Temperature and ventilation effects on the work performance of office workers (study of a call centre in the tropics)

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ABSTRACT

This paper presents findings from a recent call centre study conducted in an air-conditioned office in the Tropics. The effects of temperature and outdoor air supply rate, each kept at two set points within currently acceptable limits, were explored in a 2 × 2 balanced experimental design over a 9-week period. The results indicate that both a slightly cooler thermal environment and improved indoor air quality improve performance by reducing average call duration. Temperature and outdoor air supply rate were synergistically related to one another in affecting operator performance ($P < 0.062$). Performance improved by 4.9% ($P < 0.05$) when the air temperature was decreased from 24.5 to 22.5°C at the lower outdoor air supply rate (9.8 l/s/p) and improved by 8.8% ($P < 0.04$) when the outdoor air supply rate was increased to 22.7 l/s/p at the higher air temperature. These outdoor air supply rates are based on actual occupancy.

INDEX TERMS

Temperature; Fresh air provision; Performance; Call centre; Tropics; Intervention study

INTRODUCTION

It is a challenging task to be able to quantify office work output since the dynamic interactions involved are very complex and multidimensional. There is also significant variance in workload and performance, which gives rise to difficulty in the evaluation of numerous workers on a single performance scale. In order to derive the hypothesized impact of environmental parameters on workers' performance, well-defined indicators reflecting direct work output should be identified. Studies conducted in call centres eliminate the problematic issue of the lack of a fixed criterion. According to Wyon (2002), work in a call centre provides 'a good paradigm for many other kinds of multitasking and, unlike other office work, is routinely timed with great accuracy'.

Current understanding of performance-oriented aspects of the person–climate interface is low (Lorsch and Abdou, 1994), particularly in the Tropics where the development of such building–occupant–productivity research is very limited. Studies conducted in recent years have documented subjective improvement of the perceived indoor environment, reduced Sick Building Syndrome (SBS) symptom intensity and increased performance arising from improved thermal conditions (Wyon, 1974, 1996; Wyon *et al.*, 1979) and improved indoor air quality (Wargocki *et al.*, 1999). A recent study by Wargocki *et al.* (2002) conducted in a call centre reported some positive effects of increasing outdoor air supply rate and replacing 6-month old filters on subjects' building-related symptom intensity and on perceived air quality, both variables which may be expected to affect workers' productivity. In the light of this evidence, a call centre in the Tropics was selected to evaluate the effects of indoor environmental parameters on workers' performance.

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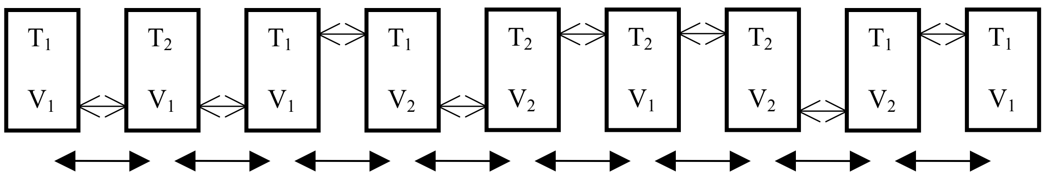
METHODS

The call centre is located at the second storey of a high-rise office building and occupies approximately 550 m^2 of the floor area with a ceiling height of 2.8 m. The call centre occupies an open plan office area with 42 workstations and the normal occupancy rate is between 50 and 72%. The typical workstation design has a spacious area and greyish-coloured medium height partitioning. The floor is covered with dark-coloured carpets. The false ceiling system serves as the return air plenum with evenly distributed light fittings and linear diffusers to discharge the conditioned air from the AHU. The air conditioning system uses variable air volume (VAV) distribution; however, for controlling the air distribution throughout this study, the supply fan speed was kept constant. Another important feature of the system is the use of electrostatic filters without pre-filters, which may considerably reduce the adverse effects associated with conventional bag filters (Wargocki *et al.*, 2002). The electrostatic filters had been maintained 3 months prior to the study and no maintenance procedure was carried out during the measurement period. The cooling coil and its fins had also been washed 1 month prior to the study. Within the experimental period, except for variations in temperature and outdoor air supply rate, all other indoor environmental variables such as lighting intensity and noise level were kept constant. The study was scheduled so that it would not coincide with a seasonal period of high call volume, to eliminate any possible confounding.

A blind intervention study was carried out for two independent variables, each maintained at two set points within their currently acceptable range. Temperature was set to either 22.5°C (T_1) or 24.5°C (T_2) and the outdoor air supply rate was adjusted to be 4.5 l/s/p (V_1) or 12.0 l/s/p (V_2) based on design occupancy. However, during the period of the study, the actual occupancy rate was low, so the average outdoor air supply rates were determined to be 9.8 and 22.7 l/s/p. A 2 × 2 balanced experimental design for repeated measures was implemented to explore the effect of increasing or decreasing temperature at both low and high fresh air supply rates. The weekly interventions were performed in such a way that all possible combinations were tested within the nine-week period. Each of the eight transitions occurred only once, as shown in Figure 1.

Week: W1 W2 W3 W4 W5 W6 W7 W8 W9



Transition: 1 2 3 4 5 6 7 8

Figure 1 Blind intervention settings of temperature (T) and ventilation (V) from Week 1 to Week 9.

Twenty-six permanent call centre staff handling inquiries about taxation procedures participated in this study by filling up questionnaires on the Thursday of each week. Questionnaires were distributed twice, one in the morning (10.00–11.30 a.m.) and another in the afternoon (03.00–04.30 p.m.) hours. Since the service provided requires a high level of relevant knowledge, all the call operators had received advanced training and were very experienced in using the computer programs that were required to answer the callers' enquiries. The same 26 call centre staffs were monitored for their call handling performance. Continuous recording of individual call duration for all the incoming calls by the computer software made it possible to examine the operators' performance in the handling of inquiries. They were not told of any performance evaluation but they were aware that air quality was being monitored. They wore clothing of their own choice and were free to adjust their clothing insulation levels throughout the experiment.

Data on subjective responses were collected on Thursdays to allow for a sufficient acclimation period and are assumed to represent their perception of the weekly exposures. During exposure, the concentration of indoor air pollutants and thermal parameters were continuously monitored at five selected indoor locations. Ventilation rates were determined by a pulse injection tracer gas method using SF_6 gas. Total viable bacteria and total yeast and mould (fungi) concentration were sampled at the same time as the subjective surveys were implemented. The intervention needed to establish the conditions for the exposure in the following week were made every Friday afternoon. The ability of the system to maintain this condition was regularly checked.

The impact on work performance was evaluated mainly in terms of call duration (talk time) as an indicator of performance, while human perceptual responses were determined from the linear visual-analog scales in the questionnaires. The call time data of each call centre staff were compiled from the original ASPECT software into a spreadsheet and analyzed as individual data comparison in the performance analysis. Call handling data were reported as 30 min blocks for five consecutive days in a week from Monday to Friday between 8.30 a.m. and 5.00 p.m. Subsequently, the first and last half an hour blocks as well as the lunch hour were excluded from the analysis. Survey data from questionnaires were transformed into numerical data as percentage full scale. The interaction between outdoor air supply rate and temperature was tested using a 2 × 2 analysis of variance followed by within-subjects analysis using either Student's paired *t*-test, if the data were Normally distributed, or the Wilcoxon Matched-pairs Sign ranks test, for response to the transit between conditions every week.

Table 1. Summary of measured concentration of indoor pollutants

INTERVENTIONS	**Unit**	**Conditions*** LT-HF			LT-LF			HT-HF			HT-LF			
Temperature	°C	22.9			22.5			24.4			24.5			
Fresh air supply	L/s/p	21.2			10.0			24.2			9.5			
IAQ PARAMETERS		**Concentrations****												**Sig.#**
Carbon dioxide	ppm	570.5	±	23.8	757.0	±	36.8	574.9	±	34.9	715.2	±	35.4	p<0.001
Carbon monoxide	ppm	1.08	±	0.01	1.00	±	0.16	1.12	±	0.11	0.70	±	0.01	-
TVOC	ppm	2.84	±	0.28	2.51	±	0.59	2.92	±	0.26	2.37	±	0.57	-
Formaldehyde	ppm	0.01	±	0.01	0.13	±	0.08	0.12	±	0.01	0.03	±	0.01	-
Ozone	ppm	0.0010	±	0.0000	0.0012	±	0.0004	0.0012	±	0.0004	0.0013	±	0.0005	-
Bacteria***	CFU/m^3	61	±	37	82	±	38	135	±	103	45	±	31	-
Yeast and moulds***	CFU/m^3	38	±	33	53	±	34	36	±	32	55	±	61	-
Respirable particulates (PM10)	μg/m^3	8.92	±	5.36	9.30	±	5.32	9.24	±	7.03	9.48	±	8.19	-

(*) : HF = higher fresh air supply; LF = lower fresh air supply; HT = higher temperature; LT = lower temperature

(**) : mean ± standard deviation of nine weeks measurement from five locations

(***) : breathing level (1.2m height), (#) : ANOVA test at 95% confidence interval

RESULTS

Objective Measurements

Table 1 shows the measured environmental conditions based on the 2 × 2 experimental plan for all four combinations of temperature and fresh air settings. Throughout each of the 9 weeks, temperature was maintained almost constant at the respective settings. Outdoor air supply rates, however, were more difficult to control due to the VAV air conditioning system used for the call centre. Changing the outdoor air supply rate resulted in measured carbon dioxide levels with an average of 736 ppm at the lower outdoor air supply rate and 573 ppm at the higher rate ($P < 0.001$). Other measured parameters suggest that relative humidity (range: 60.3–74.0%RH) and air velocity (0.06–0.24 m/s) in the office could not be fully controlled. Daily temperature and relative humidity profile are given in Tham *et al.* (2003). Table 1 includes the measured levels of pollutants, which are all well within the acceptable limits, as the outdoor air provision at both settings was maintained at or above the minimum of 10L/s/p recommended by ASHRAE standard 62 (1989).

Performance Measurements

The time of day analysis also did not suggest a significant difference in call handling performance ($P > 0.8$) between morning (9 a.m.–12 noon) and afternoon (1 p.m.–4.30 p.m.). Table 2 presents the weekly mean talk time data, the major fraction of call time involved within the typical call handling procedure apart from hold time and wrap-up time (handling time = talk time + wrap-up time + hold time). Weeks 2 and 6 (HT-LF), considerably the worst environmental settings in this experiment, had the greatest adverse effect on talk time. However, it is also interesting to note that the best performance did not occur during what were presumably the best conditions, weeks 4 and 8 (LT-HF).

Mean talk time for each operator in Weeks 2–9 was analysed in a 2 × 2 ANOVA. The interaction between temperature and fresh air levels on mean talk time approached significance ($P < 0.062$), but pair-wise comparisons between conditions were not significant ($P > 0.2$), except for comparison between low and high temperature at low fresh air settings ($P < 0.016$) and comparison between low and high fresh air levels at high temperature ($P < 0.011$). Pair-wise Student's *t*-tests on all transits, including the transit between Weeks 1 and 2, indicated that talk time was significantly affected when one of the two environmental factors was maintained in the poor condition while the other factor was improved, i.e. Week 2–3 (decreased temperature at the lower outdoor air supply rate, $P < 0.05$) and Weeks 6–7 (increased outdoor air supply rate at the higher temperature, $P < 0.04$), as shown later in Figure 2.

Table 2. Mean talk time during the experimental weeks

Week no.	Interventions		Mean talk time	Std. Dev.
	Temperature (°C)	Fresh air levels (L/s/p)	(mins)	
1	22.5	9.8	2.87	0.78
2	24.5	9.8	2.94	0.88
3	22.5	9.8	2.80	0.72
4	22.5	22.7	2.90	0.81
5	24.5	22.7	2.87	0.81
6	24.5	9.8	2.95	0.62
7	24.5	22.7	2.70	0.68
8	22.5	22.7	2.73	0.75
9	22.5	9.8	2.71	0.77

DISCUSSION

A call centre is a very specific type of environment and in which a very uniform type of work is performed. The ability to answer calls and to use the computer resources required to address customer problems determines the performance of each person. Within a short period of time, one is expected to complete a complex session in which communication (speech and interpretation), responsibility (quality of work), cordiality (social interaction) and efficiency (speed of working) are consistently maintained. Since the main focus of this blind intervention study is to investigate the effect of indoor thermal conditions and ventilation rate on office work performance, it is important to be able to minimize the experimental error due to other confounding factors. A preliminary survey to collect information on experience, training, and personal factors such as age and gender was carried out. An evaluation of previous monthly reports from the call handling time database did not show any differences due to age and gender. As the service provided is very specific, only well-trained and experienced staff are allowed to attend to customers and most of the staff have more than two years experience, which would tend to eliminate any effect of age and gender on performance.

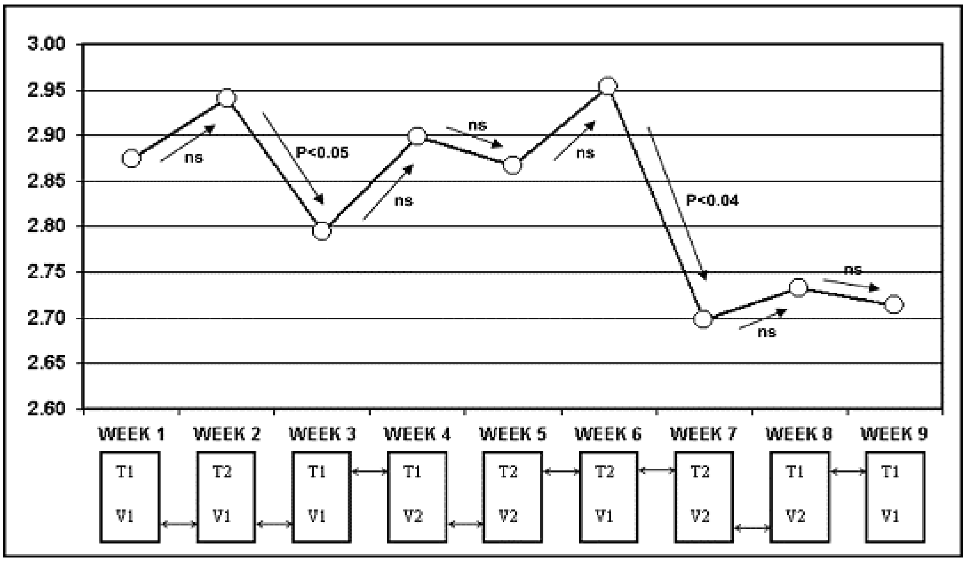


Figure 2 Mean talk time and pair wise analysis for transitions.

The main implications of these findings are:

- The effects of temperature and outside air supply rate on performance are not independent of each other. The impact of temperature on performance occurred at the lower outdoor air supply rate (9.8 l/s/p) while the impact of outdoor air supply rate on performance was significant only when the temperature was 24.5°C. Little improvement of work performance was observed when similar changes were implemented at the higher outdoor air supply rate (22.7 l/s/p) or at the lower temperature (22.5°C).
- Reducing temperature from 24.5 to 22.5°C at the lower outdoor air supply rate (9.8 l/s/p) and increasing outdoor air supply rate from 9.8 to 22.7 l/s/p at the warmer temperature (24.5°C) were found to reduce talk time by 4.9 and 8.8%, respectively. Mean total call time was 2.83 min.

The results are in good agreement with past studies of temperature and indoor air quality effects on work performance. Wyon (1974) reported better performance at lower temperature, 20°C, compared to 24°C for a typing task, suggesting either that the lower temperature increased arousal levels or that moderate heat exposure caused subjects to work slower to maintain a lower metabolic rate. Tham *et al* (2003) analysed tropically acclimatized subjects' perceptual responses and found that subjects in the present study were more comfortable at the higher temperature (24.5°C), even though performance increased when temperature was reduced from 24.5 to 22.5°C. This implies that lower temperature (22.5°C) may increase arousal level and lead to better performance (Wyon, 1996).

In the area of indoor air quality, Wargocki *et al.* (1999) has demonstrated that the presence of a common pollution source such as a fitted carpet caused a measurable reduction in work performance, presumably due to the increased intensity of SBS symptoms that was also observed. In the present study, headache and difficulty in concentrating were found to be significantly reduced when the outdoor air supply rate was increased at the warmer temperature of 24.5°C. Although there were no significant changes in pollution levels, except for carbon dioxide, increasing the outdoor air supply rate reduced talk time, which may be due to the observed reduction in reported intensity of headache and difficulty in concentrating of 19.5 and 13.2% ($P < 0.05$), respectively (Tham *et al.*, 2003). Further research is required to identify the causal mechanisms involved. A similar effect of indoor air quality on call centre operator performance and SBS symptom intensity is reported at this conference by two of the present authors (Wargocki *et al.* 2003).

CONCLUSION

This study of the office work performance of 26 tropically-acclimatized call centre operators is in good agreement with recently published results on the effect of indoor air quality on the performance of office work tasks. It provides new evidence that the performance of tropically acclimatized office workers is affected by moderate heat stress in a way that is comparable to what has been demonstrated in studies conducted on subjects acclimatized to temperate and cold climates.

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