EFFECT OF IMPROVED AIR DISTRIBUTION ON PERCEIVED INDOOR CLIMATE AND PRODUCTIVITY - A CASE STUDY IN A LANDSCAPE OFFICE

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ABSTRACT

The aim of this paper is to investigate the effect of improved air distribution on symptoms and self-evaluated productivity in a landscape office in which the air was distributed with ventilated cooled beams. The intervention consisted of the improvement of evenness of the air distribution by installing an extra whirl diffuser at the end of every second cooled beam. As a consequence, the draught risk quantified by the draught rating model DR, was reduced to some extend. During the pre-intervention conditions 34 % of the respondents experienced draught whereas after the intervention the corresponding value was 17%. The indoor questionnaire also showed that the prevalence of dry throat, stuffy nose and fatigue reduced by 4 to 8 percent-units. The self-estimated productivity increased, because 17% of the employees during the pre-intervention conditions were working below the average efficiency whereas only 12 % after the intervention. This paper shows that a relatively small decrease in air velocities may result in reduction of symptoms and increase in the self-estimated productivity.

KEY WORDS

Draught discomfort, thermal climate, symptoms, intervention study, cooled beam

INTRODUCTION

Modern office equipment and lighting installations generate notable amount of heat and consequently large airflows are needed even in winter. Distribution of large airflows in landscape offices without draught discomfort is a challenging task particularly if the room is low and densely occupied. In these conditions people are very sensitive for draught caused by air movement. Several field studies show an elevated risk for complaints on indoor environment in large landscape offices with densely located work stations, Leyten (2002), Niemelä et al (2002), Pitchurov et al (2002). Symptoms and discomfort may lead to the reduced worker performance and therefore productivity losses, Niemelä et al (2003). It is worth noting that productivity in densely occupied spaces mainly depends on performance of the employees.

The aim of this paper is to investigate the effect of improved air distribution on symptoms and self-evaluated productivity in a landscape office in which the air was distributed with ventilated cooled beams. These relatively new air distribution systems have been installed to an increasing extent, particularly in Scandinavia and Central Europe, Kosonen et al (2000).

BUILDING AND METHODS

The study was performed in an insurance department of a company with 166 employees working in the landscape offices on two floors (area 890 m^2 / floor). The study was launched in the building, because the occupational health service unit had received complaints on draught discomfort and found elevated sick leave rates. The work tasks consisted of client services on car insurance by telephone. The offices were quite densely occupied with a packing factor of 10.7 m^2/ person. The inlet air was distributed by the ventilated cooled beams which have been installed to an increasing extent during resent years. In this application the air flow supplied through the nozzles induces room air through the heat exchanger of the beam (Figure 1). The building was equipped with two central air handling units and control systems. In order to reduce air movement in the occupied zone the air diffusion efficiency was improved by installing a piece of a ventilation duct and a swirl diffuser at the end of the every second ventilation cooled beam (56 swirl diffusers). The air flow rates were also adjusted and balanced after the installation.

Because the starting-point of the study was improvement of air distribution and reduction of air movement in the occupied zone, the indoor air measurements were focused on the thermal climate and perceived work environment and symptoms. In addition, a limited number of contaminant concentrations were measured. The measurements and questionnaires were performed before and after the intervention i.e. the installation of the swirl diffusers. The before- conditions were measured at the end of January and the after-conditions in March.

Both long term and short-term thermal climate measurements were performed. Air velocity and temperature at the work stations were momentarily measured with a Dantec multipoint flow analyser according to ISO 7730 (1995). The averaging period of air velocity sampling was three minutes. In addition, the room air temperature and inlet air temperature were monitored one week before and after the intervention by the building automation system. The indoor air questionnaire with extra questions on psychosocial factors and self-reported performance evaluations was conducted by the internet. Descriptive statistics was used in analyzing the questionnaire data. Each employee served as her own reference before and after the intervention.

In order to assess discomfort caused by draught, a draught rate (DR)-index was used, Fanger et al (1988). The index predicts the percentage of persons dissatisfied due to draught according to equation below

$$DR = (34 - t_a)\,(v_a - 0.05)^{0.62}\,(3.14 + 0.37\,SDv_a),$$

where

t_a	=	air temperature,
v_a	=	air velocity, m/s
$SD\ v_a$	=	standard deviation of air velocity

Figure 1. The ventilated cooled beam (above) and the swirl diffuser (below)

RESULTS

Air temperature and velocity

After the installation of the swirl diffusers the air velocities in the occupied zone were a little reduced. Before the improvement the velocities ranged from 0.05 to 0.22 m/s (mean 0.10 m/s) and after the improvement 0.02 to 0.17 m/s (mean 0.09) (Table 1). Air velocities were clearly reduced at the head level of a sitting or standing person where air movement may easily perceive as draught (Figure 2).

TABLE 1
The summary of the air velocity measurements

	Before		After	
	mean	range	mean	range
Air temperature, °C	22.4	20.2-24.7	23.0	21.4-24.8
Air velocity, m/s	0.10	0.05-0.22	0.09	0.02-0.17
Relative humidity, %	16		19	

The results of the air quality measurements conducted in the pre-intervention conditions indicate that content of TVOC was low (30-60 mg/m^3) and the number of mineral fibres at surface was less than the detection limit (< 0.1 fibre/cm^2). Owing to these low values the air quality measurements were not repeated after the intervention. The CO_2 concentrations in both conditions remained at the same level of about 500 ppm.

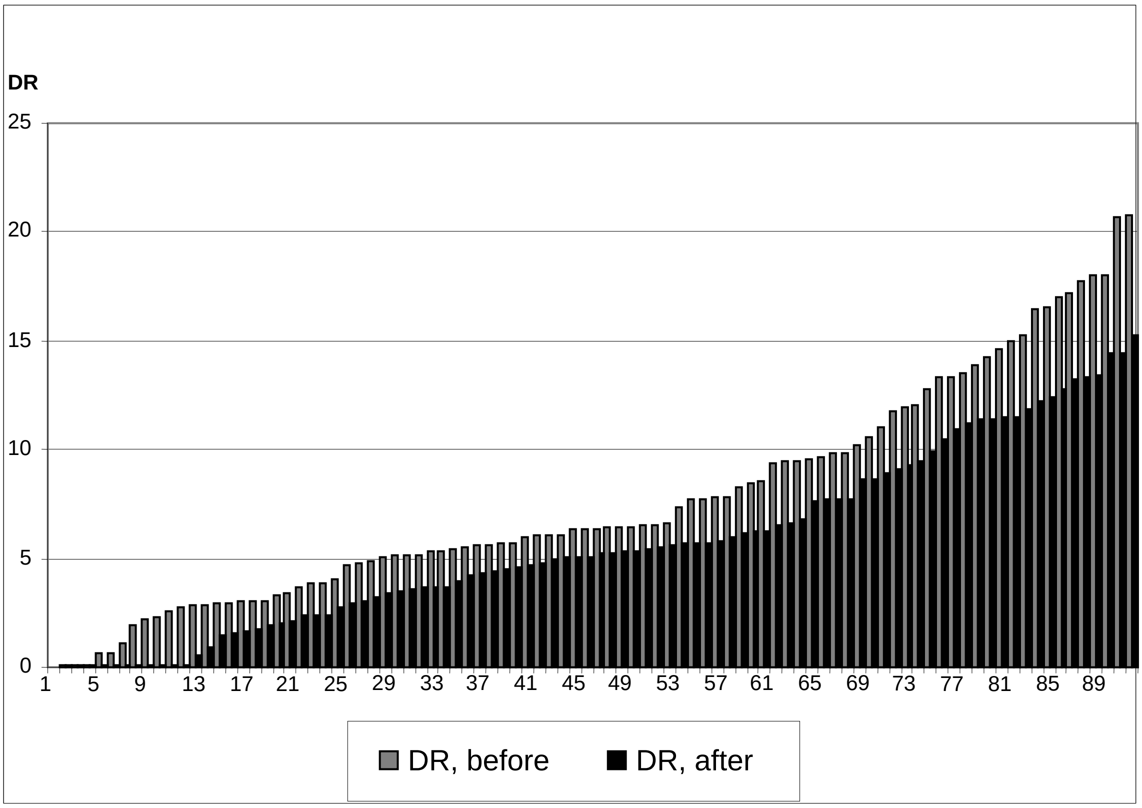

Figure 2. Draught rating model results

Perceived climate, symptoms and self-estimated productivity

Before the installation of the swirl air diffusers 34 % of the employees reported on draught, 53% on stuffy air, 49 % on dry air, and 59 % on noise (TABLE 2). The prevalence rates of these factors are higher than the corresponding prevalence rates in the reference material i.e. 22%, 34%, 35% and 17%, which are based on the responses of 11,000 office employees, Reijula & Sundman-Digert (2004).

After the installation of the extra air diffusers the prevalence rate of draught was reduced from 34 % to 17 %, and that of too low temperature from 22% to 13 % (TABLE 2). Sensation of too high temperature, stuffy air and dry air were increased whereas that of noise was remained as the same.

Prevalence of the SBS symptoms was in the pre-intervention condition was at the same level as that in the reference material (given in parenthesis). The employees reported most on irritated, stuffy nose 23% (20%), irritation of the eyes 17% (17%) and fatigue 18% (16 %). After the installation of the extra air diffusers both irritation symptoms and central nervous symptoms, excluding headache, were reduced. (TABLE 3).

TABLE 2
The perceived indoor climate

Indoor parameter	Number of respondents		Prevalence of the complaints	
	before	after	before	after
Draught	92	92	34	17
Temperature too high	90	91	21	36
Varying temperature	89	91	19	18
Temperature too low	90	92	22	13
Stuffy air	93	92	53	58
Dry air	92	91	49	56
Noise	92	92	59	55
Dim light or glare/reflections	93	93	20	16

TABLE 3
Prevalence of the SBS symptoms

Symptom	Nr of respondent		Prevalence of symptoms	
	before	after	before	after
Fatigue	93	93	18	11
Feeling heavy in the head	93	93	14	10
Headache	93	93	5	10
Difficulties in concentrating	93	93	7	4
Eyes itching, stinging or irritated	93	93	17	16
Irritated, stuffy nose	93	93	23	15
Hoarse or dry throat	93	93	15	11
Cough	93	93	4	2

DISCUSSION

As a consequence of the improvement of evenness of the air distribution, the draught risk quantified by the draught rating model DR, was reduced to some extend. The highest DR values were at a level of 21 % before the intervention but below or at 15% after the intervention. Of the complaints related to the draught discomfort, prevalence of the draught was diminished 17 absolute %-units and that of too low temperature 9 %-units. Prevalence of varying temperature remained at the same level whereas prevalence of too high temperature and dry and stuffy air were increased after the intervention. The elevated values of these complaints may be due to the slightly higher air temperature in the post-intervention condition. It has been proven that the increased temperature has impact on the perceived air quality, Toftum (2002).

The indoor questionnaire also showed that prevalence of the central nervous symptoms, excluding headache, reduced 3 to 7 absolute %-units whereas all irritating symptoms were reduced. The increased prevalence of headache may be associated with the slightly higher room temperature after the intervention.

The self-estimated productivity increased, because 17% of the employees during the pre-intervention conditions were working below the average efficiency whereas only 12 % after the intervention. This finding is in the line with the reduced SBS symptom prevalence rates.

CONCLUSIONS

This paper shows that a relatively small decrease in air velocities may result in reduction of symptoms and increase in productivity expressed as self-reported productivity, even though the air velocities were not particularly high before the intervention. In addition, the improvements were achieved with moderate retrofitting measures.

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