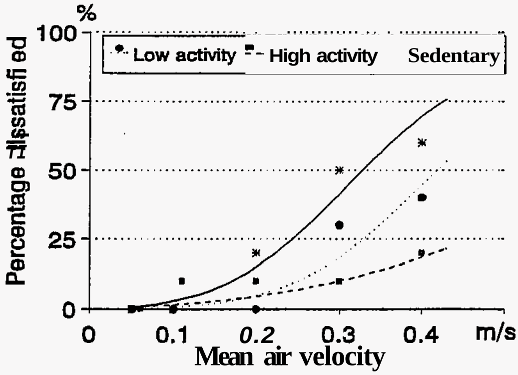

Figure 1. Percentage of dissatisfied subjects due to draught versus mean **air** velocity at sedentary, low (104 W·m^{-2}) and high (129 W·m^{-2}) activity levels at 20°C.

Under identical environmental conditions, the percentage of dissatisfied due to draught decreased, the higher the activity level. Thus, at high activity levels, people are less sensitive to draught than at low activity levels, provided the thermal state of their body is the same.

Study 2: Figure **2** shows the percentage of subjects dissatisfied due to draught as a function of the mean air velocity at two distinct levels of thermal sensation at 11°C. More subjects felt draught at a cool thermal sensation *than* at a warmer sensation. **At** 17°C, though, the difference in percentage dissatisfied between the two levels of thermal sensation was less clear. The results indicate that when a person is feeling cool in general, a local cooling of the skin is perceived to be more uncomfortable. These findings may explain why persons working in cool or cold environments often complain of draught, even at low ***air*** velocities. No significant effect of the air temperature on the number of draught complaints was observed in neither study 1 or study 2, presumably because the influence of the ***air*** temperature was masked by the differences in clothing insulation adapted to the air temperature and the workload.

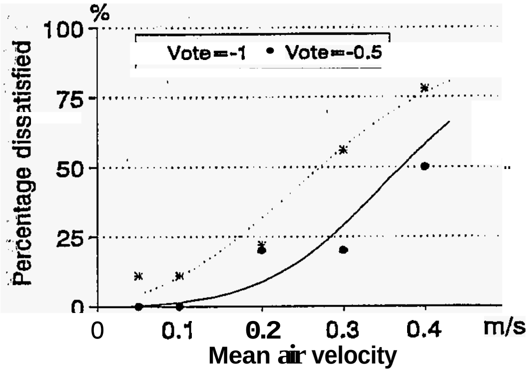

Figure **2.** Percentage of dissatisfied subjects due to draught at two levels of thermal sensation (-0.5 and -1) versus mean air velocity.

The results of study 1 and study **2** may be elucidated as shown in Figure 3. *Air* movements determine the amplitude and frequency of skin temperature fluctuations and the local skin temperature, both of which are registered by the cutaneous thermoreceptors. The activity level influences the internal body temperature and the preferred skin temperature (1), and also the thermal state of the body. The thermal state of the body is registered by the central thermoreceptors, and the integrated impulse signals from both central and peripheral thermoreceptors are decisive for the overall and local thermal comfort and discomfort. Considering the rise in internal body temperature which accompanies physical work, and taking into account that internal temperature is more important for thermoregulation than skin temperature, this result seems reasonable. Consequently, during physical activity, the impact of impulses from the peripheral thermoreceptors in the skin on perceived discomfort is probably suppressed at the expense of the impulses from the central thermoreceptors. Although the increase in internal temperature is presumed to be rather modest in the present experiments, it proved sufficient to reduce the subjects' sensitivity to draught. The results also correspond well with the fact that people with a high metabolic rate feel comfortable when their skin temperature is lower than at sedentary activity (1). **A** high frequency of impulse signals from the cutaneous thermoreceptors constitutes a warning signal of an upcoming cooling of the body that may threaten the body's thermoregulation. Due to this, when a person is feeling cool and a local convective cooling of the skin occurs, the influence of the impulse signals from the cutaneous thermoreceptors on the comfort experience will be intensified and thus cause increased discomfort.

The thermal conditions in industrial spaces have most often been evaluated with respect to the occupants' health. In contrast, it is the comfort conditions which are

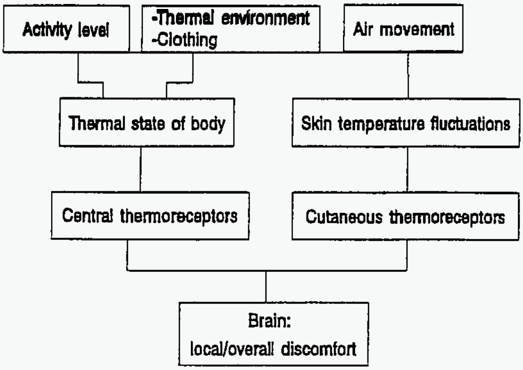

Figure 3. Flow diagram of inputs determinant for draught discomfort. Modified from (2).

considered to be most important in office environments. In moderately cool industrial spaces, no environmentally related health risk for the employees exists, but typically complaints of discomfort due to draught and cold are numerous. As only a few investigations have studied the requirements for thermal comfort in moderately cool industrial environments, there is a further need to develop evaluation methods for such "grey-zone" environments.

CONCLUSIONS

Working at a high activity level resulted in fewer dissatisfied due to draught compared with a lower activity level, whereas a cool thermal sensation increased human sensitivity to draught. Especially the latter result may explain why persons working in cool environments often complain of draught even in spite of low *air* velocities.

ACKNOWLEDGMENT

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