Building and Environment 47 (2012) 288–299

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

A measurement procedure to assess indoor environment quality for hypermarket workers

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ARTICLE INFO

Article history:
Received 13 April 2011
Received in revised form
11 July 2011
Accepted 12 July 2011

Keywords:
Thermal comfort
Acoustic comfort
Visual comfort
IAQ
Hypermarkets

ABSTRACT

The paper discusses the suitability of an on-site measurement procedure to assess indoor environment quality for hypermarket workers. The method is based on the collection of both objective measurements of environmental parameters and subjective perceptions of Indoor Air Quality (IAQ) as well as thermal, acoustic, and visual comfort. Given the particular (and variable) indoor conditions observed in hypermarkets, a preliminary field study was carried out to verify the understanding of the questions and their effectiveness in describing subjects' perceptions and the suitably of the survey method to assess indoor environmental quality and comfort. A hypermarket located in Southern Italy was selected as a pilot study during which the exposure data and subjective responses of employees were acquired simultaneously through physical measurements and questionnaires. A major aspect that required to be verified was the use of fixed positions to avoid, as far as possible, any interference with workers' activities. In fact, workers were asked to move to the measuring point and fill in a questionnaire to rate their subjective perceptions. Measuring points were chosen to represent the typical conditions inside the hypermarket. However, in a few cases more extreme conditions (less representative of the average conditions) were selected in order to widen the range of the measured parameters and subjective reactions. Data collected at fixed point locations showed only minor (and predictable) biases due to expectation and to transition through different thermal environments, confirming that the proposed method is effective in this kind of environment and minimizes interference with working activities.

1. Introduction

The concept of "health", according to the WHO, is the result of psycho-physical and social well being, rather than simply "lack of illness". It is extended to include global comfort, which depends on several factors such as the thermal environment, indoor air quality, visual and acoustic conditions, and is not easy to characterize. Since the 1970s several studies have been carried out to understand comfort conditions in indoor environments. Thermal comfort in residential and office buildings received the greatest attention after the seminal studies by Fanger [1] that led to widespread literature on this subject [2–4] and to many national and international standards [5,6]. However, new research trends suggested the inclusion of expectation and adaptation in the general framework [7–9], as well as the use of different prediction models. Similarly, many Indoor Air Quality (IAQ) studies have been carried out with reference to office buildings also investigating possible relations with thermal comfort [10,11]. A lot of research has been carried out to study disturbance due to office noise [12–15] and, a smaller number, to study visual comfort and its relation with working activities [16]. Possible interactions between all the above comfort aspects have been studied [17–19], but evidence of possible correlations is little and, in any cases, seems to suggest a major contribution from thermal aspects to the global perception of the environment.

All the above mentioned literature is mostly focused on office buildings, while only a little research concerns large-scale retail trade buildings [20–22]. These buildings include supermarkets, hypermarkets, department stores and shopping malls in ascending order of complexity and dimension. They are characterized by a huge range of products, from groceries to electrical appliances and furniture, and their environment is not homogeneous, but consists of several spaces with different thermal, acoustic and visual conditions which have to be studied individually. The spread of hypermarkets at the expense of small trade retailing means that greater attention must be paid towards the assessment of comfort conditions in these commercial buildings both for customers and staff. In fact, fixed workplaces for the staff, and longer stays for the

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doi:10.1016/j.buildenv.2011.07.011

Symbols

ADI	Acoustic Desired Intensity
AMV	Actual Mean Vote
API	Acoustic Perceived Intensity
ASat	Acoustic Satisfaction
DTS	Desired Thermal Sensation
ETS	Expected Thermal Sensation
FP	Freshness Perception
GSat	Global Satisfaction
HP	Humidity Perception
IAQSat	IAQ Satisfaction
OP	Odor Perception
PI	Perceived Illumination
PMV	Predicted Mean Vote
PTS	Previous Thermal Sensation
TSat	Thermal Satisfaction
VSat	Visual Satisfaction

customers, require greater attention to their global comfort conditions.

The aim of this study is to propose a survey protocol to investigate comfort conditions for workers in hypermarkets and verify its suitability to describe subjective sensations by means of the proposed objective measures.

2. Methods

2.1. Local climate

The research was carried out in a hypermarket located in Bari, a city in Southern Italy facing the Adriatic Sea.

It has climate conditions common in Mediterranean area, with warm humid summers and mild winters. The Adriatic Sea gives mild temperature ranges: in January, the coldest month, the mean temperature is 8.7 °C while in August, the warmest one, it is 24.3 °C (Table 1). The conventional period in which heating is used starts on November 15 and ends on March 31.

2.2. Building description

The shopping center is a prefabricated one-floor structure built between 2000 and 2005. It is situated at road level and consists of a shopping arcade and a hypermarket. The shopping arcade includes cafes, restaurants, non-food stores and services such as a post office.

The hypermarket covers a total floor area of about 17,000 m^2, 10,900 m^2 of which is occupied by the air-conditioned sales floor, 4200 m^2 by naturally ventilated warehouses and 1900 m^2 by air-conditioned food processing divisions. The mean ceiling height is 6.5 m in the sales area and warehouses, and 3.5 m in the food processing divisions because of suspended ceilings. The entrances for customers and staff are different in fact, the first get to the sales area through the shopping arcade and the latter from the office area which is directly connected to the outside environment.

The arrangement of different goods is outlined in Fig. 1. Personal healthcare products, pharmacy, non-perishable goods, refrigerated decks, fish, fruit and vegetables divisions and the frozen food section may be found near the checkouts. Full and limited service divisions (butcher's, a delicatessen, bakery and confectioner's), beverages, home cleaning products, household goods, stationary, electrical appliances and furniture are located in the peripheral areas.

The hypermarket is mostly lit by artificial lighting. Only the checkouts and warehouses benefit from daylight. Artificial light consists of downlight located at a height of about 6.5 m.

The sales floor is air conditioned by three Air Handling Units (AHU), and the food processing divisions by a fourth AHU dedicated to cold stores. The system provides heating in the conventional period, cooling in summer, and fresh air supply in the remaining periods.

2.3. Data acquisition

The surveys investigated the comfort of the hypermarket staff mainly in winter and summer, analyzing environment quality with the most unfavorable climatic conditions [2,3,23,24]. However field measurements were also carried out during spring to study the influence of the step changes in external climatic conditions on comfort sensations.

Continuous physical measurements were carried out on working days, for time intervals from one to five hours at every measurement point, taking into consideration the HVAC system functioning time.

At the same time, employees were randomly invited to answer a questionnaire, while they were occupied in their work, moving to the measurement station closer to their usual workplace. Anyway, they were asked to answer considering their subjective sensations when and where the questionnaire was filled in, even if it was not their customary workplace. To take into account human adaptation responses from workers performing mostly static jobs were collected only when the monitoring point was in close proximity to the workplace (Fig. 2).

The questionnaire was anonymous and it was filled in a completely independent way to avoid influences from survey team members, co-workers or superiors.

For thermal environment measurements, a microclimatic station was used with a datalogger, complying with ISO 7726 standard [25]. The probes used were: a 150 mm diameter globe thermometer (0.01 °C resolution and ±0.01 °C accuracy), a floor temperature probe (0.01 °C resolution and ±0.01 °C accuracy), an omni-directional hot wire anemometer (0.01 m/s resolution and ± 0.02 m/s accuracy from 0 to 1 m/s and ± 0.1 m/s accuracy from 1 to 5 m/s), a net radiometer for radiation asymmetry

Table 1
Outdoor climate conditions in Bari (average from 1971 to 2000).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
$T_{max\ mean}$ (°C)	12.6	12.9	15.0	18.0	22.8	26.8	29.2	29.2	25.9	21.5	16.8	13.9
$T_{min\ mean}$ (°C)	4.9	4.8	6.3	8.6	12.9	16.7	19.3	19.4	16.3	12.6	8.6	6.2
T_{mean} (°C)	8.7	8.8	10.6	13.3	17.8	21.7	24.2	24.3	21.1	17.0	12.7	10.0
UR (%)	76	73	72	69	69	66	65	67	70	75	77	77

(Data from Atlante Climatico d'Italia, Servizio Meteorologico dell'Aeronautica Militare http://www.meteoam.it/).