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The effect of air temperature on labour productivity in call centres—a case study

Raimo Niemelä[a,*], Mika Hannula[b], Sari Rautio[a], Kari Reijula[a], Jorma Railio[c]

[a]*Finnish Institute of Occupational Health, Topeliuksenkatu 41 aA, FIN-00250 Helsinki, Finland*
[b]*Tampere University of Technology, Tampere, Finland*
[c]*Association of Finnish Manufacturers of Air Handling Equipment, Helsinki, Finland*

Abstract

The aim of this paper was to investigate the effect of air temperature on labour productivity in telecommunication offices. The study was conducted as a case study in two call centres because the work in the call centres can be considered to represent typical activities in the telecommunication industry. The study design consisted of an observational approach and an intervention approach. In Call Centre I, the productivity between two zones with temperature difference was compared. In Call Centre II, the intervention was conducted by installing cooling units to lower high temperature in the summer. Productivity was monitored both before and after the intervention, and it was measured as labour productivity by monitoring the number of telephone calls divided by the active work time. The indoor climate of both call centres was determined by measuring thermal climate and concentrations of relevant air pollutants as well as the acoustical environment and lighting levels. The study shows that productivity may fall by 5–7% at the elevated indoor temperatures.
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Keywords: Air temperature; Labour productivity; Call centres; Air quality; Work environment; Intervention study; Observational study

1. Introduction

Productivity is one of the most important factors affecting the overall performance of any organisation, from small enterprises to entire nations. Increased attention has been paid to the relationship between the work environment and productivity since the 1990s. Laboratory and field studies show that the physical and chemical factors in the work environment may have a notable impact on the health and performance of the occupants, and consequently on productivity [1–4]. A common allegation is that improving the work environment results in productivity gain. This relationship, however, has been insufficiently explored. Generally, mainly anecdotal evidence of linkages between the indoor environment and productivity exist, whereas hard scientific data are sparse. One reason for the lack of data on such linkage may be that productivity as a concept is a multidimensional issue, and consequently there are numerous ways to define it. Actually, productivity is—or at least should be—universally defined as the ratio of output to input. However, there are a number of ways to conceptualise productivity in practice. Also the measurement of productivity is usually seen as rather complicated [5].

In this connection, the essential difference between field and laboratory research should be noted. If the primary emphasis is on the actual world, field investigations are generally conducted. In field studies, we have to make several compromises concerning the variables to be controlled, study design, available data, etc. In laboratory studies, on the other hand, which are usually based on short-term tests, the test conditions and the treatments are well controlled and repeatable. However, their link to the real world is weak. The direct measurement of labour productivity in office environments is difficult to accomplish, in call centres, however, the labour productivity can be directly measured because computerised systems are used for monitoring response and queuing times.

This study investigated the effect of elevated temperatures in the summer on the labour productivity in two call centres by long-term monitoring of both productivity and the indoor climate.

2. Methods

The study design consisted of an observational approach and an intervention approach. In Call Centre I, the productivity between two zones with a temperature difference was compared. In Call Centre II, the temperature was reduced by

* Corresponding author.

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installing additional cooling capacity. Productivity was monitored before and after the intervention.

Call Centre I was located in the top floor of a business building. Eighteen female employees worked in six rooms (area 19 m^2) with 2–4 persons in the northern zone of the building and 16 women and 1 man in similar rooms in the southern zone of the same building. The number inquiry assignments were done with personal data terminals. The employees worked in two shifts under the same management. The northern and southern zones were equipped with separate HVAC systems. The supply air was filtered with the EU-6 class filters. According to the maintenance staff the recirculation air was not used in the summer. It was anticipated that the southern zone would be warmer and hence differences in productivity between the two work zones may occur.

Call Centre II was a landscape office (area 166 m^2) with 15 female employees. The HVAC system was equipped with the G-85 class supply air filters. According to the maintenance staff the system used the recirculation air in the heating season only. The intervention was carried out by installing of extra cooling units to lower high room temperatures in the summer. The labour productivity and air temperature as well as CO_2 concentrations were measured before and after the intervention. The other environmental factors, i.e. air contaminants, acoustical and lighting conditions were measured after the intervention only because the installation of the additional cooling capacity was expected to have an insignificant or no effect on these factors. The room air velocities were measured after the intervention because the smoke tests before the intervention did not show notable air movement in the occupied zone.

The computerised monitoring system recorded the number of calls, the total work time and the active work time of each employee in every shift. It was estimated that the best productivity indicator was the number of telephone communications divided by the active work time. The monthly average productivity of each employee from Call Centre I and the monthly group average from Call Centre II was available for this study. It is worth noting that the productivity data are presented in Sections 3 and 4 in relative values for confidentiality.

The indoor climate of the workrooms was characterised by measuring thermal climate, concentrations of relevant air pollutants, i.e. carbon dioxide, particles, TVOCs, microbes in the ventilation systems as well as acoustical environment and lightning levels. In addition to short-term measurements of these parameters, the room air temperature, supply air temperature and concentration of carbon dioxide were continuously monitored over four calendar months. The short-term measurements were done once during 1 or 2 days. The room air velocities were determined with a multi-point flow analyser with the omni-directional velocity probes. The averaging time of the velocity readings was 3 min. The exhaust air flow rates from the rooms were measured at the exhaust terminals by an air flow detector head and a hot-wire anemometer. The supply air flow rates and the temperature set point as well as other operating parameters of the HVAC system were taken from design documents, or the maintenance staff were consulted. The acoustical environment was characterised by measuring a reverberation time and a noise level. The scale of the noise level meter ranged from 50 to 100 dB.

The indoor climate questionnaires were administered once simultaneously with the indoor climate monitoring. The questionnaire inquired questions about the sensations of indoor air factors, symptoms related to the indoor air and the psycho-social environment of the workplace.

The measurement data were analysed with a spreadsheet package. The comparison of means was done in a conventional way by the one sample or paired *t*-tests.

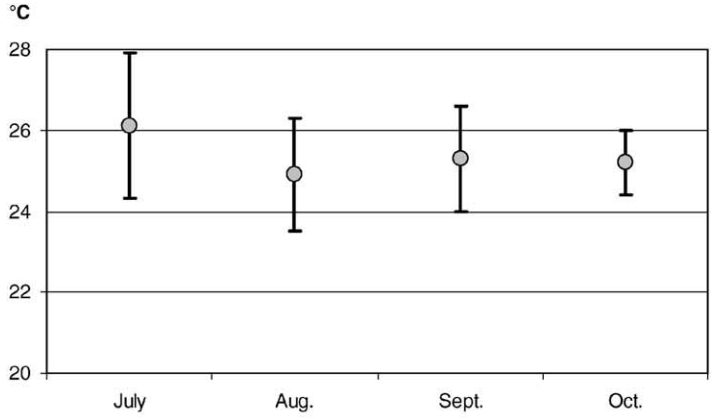
3. Results

The mean air temperature was 23.6 °C (range 21.9–27.8 °C) in the northern zone and 25.2 °C (range 22.8–28.5 °C) in the southern zone in Call Centre I, respectively. The mean air temperature in Call Centre II before the intervention was 25.1 °C (range 20.9–29.6 °C) and after the intervention 22.6 °C (range 19.1–25.9 °C). The monthly means and standard deviations of the air temperature from July to November in both call centres are shown in Fig. 1. The corresponding time course of the recorded CO_2 concentrations is shown in Fig. 2. The CO_2 concentrations were approximately at the same level in both call centres. In Call Centre I, the monthly average of the CO_2 concentration in the southern zone was slightly lower than in the northern zone. In Call Centre II, the CO_2 levels were slightly higher after the intervention.

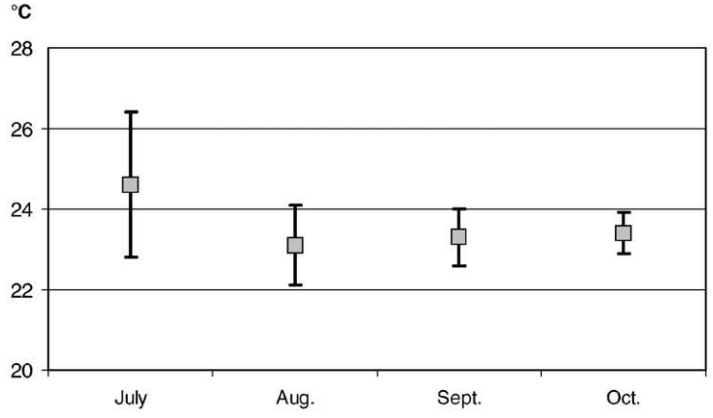
The results of the measured indoor parameters are summarised in Table 1. There was no notable differences in the particle concentrations, TVOC levels and CO_2 levels between the northern and southern zones in Call Centre I. The surface samples taken from the air conditioning systems did not reveal any indication of microbial growth. The levels of air-borne contaminants in Call Centre II were about at the same level excluding TVOC and number concentration of particles with diameter less than 0.3 μm which were roughly two-fold. Typical air velocity values based on the short-term measurements from both call centres ranged from 0.04 to 0.15 m/s. The exhaust flow rates in the rooms in the northern zone (range 43–47 l/s) were 25% lower than those in the southern zone (range 59–62 l/s). The visual inspection of the air conditioning system in Call Centre II indicated that the ducts and the fan were dustier than those in Call Centre I.

The lighting conditions in the northern zone were similar to those in the southern zone. The measured illuminance level of the desk surface ranged from 120 to 840 lx, and of the manual book surfaces from 50 to 600 lx. At some desks, the luminance contrast was high because of windows and lamps behind the monitor. The illuminance levels in Call Centre II ranged from 40 to 700 lx depending on the use of the lamps and the location of the windows.

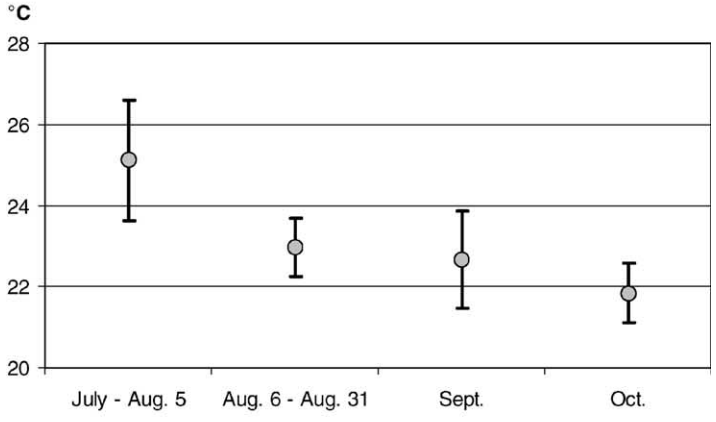
According to the indoor air questionnaire, conducted once in both call centres, the percentage of the dissatisfied



(a) **Call Centre I, South**



(b) **Call Centre I, North**



(c) **Call Centre II**

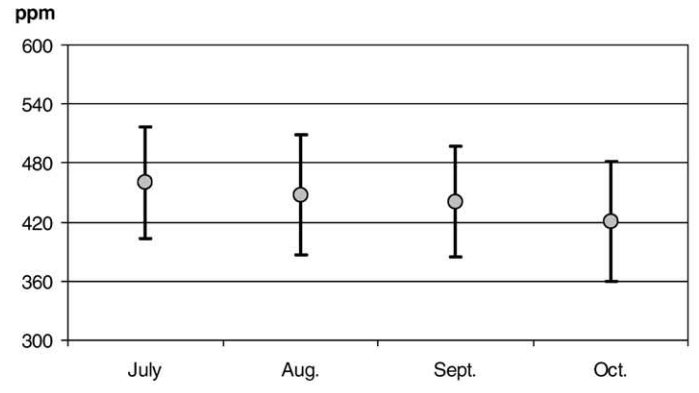
Fig. 1. Air temperature in the call centres.

persons complaining high room temperatures exceeded 50%. In Call Centre II, where the questionnaire was answered before the intervention, the room air was perceived stuffy and dry.

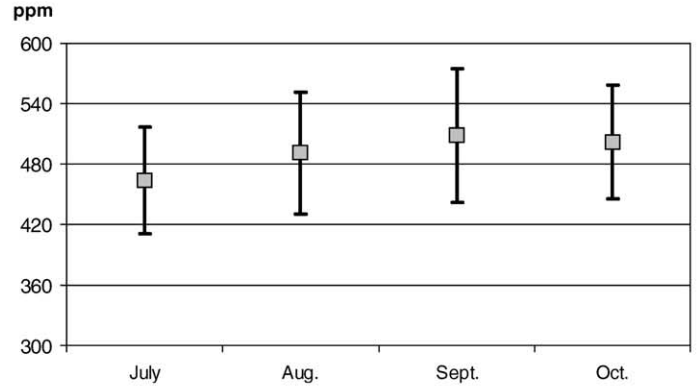
The results of the direct productivity measurements from both call centres were analysed in different ways and with different subpopulations. The following cases were considered.

Call Centre I:

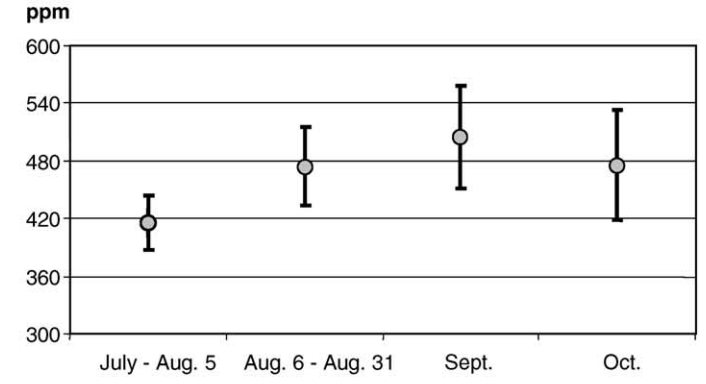
(a) Productivity of 18 employees working in the southern zone at elevated temperatures (about 25 °C) during the



(a) **Call Centre I, South**



(b) **Call Centre I, North**



(c) **Call Centre II**

Fig. 2. Carbon dioxide concentrations in the call centres.

entire monitoring period July–October. Each person acted as her own reference.

(b) Productivity of 17 employees working in the northern zone during the entire monitoring period July–October. The room air temperature was high in July (roughly 25 °C) but after that about 23.5 °C. Each person acted as her own reference.

(c) The productivity difference of these two groups (south–north) was compared.

Call Centre II:

(d) Productivity before and after the intervention was compared. The monthly mean productivity data of 15 employees were available for the comparison.

The results of cases (a), (b) and (d) are shown in Table 2 and case (c) in Fig. 3. The results in Table 2 are presented as relative values, keeping the productivity value in July as a

Table 1
Summary of the environmental factors in the call centres

	TVOC (mg/m^3)	Particle mass concentration (mg/m^3)	Particle number concentration (cm^{-3})			CO_2 concentration (cm^3/m^3)	Exhaust flow rate ($l/s\ m^2$)	Acoustical environment		Illumination level on a table (lx)
			>0.3 μm	>0.5 μm	>1 μm			Reverberation time (s)	Noise (dB)	
Call Centre I										
Northern zone	0.10	0.02	18.5	1.1	0.09	489	2.4	0.13	<50	120–840
Southern zone	0.11	0.04	16.4	0.9	0.11	443	3.2	0.13	<50	150–540
Call Centre II	0.26	0.04	29.5	1.0	0.16	415[a], 487[b]	0.6	0.41	55.9	50–700

[a] Before the intervention.
[b] After the intervention.

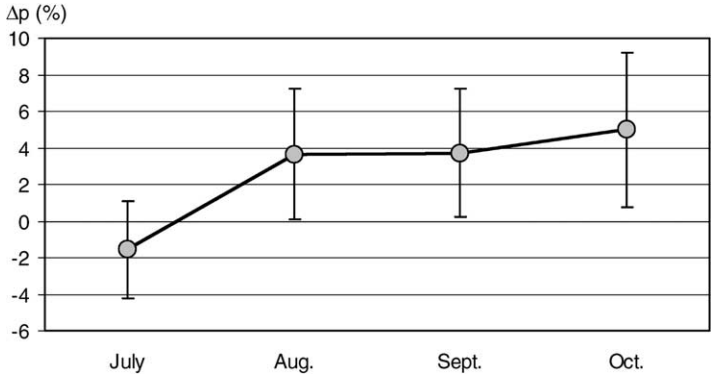


Fig. 3. Relative difference in the labour productivity between the northern and southern zones ($\Delta p = (p_{North} - p_{South})/p_{South}$) in Call Centre I.

reference. In case (a), the southern zone with the high temperature, the productivity remained at about the same level over the entire monitoring period and no statistically significant difference between July and other months was observed. In case (b), productivity in July was 5% lower than the average of three other months. The difference was statistically significant ($P < 0.01$). The relative difference in productivity (case (c)) between two zones in Call Centre I is shown in Fig. 3. The curve in the figure shows that the average productivity during the period August–November was 5.7% higher than that of July, when the room temperature in both zones was high. In Call Centre II (case (d)), where productivity before the intervention was compared with productivity after the intervention, the productivity increase was 7% higher after the intervention. The finding is statistically significant ($P < 0.01$).

Table 2
Summary of the labour productivity measurements

	July	August	September	October
Call Centre I				
Southern zone	1.00	1.00	0.98	0.99
Northern zone	1.00	1.06	1.03	1.06
Call Centre II	1.00[a]	1.08[b]	1.07[b]	1.07[b]

The productivity in July is kept as a reference.
[a] Before the intervention.
[b] After the intervention.

4. Discussion

The research strategy of this study was to analyse the labour productivity differences and compare them to thermal conditions. Also other relevant environmental factors were measured. In addition, a questionnaire was done in order to characterise the perceived environment and the psychosocial and organisational atmosphere in the call centres.

In our earlier paper, the observed productivity difference in Call Centre I was related to air temperature; the productivity difference was divided by the average temperature difference between these zones [6]. This procedure indicated that a change of 1 °C corresponds to a 1.8% in labour productivity in the range of temperature from 21.9 to 28.5 °C. According to the same procedure, the productivity reduction is 2.4%/°C in the Call Centre II described in the present study. However, this analysis obviously underestimates the temperature effect on productivity because the domain of thermal neutrality is included. Thermal neutrality may roughly be estimated to range from 21 to 25 °C in the summer conditions. Another prerequisite is, of course, that the change observed in productivity is merely due to the differences in air temperature.

In the case of Call Centre I, we analysed the productivity–temperature relationship in terms of three data sets, i.e. merely the southern zone, merely the northern zone and by comparing productivity in these zones. We can see that productivity remained constant in the southern zone at the elevated temperatures all the time. In the northern zone, the productivity increased about 5% after July when the room temperature decreased. It is worth noting that in these cases the same employee populations were considered. If we compare productivity of these zones, we can see that, when the heat exposure in both zones was high, there was no notable differences in the productivity between the zones taking into account the dispersion of the data (see Fig. 3). After July the productivity in the northern zone was 4.1% higher than in the southern zone. If July is included the average difference is 5.7%.

In the case of Call Centre I, there were no differences in the measured concentrations of air pollutants that may affect air quality between two zones shown in Table 1. The air velocities were at same low levels in the rooms of both zones. According to the physical measurements and the questionnaire the acoustical environment did not cause discomfort. Also the lighting conditions were rather similar in both zones. Although the monitoring of all relevant environmental factors was not as comprehensive as the temperature, the only environmental parameter which differed was the air temperature. There was no opportunity to try a cross-over change of the employees working in the different zones in order to completely eliminate all possible confounding factors, such as organisational and psychosocial factors, as well as personal differences, such as competence and motivation. This is a normal situation in field investigations. These non-climatic factors may have a notable effect on productivity [7]. However, both groups in the two zones were working under the same supervisors. According to the Department Chief both groups were rather homogeneous. Therefore, there was no indication of an alternative explanation for the difference in productivity.

The findings obtained in Call Centre I were confirmed by the results of Call Centre II. The average increase in productivity after the intervention in Call Centre II was 7.0%, i.e. very close to the findings in Call Centre I. In the case of Call Centre II, where the cooling intervention was performed, no other explanation than the temperature change was evident.

Even though the study designs possible in this study do not comply with the criteria of the causality, we can with a high probability conclude that the productivity changes observed were due to the temperature differences.

The findings on the two call centre cases can be summarised as follows. The labour productivity in the call centre work decreased 5–7%, when the air temperature exceeded 25 °C. It is worth noting that these are average values and considerable variations occurred in the productivity records. The results of this case study are in agreement with those obtained in other studies on office environments. The results obtained from these real cases point to a strong association between the indoor air temperature and the labour productivity. This study and the conclusions of the Workshop on Healthy Buildings [8] demonstrate the need for further multi-disciplinary studies to determine exactly the connection between indoor climate and productivity.

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