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Association between objective and subjective assessments of environmental ergonomic factors in manufacturing plants

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ABSTRACT

The association between objective and subjective assessments of environmental ergonomic factors including noise, lighting and heat were conducted in a field study in three manufacturing plants. Data were collected from 130 workstations using questionnaire and physical measurements of the noise (noise dosimetry), lighting (task area illuminance) and heat (wet bulb globe temperature – WBGT) levels. The recommended noise, illuminance and WBGT levels were not met in about half of the workstations surveyed, which was in agreement with low satisfaction levels with the environmental factors in the workplace. A considerable effect of the environmental factors was found on perceived workers' job performance, safety and health. The results from contingency coefficient analysis indicated a relatively good agreement between the measured noise, illuminance and WBGT levels and the workers' perception of these factors. The results suggest that quantitative physical measurements should be supplemented by qualitative subjective assessments to provide more specific and additional details about the environmental conditions in each workplace and consequently to improve workers' satisfaction, job performance, safety and health.

Relevance to industry: The findings highlight the importance of environmental ergonomics and have implications for improvements in the design of the workplace to enhance workers' satisfaction, job performance, safety and health on areas where the environmental factors are not favourable. A better understanding of the environmental conditions and their effects in each working environment has the potential for a notable impact on productivity and workers' quality of life.

1. Introduction

Environmental ergonomics can be defined as the scientific study of the effects of ambient environmental conditions on human comfort, performance and health (Hedge, 2000). Interaction between workers and their surrounding environment is one of the key important issues in almost all workplaces. In a work environment, there is a continuous and dynamic interaction between the workers and their surrounding environment that causes a number of physiological and psychological responses in workers, and consequently affects their comfort, performance, productivity, safety and health (Parsons, 2000). The effects of environmental factors on the workers can, therefore, be studied in terms of the effects on satisfaction, performance, health and safety. The importance of the environmental conditions in different workplace settings have been well documented in the literature (Räsänen et al., 2000; Dawal and Taha, 2006; Kahya, 2007; Newsham et al., 2009; Lundh et al., 2011; Nazari et al., 2012; Dianat et al., 2013). The results from these studies indicate the adverse effects of environmental factors on workers' satisfaction, job performance, health and safety. Obviously, workers in different workplaces may be exposed to various environmental conditions. It has also been acknowledged that the human responses to the environmental factors depend on a number of factors including physical, physiological and psychological as well as individual differences (Parsons, 2000). Thus, it is necessary to conduct studies in each working environment to find out how these factors will affect the workers in that work setting.

It has been suggested that for reliable assessment of the environmental factors in each working environments it would be helpful to take into account both objective and subjective aspects (Küller et al., 2006; Dianat et al., 2013). Moreover, the combination

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of both objective and subjective evaluations may lead to a better understanding and a more detailed analysis of several different parameters of the environmental factors. Several previous studies on this issue have considered both objective measurements (e.g. physical measurements of noise, lighting and heat) along with subjective assessments (e.g. satisfaction, comfort, perceived job performance and health and safety consequences) (Küller et al., 2006; Gavhed and Toomingas, 2007; Newsham et al., 2009; Dianat et al., 2013). Also, consideration of various aspects of environmental factors through subjective assessments seems to be helpful because physical measurements might be complex, time consuming or not available. A better understanding of the environmental conditions and their effects in each working environment has the potential for a notable impact on productivity and workers' quality of life.

Based on the above-mentioned background, the purposes of this field study were to: (1) evaluate the physical noise, illuminance and heat levels in indoor workplaces in three packing plants as an exemplar manufacturing setting (objective assessments), (2) examine the workers' subjective assessments of the environmental factors (including noise, lighting and heat) and their effects on workers' satisfaction, perceived job performance, safety and health (subjective assessments), (3) determine how objective and subjective assessments are related, and (4) propose possible solutions for improving environmental factors based on the subjective ratings.

2. Methodology

2.1. Study design and setting

This field study was conducted in three packing plants in Saveh in central Iran. The research sites included different indoor working areas such as services, paper production, paperboard conversion, pasting, cutting, printing and puncture sites. The data collection was performed using both subjective (questionnaire) and objective (physical measurements of the environmental factors) methods. A questionnaire, developed by the authors, was administered to collect data about the environmental factors (e.g. noise, lighting, and heat conditions) in the working environment, and their influences on subjective assessments for employee satisfaction, perceived job performance, safety and health. Questions regarding potential improvements to the environmental conditions were also included. The questionnaire was used as a basis for semi-structured interviews conducted by one of the authors. The physical measurements included illuminance (in lux), noise dosimetry (in dB) and wet bulb globe temperature (WBGT) (in °C) measurements throughout research sites. The physical measurements were taken during data collection and evaluated based on the recommended standards for lighting (EN 12464-1, 2002), noise (OSHA, 1983) and thermal conditions (ISO 7243, 1989). These standards were used as a criterion to determine whether or not the environmental conditions in each workstation met the standard. Each workstation was scored as “met” if the noise or WBGT levels measured in that workstation were equal or lower than the recommended standard and if the illumination level was equal or higher than the recommended standard; otherwise it was scored as “not met”. The study protocol was reviewed and approved by Ethical Review Committee of the Tabriz University of Medical Sciences.

2.2. Participants

The three plants had a total number of approximately 300 employees at the time of study. To calculate sample size for the study, basic information was obtained from a study conducted by Dawal and Taha (2006) on the primary endpoint of correlation between environmental factors and job satisfaction. For this, a minimum effect size of 0.2 was considered to obtain the maximum sample size. Considering a confidence level of 95%, a power of 80% and two tailed tests, the minimum sample size determined as 134 by G-power software (version 3.1.2). Being in good general health and not having any visual and hearing problems were considered as inclusion criteria for the study. Participants were all male volunteers, with their ages ranging from 20 to 44 years (mean = 31.6 years, SD = 6.3 years), and had been working in their current job between 1 and 8 years (mean = 3.97 years, SD = 2.1 years). The majority of participants were married (74.6%) and had secondary education (62.3%). Each participant signed a written informed consent form before participation in the study and was not paid for his participation.

2.3. Data collection

A questionnaire was developed by the authors to collect data about the environmental factors including noise, lighting and heat in the working environment, and their influences on subjective assessments for employee satisfaction, perceived job performance, health and safety. Demographic data including age, educational level and marital status, as well as job details (job category, job experience and daily working hours) were recorded in the first part of the questionnaire. The questionnaire also evaluated the effects of noise (15 questions), lighting (16 questions) and heat (13 questions) in the working environment on employee satisfaction, perceived job performance, safety and health. Using a 5-point Likert scale (where 1 = very low, 2 = low, 3 = moderate, 4 = high and 5 = very high) participants rated their reactions to environmental conditions as well as to improvements to working environment. The content and face validity of the measure were evaluated by a panel of 10 experts in the field of ergonomics and occupational health, and slight word modifications were made on some items in the questionnaire. The internal consistency reliability of the constructs was evaluated by Cronbach's α in a pilot study by 30 subjects. The reliability coefficients for the constructs indicated good internal consistency (with Cronbach's α coefficients ranging between 0.71 and 0.92). The whole questionnaire took about 20 min to complete.

Physical measurements of the environmental factors (including noise dosimetry, task area illuminance and thermal stress using wet bulb globe temperature [WBGT]) were also taken throughout research sites during data collection. A noise dose meter (model TES-1354) together with a calibrator (model TES-1356) was used for noise dosimetry. The illuminance levels (in lx) were measured at the horizontal task area of each of the employees using a calibrated luxmeter (Hanger Digital Lux Meter, model EC1). Measurement of the heat stress in the working environment was performed using WBGT index.

2.4. Data analysis

The analysis of the data, including descriptive statistics, was performed using SPSS software version 16.0 (SPSS Inc., Chicago, IL). Non-parametric Friedman tests were employed to test whether the ratings observed were significantly different between categories of each environmental factor. This analysis was followed by related post hoc tests adjusted for error rate by Bonferroni method. The agreement between employees' perception of the environmental factors and the actual measurements was evaluated by contingency coefficient test to fulfil the assumptions with regard to ordinal measurement of the variables. For the same reason, Spearman's correlation coefficients were used to examine possible relationships between the study variables. A significance level of $P < 0.05$

was considered for all statistical tests.

3. Results

3.1. Demographic and job details

Table 1 presents demographic and job characteristics of the study participants. All study participants had a normal 8 h work shift. The age of participants ranged between 20 and 44 years, of which about half of them (n = 66; 50.7%) aged 25–29 years. The job experience of the sample ranged between 1 and 8 years (mean = 4.0 years; SD = 2.1 years). The majority of the employees were married (n = 97; 74.6%). Twenty seven participants (20.8%) had primary school education, 81 (62.3%) had secondary education and 22 (16.9%) had university degrees.

3.2. Physical measurements of the environmental factors

The results of physical measurements of the environmental factors in different working areas are summarized in Table 2. The physical measurements were carried out in 130 work areas. As can be seen from this table, a considerable variation was found in the illumination levels, but not for the noise and WBGT levels. The levels of illuminance for different workspaces ranged from 50 lux to 583 lux. This range for the noise was from 72.1 dB to 92.5 dB and for the WBGT was from 24.6 °C to 28.1 °C. The level of noise, illuminance and heat were not met the standards in 41.5% ($n = 54$), 46.9% ($n = 61$) and 54.6% ($n = 71$) of the workplaces, respectively (as shown in Table 3).

Table 4 illustrate the percentages and mean ratings (SD) of the environmental conditions assessed by the workers. As can be seen from this table, 73.1% and 97.6% of the workers reported that noise and heat levels were not appropriate (i.e. medium to very high on the scale), respectively. The percentages of workers who indicated that the light level in their work environment was not appropriate (i.e. very low to medium on the scale) was 67.1%.

Table 3 also indicates the mean ratings of the noise, light and heat levels assessed by the participants (subjective assessment) as compared to the physical measurements (objective measurement) in work areas that met vs. did not meet the standard. The results of contingency coefficient test indicated a relatively good agreement between the physical measurements of the environmental factors (including noise, lighting and heat) and the employees' perception of those factors. This indicated that the respondents' perception of the noise (mean rating = 3.2; SD = 1.13), light (mean rating = 3.4; SD = 0.97) and heat (mean rating = 3.3; SD = 0.77) levels in working areas that met the standard were significantly different from those areas that noise (mean rating = 3.9; SD = 1.07), light (mean rating = 2.7; SD = 0.98) and heat levels (mean rating = 4.1; SD = 0.81) did not meet the standard. In other words, the respondents' perceptions of the environmental factors reflected the actual situation so that the subjective assessment was likely to be more appropriate if that workstation met the standards and vice versa.

Table 1
Demographic and job characteristics of workers (n = 130).

Variables	Number (%)
Age (yrs)	
20–24	25 (19.2)
25–29	66 (50.7)
30–34	29 (22.3)
35–39	5 (3.9)
40–44	5 (3.9)
Education level	
Primary school	27 (20.8)
Secondary school	81 (62.3)
University graduate	22 (16.9)
Marital status	
Single	33 (25.4)
Married	97 (74.6)
Job experience (yrs)	
1–2	34 (26.1)
3–5	70 (53.8)
>5	26 (20.1)
Job category	
Services	21 (16.2)
Paper production	15 (11.5)
Paperboard conversion	17 (13.1)
Pasting	21 (16.2)
Cutting	26 (20.0)
Printing	19 (14.6)
Puncture	11 (8.4)

3.3. Effects on employees' satisfaction, perceived job performance, safety and health

The effects of environmental factors including noise, lighting and heat on employees' satisfaction, perceived job performance, safety and health are summarized in Tables 4 and 5. Only 2.3%, 10.0% and 28.5% of the respondents expressed high or very high levels of satisfaction with the noise, heat and lighting at their working environment, respectively (as shown in Table 4). Moreover, 28.5%, 43.1% and 45.4% of the employees believed that the noise, lighting and heat levels had adverse effect (e.g. moderate to very high on the scale) on their job performance (shown in Table 4). The effects of environmental factors on employees' health and safety are also summarized in Table 5.

3.4. Correlations among the variables

Spearman's correlation coefficients showed a number of significant correlations among the study variables, of which some of the more interesting findings are reported here. The measured noise level was found to be highly correlated with employees' satisfaction with noise ($r = 0.653$, $p < 0001$) and perceived job performance ($r = 0.652$, $p < 0.0001$). Significant correlations were also found between noise level and physiological responses ($r = 0.435$; $p < 0.001$), psychological responses ($r = 0.451$; $p < 0.0001$), hearing loss ($r = 0.310$; $p < 0.0001$) and speech communications ($r = 0.303$; $p < 0.0001$).

The results of Spearman correlation analyses also indicated significant correlations between the measured illuminance levels and workers' satisfaction with lighting ($r = 0.587$; $p < 0.001$), perceived job performance ($r = 0.265$, $p < 0.003$), eye tiredness ($r = 0.400$, $p < 0.001$) and changing posture for better view ($r = 0.252$, $p < 0.004$). The light level was also found to be correlated with the age ($r = 0.223$, $p < 0.05$) of respondents.

Finally, the physical heat measurement was found to be highly correlated with workers' satisfaction with heat ($r = 0.701$; $p < 0.0001$) and also with the perceived job performance ($r = 0.414$; $p < 0.0001$) and heat disorders ($r = 0.429$; $p < 0.0001$).

3.5. Improvements to environmental conditions

Table 6 shows the mean ratings for the improvements to working environment. The results indicated significant differences between the ratings for improvements to noise and heat ($p < 0.001$), but not for lighting condition. For the noise improvement, the post hoc tests revealed that the provision of additional noise absorbers and reduction of noise exposure time were rated significantly higher than all other solutions ($p < 0.001$). The

Table 2
Physical noise, illuminance and WBGT measurements across different departments.

Research sites	Workstations surveyed	Noise (dB)		Illuminance (lux)		WBGT (°C)	
	n	Mean	Min–max	Mean	Min–max	Mean	Min–max
Services	21	78.8	72.1–85.4	193	71–367	26.4	24.6–28.1
Paper production	15	86.2	83.0–89.4	267	102–455	27.8	27.1–28.0
Paperboard conversion	17	88.3	84.2–92.5	163	71–300	25.4	25.1–27.8
Pasting	22	83.3	83.0–83.8	182	55–583	27.3	27.2–27.8
Cutting	26	83.1	81.4–84.8	188	68–494	25.5	25.2–25.6
Printing	19	85.3	81.2–89.4	212	50–583	27.4	26.9–27.5
Puncture	11	82.0	80.0–84.0	140	52–236	26.2	26.5–25.8
All	130	–	–	–	–	–	–

Table 3
Workers' assessment of the environmental factors (subjective assessment) as compared to the physical measurements (objective assessment) in work areas that met vs. did not meet the standard.

Environmental factors	Met the standard		Did not meet the standard		Contingency coefficient
	n[a]	Employees' subjective assessment	*n*[a]	Employees' subjective assessment	
		Mean rating (SD)		Mean rating (SD)	
Noise	76 (58.5)	3.2 (1.13)	54 (41.5)	3.9 (1.07)	0.704
Lighting	69 (53.1)	3.4 (0.97)	61 (46.9)	2.7 (0.98)	0.637
Heat	59 (45.4)	3.3 (0.77)	71 (54.6)	4.1 (0.81)	0.725

[a] Number of workstations surveyed.

Table 4
Subjective assessments of the level of environmental factors, satisfaction and the effects on perceived job performance.

	Respondents (%)					Mean ratings[a] (SD)
	Very low	Low	Moderate	High	Very high	
Level of environmental factors						
Noise	5 (3.8)	30 (23.1)	16 (12.3)	53 (40.8)	26 (20.0)	3.50 (1.16)
Lighting	13 (10.0)	3 (2.3)	71 (54.6)	34 (26.2)	9 (6.9)	3.18 (0.96)
Heat	0 (0)	3 (2.3)	58 (44.6)	38 (29.2)	31 (23.8)	3.75 (0.84)
Satisfaction						
Noise	64 (49.2)	19 (14.6)	44 (33.8)	2 (1.5)	1 (0.8)	1.87 (0.94)
Lighting	13 (10.0)	5 (3.8)	75 (57.7)	26 (20.0)	11 (8.5)	3.10 (0.96)
Heat	56 (43.1)	17 (13.1)	44 (33.8)	9 (6.9)	4 (3.1)	2.09 (1.09)
Perceived job performance						
Noise	42 (32.3)	22 (16.9)	29 (22.3)	27 (20.8)	10 (7.7)	2.55 (1.33)
Lighting	39 (30.0)	7 (5.4)	28 (21.5)	33 (25.4)	23 (17.7)	2.95 (1.49)
Heat	28 (21.5)	11 (8.5)	32 (24.6)	30 (23.1)	29 (22.3)	3.16 (1.43)

[a] On a 5-point scale from 1 = very low to 5 = very high.

Table 5
Effects on workers' health and safety.

	Respondents (%)					Mean ratings[a] (SD)
	Very low	Low	Moderate	High	Very high	
Noise						
Speech communications	109 (83.3)	7 (5.4)	10 (7.7)	2 (1.5)	2 (1.5)	1.32 (0.80)
Hearing loss	72 (55.4)	31 (23.8)	24 (18.5)	3 (2.3)	0 (0)	1.68 (0.85)
Physiological responses	78 (60.0)	18 (13.8)	14 (10.8)	17 (13.1)	3 (2.3)	1.84 (1.19)
Psychological responses	77 (59.2)	19 (14.6)	14 (10.8)	17 (13.1)	3 (2.3)	1.85 (1.19)
Lighting						
Eye tiredness	76 (58.5)	13 (10.0)	16 (12.3)	14 (10.8)	11 (8.5)	2.01 (1.38)
Changing posture for better view	61 (46.9)	27 (20.8)	20 (15.4)	11 (8.5)	11 (8.5)	2.11 (1.31)
Falls/slips	105 (80.8)	7 (5.4)	8 (6.2)	7 (5.4)	3 (2.3)	1.43 (0.98)
Heat						
Heat disorders	61 (46.9)	16 (12.3)	19 (14.6)	19 (14.6)	15 (11.5)	2.32 (1.46)
Physiological responses	68 (52.3)	16 (12.3)	19 (14.6)	14 (10.8)	13 (10.0)	2.03 (1.33)
Psychological responses	105 (80.8)	16 (12.3)	4 (3.1)	2 (1.5)	3 (2.3)	1.32 (0.80)

[a] On a 5-point scale from 1 = very low to 5 = very high.

Table 6
The mean ratings (SD) of improvements to working environment.

Recommended improvements	Ratings (1 = very low to 5 = very high)
Noise	
More appropriate maintenance of machinery/equipment	2.31 (1.40)
Provision of additional noise absorbers	3.62 (1.06)
Provision of remote control	2.53 (1.99)
Reduction of exposure time	3.50 (1.33)
Use of appropriate personal protective equipment	3.14 (1.13)
Lighting	
Provision of additional artificial light sources	3.37 (0.88)
Provision of additional windows/natural lighting	3.34 (1.01)
More appropriate maintenance or installation of lighting fixtures	3.44 (0.79)
More appropriate combination of natural and artificial lighting	3.36 (1.13)
More appropriate combination of light colours	3.26 (0.88)
Heat	
Provision of appropriate air conditioning systems	3.52 (0.93)
More appropriate insulation of heat processes	3.34 (0.92)
More appropriate isolation of heat processes	3.51 (0.93)
Design of more appropriate work–rest schedules	3.48 (1.05)
Increasing food and drink intakes	3.32 (1.15)
Use of appropriate personal protective equipment	3.04 (1.03)

provision of appropriate air conditioning systems, more appropriate isolation of heat processes and design of more appropriate work–rest schedules were more likely to offer some improvement to heat condition in the working environment ($p < 0.001$).

4. Discussion

The present study was conducted to evaluate the environmental conditions (including noise, lighting and heat) in manufacturing environments and their effects on workers' satisfaction, perceived job performance, safety and health and to find the most appropriate methods of improvement to working environment. It was also intended to compare the workers' perceptions of the environmental factors with the actual physical measurements to determine how they are related to one another. The main findings of the study were that the noise, illuminance and WBGT levels were not met the standards in 41.5%, 46.9% and 54.6% of the workplaces, respectively. This result was in agreement with the workers' perception of the environmental factors, and with low satisfaction levels with those factors in the work environment. The correlation coefficients provided additional evidence that each environmental factor had a different effect on workers' satisfaction, perceived job performance, safety and health. These findings provide further evidence that in addition to physical measurements, it might be useful to consider various aspects of environmental conditions through subjective assessments as they may provide more specific and additional details about these conditions in each working environment.

As shown in this study, in about half of the work areas the measured noise, illuminance and WBGT levels were not met the recommended standards. On the other hand, more than half of the workers believed that the environmental conditions in their working area were not appropriate. According to the contingency coefficient analysis, there was a relatively good agreement between the measured noise, illuminance and WBGT levels and the workers' perception of these factors. Taken together, these findings suggest that in most cases the workers' assessment reflected the actual situation in such a way that the subjective rating was likely to be more appropriate if that work area met the standard and vice versa. In other words, the workers' assessment generally reflected the actual situation so that no underestimation or overestimation was observed between subjective and objective assessments. The results of a recent study in a hospital setting also indicated a relatively good agreement between the measured illuminance levels and the employees' perception of the light level (Dianat et al., 2013). These findings highlight that there is a potential that the workers' assessment may reflect the actual circumstances of the working environment. These may have possible implications for the evaluation of environmental factors in the working environment since the objective measurements might be complex, time consuming or not available.

The majority of respondents in this study indicated that they were not satisfied with the environmental conditions, particularly with the noise and heat levels, at their working environment. However, when asked to rate the effectiveness of a number of possible improvements to noise at the working environment, the provision of additional noise absorbers and reduction of noise exposure time were rated the most popular. Also, the provision of appropriate air conditioning systems, more appropriate isolation of heat processes and design of more appropriate work–rest schedules were more likely to offer some improvement to heat condition in the working environment. These findings highlight the importance of participatory approach as one solution to improve facility design. It is interesting to note that the results of Spearman correlation analysis indicated that the recorded noise, illuminance and WBGT levels were highly correlated with workers' satisfaction with these environmental factors in the work environment. Again, these findings may suggest that the satisfaction of the workers with the environmental factors tended to reflect the actual circumstances of the working environment. This is in agreement with the findings of several previous studies conducted in industrial and healthcare settings (Räsänen et al., 2000; Dawal and Taha, 2006; Dianat et al., 2013). These findings may help to find out how the workers feel about their working environment and consequently to improve our understanding about the environmental conditions of the workplace. In addition, satisfaction with lighting was found to be negatively correlated with the age of respondents, which is perhaps not surprising as previous research has shown that the environmental conditions of the workplace may affect older workers more than younger workers (Stedmon et al., 2012).

However, compared to the effects on workers' satisfaction, lower percentages of respondents indicated that noise (28.5%), lighting (43.1%) and heat (45.4%) in their working environment had an adverse effect on their job performance. Interestingly, the results of Spearman correlation analysis indicated significant correlations between the recorded noise, illuminance and WBGT levels and perceived job performance. This supports the findings of previous studies which have reported significant relationships between different environmental factors including noise, lighting and

thermal conditions and workers' productivity in industrial settings (Juslén et al., 2007; Kahya, 2007; Ismail, 2011). These findings highlight the importance of appropriate environmental conditions in the workplace to improve workers' job performance.

Regarding the health and safety consequences of the environmental factors, about one-third of the respondents indicated that the noise at their working environment could cause physiological and psychological responses, which is not surprising in view of previous research (Parsons, 2000). However, noise was less a problem in terms of speech communications. Moreover, more than one-third of the respondents reported that lighting condition at their working environment could cause eye tiredness to them, and that they needed to change their posture for better viewing of the objects or work area due to low illuminance levels or lighting disturbances (i.e. flickering lights, glare sources and unwanted shadows), which may be important from the ergonomics point of view (Vahedi and Dianat, 2014). Finally, compared to psychological responses to heat, higher percentages of respondents indicated that heat in their workplace caused physiological responses and heat disorders to them. These findings provide additional evidence and a useful support for the experimental findings on the effects of environmental conditions and the utility of their applications to manufacturing work environments. These findings also provide further evidence that, in addition to physical measurements, it might be useful to consider various aspects of environmental conditions through qualitative subjective assessments as they may provide more specific and additional details about the real conditions of each working environment.

5. Conclusions

The aims of this study were to evaluate the workers' perception of different aspects of environmental conditions in manufacturing settings, and to compare these perceptions with the actual physical measurements to determine how they are related to one another. These findings provide additional evidence and a useful support for the laboratory findings on the effects of environmental factors including noise, illumination and heat on workers' satisfaction, perceived job performance, safety and health. The recommended noise, illumination and WBGT levels were not met in about half of the workstations surveyed, which was in agreement with the workers' perception of the environmental factors, and with low satisfaction levels with those factors in the work environment. The results also showed a considerable effect of environmental factors on workers' job performance, health and safety, which was in line with previous observations. It was also shown that each environmental factor had a different effect on workers' satisfaction, perceived job performance, safety and health. The findings highlight the importance of environmental ergonomics as a valuable tool in workplace building design. It can be concluded based on the results of this study that quantitative physical measurements should be supplemented by qualitative subjective assessments to provide a more holistic approach where specific and additional details about the environmental conditions in each working area are incorporated from the workers' perspective. The results of this study have implications for improvements in the design of the workplace to enhance workers' satisfaction, job performance, safety and health on areas where the environmental factors are not favourable.

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