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Measured and perceived environmental comfort: Field monitoring in an Italian school

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ABSTRACT

Microclimatic conditions were recorded in an Italian school and Fanger's indexes PMV and PPD were calculated under different conditions. Students' sensations were investigated four times by means of two surveys, one related to actual microclimatic conditions and one on overall satisfaction, interaction occupant-building and reactions to discomfort. Pupils' classroom position was considered to look for possible influence on thermal comfort: a difference emerged from PMV and the survey, but the results obtained from the two approaches differ for both the entity of discomfort and its distribution within each classroom. Innovative multivariate nonparametric statistical techniques were applied to compare and rank the classrooms in accordance with students' subjective perceptions; a global ranking has been also calculated, considering thermal and visual comfort and air quality. Comparing pupil-sensation-based ranking with environmental parameters no clear correspondence was found, except for mid-season, where PMV, CO_2 concentration and desk illuminance were similar in all the classrooms.

1. Introduction

Living in a pleasant, comfortable environment enhances people's wellbeing and satisfaction. These conditions are particularly important in commercial, educational and healthcare buildings, where good Indoor Environmental Quality (IEQ) influences productivity, learning and convalescence (Frontczak and Wargocki, 2011). This study focuses on Italian children (9–11-years-old) and their school, where they usually spend about 8 h a day, i.e. one third of their daytime. Children are very sensitive to indoor conditions since they are at growing age and they may develop hypersensitivity if they are exposed to poor indoor conditions (Mendell and Heath, 2005). Bakó-Biró et al. (2012) investigate the influence of poor air quality on pupils' attention and vigilance, and results reveal that poor ventilation lowers memory and concentration.

Many Italian schools have structural problems, such as insufficient space, safety, poor indoor air quality, low thermal comfort, and bad acoustics; they are often energy inefficient due to obsolete systems, the facades are poorly, if at all insulated, and in some cases windows are single-glazed.

Many studies have evaluated the indoor conditions of educational buildings, taking into account single aspects (Mendell and Heath, 2005; Bakó-Biró et al., 2012; Corgnati et al., 2009; Humphreys, 1977), or various aspects of overall comfort perception (De Giuli et al., 2012a; Astolfi et al., 2003; Astolfi and Pellerey, 2008; Mumovic, 2009; d'Ambrosio et al., 2010). This study looks at a range of aspects.

Four different classrooms and a total of 62 students were involved in this research. The school is attended by pupils from different countries and many of them belong to families with economic difficulties; therefore the sample represents a range of cultures, habits and social classes, which may influence perception of comfort and expectations. Some studies have analyzed the role of ethnicity, socioeconomic status, teacher quality and school size in learning achievements (Nichols, 2003; Toutkoushian and Curtis, 2005). One study surveyed New York City public schools in order to clarify the role that the condition of school facilities plays in educational outcomes (Duran-Narucki, 2008), starting from the fact that poor living conditions are related to a higher risk of social and emotional difficulties (Evans and English, 2002).

The IEQ analysis presented here is a development of the methodology explained and applied in (De Giuli et al., 2012a), where environmental snapshots were taken in seven primary schools near Venice; spot measurements were taken and pupils filled in a survey about their general satisfaction with indoor conditions. In that study, no specific reference was made to actual conditions, except for thermal sensation; moreover, spot measurements were recorded only once and no continuous

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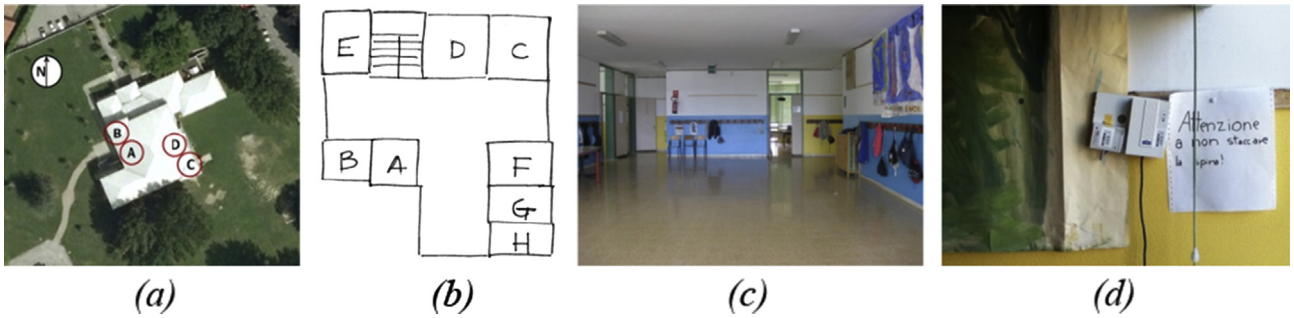

Fig. 1. Building location (a), map with key (b), corridor (c) and sensor position in a classroom (d).

measurements were carried out. The present analysis, however, overcomes these limits with a specific "spot survey" designed to compare recorded parameters with actual personal feelings; long-term measurements were also taken.

2. Case study

In this study, indoor microclimatic conditions and the level of children's satisfaction have been investigated in an educational building, by means of a comprehensive methodology, which involves both an objective and a subjective approach, measurements and survey administration, respectively.

The school itself is in a residential area near the centre of Padova (Fig. 1(a)). In Italy, children begin primary school when they are six and they finish when they are eleven. School starts in mid-September and ends in early June. This research studied four of the school's classrooms: two were west-facing (A, B) and two east-facing (C, D). These classrooms were used by two fourth-year classes and two fifth-year classes, the oldest years at the school. The research lasted three months, from March to June, therefore it covered one month in heating conditions (until April 16) and two months in free-running conditions.

The four classrooms are the same size (around 45 m^2); their façade is singled-glazed, shaded with internal Venetian blinds (Fig. 2), and the blackboard is opposite the windows. Classrooms B and C have two facades, but classrooms A and D only one. All of the classrooms are heated by radiators, and lit by four fluorescent lamps; they have no cooling or mechanical ventilation systems.

Pupils used two classrooms during the monitoring period: the fourth-year classes moved between classrooms A and B, while the fifth-year classes moved between classrooms C and D (Fig. 1(a) and (b)).

The aim of this study is to find a possible correlation between the recorded values and children perception of indoor conditions. As regards thermal comfort, Fanger's indexes PMV and PPD (Fanger, 1982; EN ISO 7730: 2005) have been calculated and compared to children actual thermal sensation, to see if Fanger's approach could be suitable even for children. Moreover, the influence of children' position inside the classroom in terms in thermal comfort has been investigated, to see if the ones seated along the external and glazed wall express a different comfort level with respect to the ones seated far from the windows. Finally, from the answers given in the survey, an innovative statistical approach has been applied to provide a global ranking of the four classrooms, considering together thermal comfort, air quality and visual comfort: this ranking has been compared to the relative recorded parameters, to look for a possible correspondence between subjective and objective evaluation. Considering classrooms' orientation and position inside the building, it could be expected that, as regards thermal aspect, classroom B should result the worst comfortable (North-West oriented and two external façades).

3. Methods

During each survey administration, the researcher noted the general condition of the classroom: door and window open or closed, shading up or down, lights on or off. Moreover a general impression of the students, in terms of clothing level, mood and excitement has been observed.

Measuring campaigns consisted in spot and long-term measurements, which started on March 14 and ran until June 6 2012. Spot measurements were recorded on four different days (March 14, April 11, May 9, and June 6); each day was characterized by different indoor and outdoor microclimatic conditions. Measurements were made with an Indoor Climatic Analyzer at the prescribed height of 0.6 m (ISO EN 7726: 1998). Air temperature, plane radiant temperatures, mean air velocity and relative humidity were also recorded in order to calculate Fanger's indexes (PMV and PPD) (Fanger, 1982; EN ISO 7730: 2005). Three different measurement points were selected in each classroom in order to establish possible differences between operative temperatures in the same room: one in the centre of the classroom, one close to the windows and one close to the wall opposite the windows. A room's operative temperature may vary greatly, especially in the extreme weather conditions of winter and summer when there is major asymmetry between the radiant temperature of the windowed wall and that of the opposite wall. In the previous version of the survey, pupils' classroom position was not taken into account; in this version, however, it was identified with a reference number. On each monitoring day, a desk map was drawn and pupils were asked to write their identification number in the spot survey. It was therefore possible to compare pupils' thermal sensation with the microclimatic conditions recorded at their classroom position.

Visual comfort was evaluated with illuminance measurements over the desks, and this was then compared with the pupils' visual satisfaction expressed in the survey.

Continuous monitoring consisted in recording air temperature, relative humidity and CO_2 concentration with a time step of 5 min by means of a data-logger fixed vertically in each classroom (Fig. 1(d)). The used data-loggers have the following characteristics: temperature range was from −20 °C to 70 °C, RH 5%–95%, and CO_2 concentration 0 ppm to 5000 ppm.

Two different surveys were administered to pupils in a subjective approach; one referred to actual conditions (i.e. the spot survey) and one (i.e. the general survey) to satisfaction with building-related aspects (e.g. building, space, furniture, etc.), occupant-building interaction (raising/lowering blinds, switching lights on/off, opening/closing windows) and reactions to discomfort.

The spot questionnaire was distributed four times during the recording of spot measurements. The general survey was administered only twice, at the beginning and at the end of the research. Although it was completed anonymously, each questionnaire had