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Global comfort and indoor environment quality attributes for workers of a hypermarket in Southern Italy

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ABSTRACT

The paper investigates the interactions between global satisfaction for workers in hypermarkets and the different attributes that contribute to it. Thermal, acoustical, visual, and air quality conditions were investigated through both subjective and objective measures carried out in a hypermarket in Southern Italy. Questionnaires were collected over a two-years time span. Simultaneously, measurements of the main objective descriptors of indoor quality were carried out. The study took advantage of different statistical techniques, including factor analysis, multiple linear regression analysis, and nonlinear methods based on Kano's satisfaction model. Factor analysis pointed out the existence of two main groups of dissatisfied. The first one gave greater relevance to visual, and acoustic aspects while being neutral towards thermal aspects. Conversely, the second group was more influenced by lack of thermal comfort and presence of local discomfort, while showing indifference towards visual and acoustic aspects. Application of Kano's model showed that thermal local discomfort and IAQ were considered "basic" aspects (i.e. they have negative effect on global satisfaction when they underperform), while acoustic comfort was considered a "bonus" aspect, capable to improve overall rating when it performed well. Visual and thermal comfort, had a mostly linear influence on global satisfaction but also proved to have the highest impact.

1. Introduction

The assessment of global comfort conditions in indoor environment is getting more and more attention in the scientific community as most of our life is spent indoor and consequently health, well-being and performance are unavoidably affected. Two recent reviews surveyed the most important contributions to understand the different factors that affect global comfort [1], and the existing models for indoor environmental quality (IEQ) evaluation [2]. The first paper pointed out the definition of the individual aspects that contribute to comfort, usually assumed to be thermal, visual, acoustic, and indoor air quality. Then it showed that, among the researches that covered all the aspects together, very little agreement could be found in terms of ranking and relative weight of the different environmental conditions. Similar conclusions were drawn at the end of the second study.

Just to mention some of the most interesting results, one of the first studies was made by Humphreys [3] who analysed 26 office buildings through multiple regression analysis based on subjective ratings for warmth, air movement, light and noise. He concluded that temperature and air quality were the most significant parameters to affect IEQ, while noise and light were the lowest. In another study by Wong et al. [4], subjective evaluations (made using a dichotomous assessment scale) by 293 office occupants were collected. Such data were correlated to environmental parameters (operative temperature, CO_2 concentration, Leq(A), and illuminance) through a multivariate logistic regression model. Results showed that temperature affected IEQ most, followed by air quality, and noise, while illuminance level was the least important. However, the same approach applied to assess residential buildings [5] led to slightly different results, with temperature being the most important parameter, but air quality becoming the least important.

What emerged from the above mentioned papers was a slightly higher importance of thermal environment over the other aspects, but no firm conclusion seemed possible. In addition, according to the review from Frontczak and Wargocki [1], a number of other factors, from purely subjective to workspace characteristics, seemed to have some influence on perceived IEQ. Amount of space, office furnishing, cleanliness, and possibility to control the

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environment were among such factors. From this point of view, two independent studies from Frontczak et al. [6] and Kim and de Dear [7] analysed the data set from the Centre for the Built Environment at the University of California, Berkley. Despite they used different approaches (in the first case based on proportional odds ordinal logistic regression, and in the second based on Kano's model for customer satisfaction [8]), results converged showing that amount of space, visual privacy and noise level were the most important factors influencing IEQ. Anyway, application of Kano's model was interesting as it introduced a distinction between "basic" or "must be" factors (i.e. those that, if missing, have a stronger effect on dissatisfaction), "proportional" or "one-dimensional" factors (contributing to both satisfaction and dissatisfaction), and "bonus" or "attractive" factors (contributing only to satisfaction if they are present). In this way it became clearer that simple compensation between factors is usually very difficult to achieve when dealing with global comfort and satisfaction and, at the same time, that factors other than the usual environmental attributes could considerably affect individual ratings. A similar conclusion was found in Huang et al. [9] where the effect of thermal, acoustic, and luminous environment on overall satisfaction were investigated through laboratory investigation. Here, thermal and acoustic factors proved to have a "veto power", as when subjects felt dissatisfied with just one of them no combination of the other parameters could provide a satisfactory outcome in terms of overall judgement. These results are particularly interesting as many other researches [10–13] support the idea that some sort of trade-off may exist between different factors.

More recent researches were also made using the same CBE database to understand the effect of different ventilation systems [14], the role of gender differences in occupants' response to IEQ [15], and the differences between LEED and non-LEED certified buildings [16]. Other studies, combining all IEQ factors have been carried out to characterize green buildings [17], and classrooms [18]. However, with reference to hypermarkets and large retail buildings, the literature still offers a limited number of contributions, mostly focussed on specific aspects [19–24]. Such buildings have indoor characteristics that are not homogeneous, consisting of several sub-spaces with different combinations of environmental parameters. With few exceptions (such as cashiers) workers rarely occupy a fixed position and they have to move between different subspaces. Thus any simple extension of findings found in different kinds of spaces seems hardly applicable.

The present study takes advantage of a long and detailed survey carried out in a large hypermarket, in which data were collected about workers' comfort conditions both through subjective and objective measures involving all the IEQ factors together. Previous papers have been published presenting details of the survey method [25] and of the main findings from the thermal [26], acoustical [27], and air quality [28] point of view. Even though collecting data in a single hypermarket may apparently limit the extent of the analysis, it should be noted that the specificity of this group of buildings relies in the way the interior is arranged and how different sub-spaces are connected. From this point of view many similarities may be found between the surveyed building and the others, thus broadening the significance of the findings.

In particular, the paper aims at understanding how different IEQ factors combine together to shape global satisfaction ratings and how this information can be used to optimize the environment by changing objective parameters. To do so, the relations between subjective attributes and global satisfaction were first investigated using factor analysis to point out possible group behaviour. Subsequently, stepwise multiple regression and Kano's models were applied. Finally, the practical implications of the results found were discussed.

2. Methods

2.1. Site description

The research was carried out in a hypermarket located in Bari, in Southern Italy. The city 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. The conventional period in which heating is used starts on November 15 and ends on March 31.

The shopping centre was built between 2000 and 2005 and includes a shopping arcade and a hypermarket. 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 area, 4200 m^2 by the naturally ventilated warehouses and 1900 m^2 by the 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 hypermarket is mostly lit by artificial lighting. Only checkouts and warehouses benefit from daylight. Artificial light consists of down-lights located at a height of about 6.5 m. The average number of daily customers is about 3000. The arrangement of different goods on sale is outlined in Fig. 1. The air conditioning system provides heating in the conventional period, cooling in summer, and fresh air supply in the remaining periods.

2.2. Data acquisition and questionnaires collection

The survey investigated the comfort conditions of the hypermarket staff mainly in winter and summer, analysing environment quality with the most unfavourable climatic conditions. However, field measurements were also carried out during spring and fall to study the effect of transition from heating to cooling, and vice versa, on comfort sensations. As objective descriptors are not directly discussed in the present paper, for the sake of brevity, details of the instruments and measurement procedure are omitted. In any case all relevant international standards were respected as extensively described in Refs. 25–27.

As most employees have jobs that require them to move between many different areas, it was hard to define a fixed workplace. Because of the slow response time of some instruments, monitoring and evaluation points were kept fixed. After a detailed preliminary investigation of the environmental conditions the location of fixed point was decided taking into account the hypermarket layout (Fig. 1), the specific features of each job and the need to characterize every workplace, including, in particular, those showing interesting deviations from the average conditions. Continuous physical measurements were carried out during working days for time intervals from one to 5 h at every measurement point, taking into consideration the HVAC system functioning time.

Employees working within the range of the measuring station were randomly invited to answer the questionnaire. In some cases they were asked to move closer to the measurement station, but when this happened 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. The questionnaire was anonymous and it was filled in avoiding any external influence. In order to correlate objective parameters with subjective responses, the latter were paired with instrumental measurements averaged over the 10-min interval before subjects returned their questionnaire.

The questionnaire layout and questions were based largely on the survey form developed in the HOPE project [29] and on ISO