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Occupant response to transitions across indoor thermal environments in two different workspaces

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ABSTRACT

To understand how transition across different thermal zones in a building impacts the thermal perception of occupants, the current work examines occupant feedback in two work environments — nursing staff in hospital wards and the workers in an office. Both studies used a mix of subjective surveys and objective measurements. A total of 96 responses were collected from the hospital wards while 142 were collected from the office. The thermal environment in the hospital wards was perceived as slightly warm on the ASHRAE thermal sensation scale (mean TSV = 1.2), while the office workers rated their environment on the cool side (mean TSV = −0.15). The results also show that when the transitions were across temperature differences within ±2 °C, the thermal perception was not impacted by the magnitude of the temperature difference — as reflected in occupant thermal sensation and thermal comfort/thermal acceptability vote. This would imply that the effect of temperature steps on thermal perception, if any, within these boundaries, was extremely short lived. These findings go towards establishing the feasibility of heterogeneous indoor thermal environments and thermal zoning of workspaces for human comfort.

1. Introduction

Research efforts and standards regarding indoor comfort have been primarily focused on occupants in a steady frame and do not stress on spatial thermal transitions [1,2]. Relatively fewer works have looked at occupant perception during transitions, looking at adaptation time and thermal perception immediately following transitions across different thermal environments [3].

Studies have looked at the effect of transitions across large temperature differences, which would be emulative of an occupant moving between outdoors and indoors, in controlled, laboratory conditions [4–10] and field settings [5,11–15]. A distinction has been noted between laboratory and field studies, the proposition being that under field conditions, occupants quickly passing through transitional spaces can adapt their thermal expectations over a wider range [5]. Some recent works have also examined and analysed thermal perception of occupants moving into and out of temporarily occupied spaces like malls, markets, and railway/bus stations and airports [16–21].

Results from these studies implied that thermal exposure history [5,8,15], duration spent in a transitional space [18,21], and magnitude of the air temperature difference across which the transition was made [11] impacted thermal perception during transition. They also point to the fact that for comfortable occupants, changes of ≤2 °C magnitude go unnoticed [11,14] but occupants who are uncomfortably cold or warm would notice even transitions of 1 °C [11].

The aforementioned works focused on how the spatial transition between outdoors and indoors affects occupant perception. However, the spatial transitions that occupants have to regularly go within a building have not been studied under field settings, with only one work coming close, in a controlled, laboratory setting [6]. As the modern office space rapidly evolves, with concepts like flexible working space, and layouts imposing break rooms along with work spaces, design of office HVAC systems would need to be considerate of such spatial transitions. Thermal zoning of indoor space, depending on orientation, usage, and occupancy, varying set-point air temperature across the floor space can be utilised to improve comfort while also saving energy [3,6,22]. This is also of relevance with the shift towards renewable energy [23]. This shift makes energy supply variable and intermittent and synchronization of demand and supply would likely introduce variabilities in the indoor thermal environment [24].

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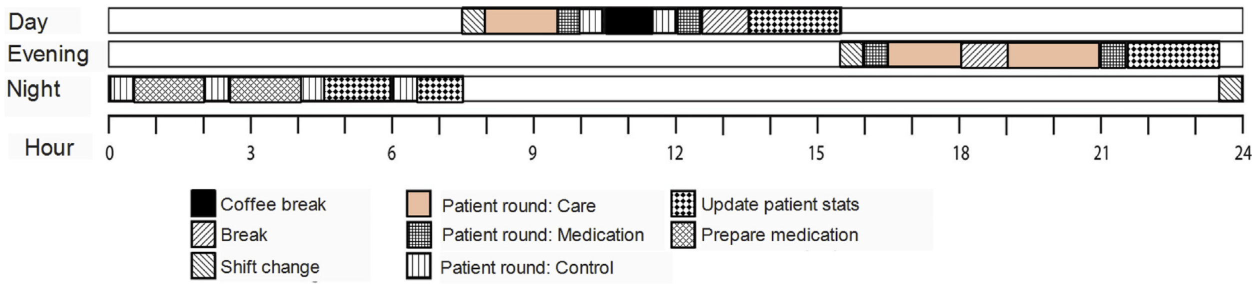

Fig. 1. Typical schedule of the nursing staff — as garnered from interview with the head nurse.

Laboratory experiments have proposed an acceptable magnitude of 3 °C for thermal steps in terms of thermal perception [3,9] and of 4 °C in terms of thermoregulatory burden [25]. In this work, the thermal comfort perception of occupants was examined as they moved across different thermal environments within their everyday workspaces. One case examined thermal perception of nursing staff in hospital wards. The other did the same in a university office building, involving academic staff in cellular offices, by targeting their movement between office space and the adjoining hallways and pantry space, which they used only during short transitions, as different from their regular workspace. The university office building was chosen as a representative for typical, cellular office spaces.

In a hospital, different occupant groups have different thermal preferences [26]. There are, to mention a few groups, patients, visitors, and the caregivers. Since they have different clothing and activity levels, their thermal preferences also vary. Considering that there is a dearth of literature regarding thermal comfort of care-professionals, a pilot, mixed methods study had been undertaken to examine the thermal comfort perception of nurses. A complete description of the study and the results regarding thermal comfort perception of nurses and how it affects their self-assessed work performance have been reported in a recent work [27]. Fortuitously, nursing staff also have to frequently move across rooms/zones with different functional purposes. The active nature of the nurses' job also contrasts well with the near sedentary nature of the office workers' activities, providing a chance to examine how spatial transitions affect thermal perception over a wider occupant activity range.

Since the works performed in climate chambers suggest that thermal perception is not significantly affected when the air temperature difference across which the transition takes place keeps within ±3 °C, we intended to verify if a similar conclusion may be reached for similar magnitudes of temperature transitions in workspaces. It was intended to ascertain this through occupant feedback regarding thermal sensation and acceptability/comfort.

2. Methods

Measurements in the hospital wards were carried out during 11–29 July (First period) and 7 October–11 November (Second period), 2016. The wards had patient rooms and the nurses' break room positioned along their perimeter while the reception, medicine room, meeting room, and chief's office are positioned in the core of the building, >8 m from the façades. The offices examined were in a building of the Eindhoven University of Technology. Unlike the hospital wards though, the office occupants can open their room's window and adjust the Building Management System (BMS) temperature settings over a range of ±3 °C (depending on the prevalent conditions and the demand on the induction unit). The occupants cannot see the actual set temperature value. Measurements in the office were conducted during 31 October–4 November (First period) and 21–25 November (Second period), 2016.

In both settings, it was preferred to divide the measurements over two periods so as to provide the participants an intermediate break period. The break lowered chances of onset of survey fatigue and also let us do some preliminary analysis of the participant responses, ensuring they were not being inconvenienced by either the subjective or the objective portion of the surveys.

The office building was located within the University's campus and surrounded by other similar buildings that housed both classrooms and administrative facilities. It is at least 300 m from any major roads and the campus itself has over 35% of its area under greenery coverage. The hospital is about 3 km from the city's centre and the ward itself is about 300 m from the nearest major road. While there are other buildings on the north and south of the hospital, on the east and west, the hospital is bordered by green space, which are parks and gardens. Both locations have similar climate, a temperate oceanic climate as per Köppen classification. The average maximum and minimum annual temperature for both locations are close to 14.5 and 6 °C, respectively.

Both workspaces have spaces with different thermal conditions, across which the occupants have to move in course of their regular work related activities. This provided an opportunity to study occupant perception immediately following such spatial transitions. We focused only on transitions that were between different portions of the workspaces and not transitions between outdoor–indoor or between different buildings.

2.1. Preliminary measurements

Before starting the surveys, preliminary measurements of indoor thermal conditions were conducted. This was done in order to better understand the buildings' thermal environments, helping decide on the sensor locations during the actual survey periods.

An interview with the head nurse provided an overview of the most frequent transitions nurses made in their workday (presented in Fig. 1). Preliminary measurements were performed at locations based on this information, using two stands that had three Rotronic sensors (specifications in Table 2), each measuring temperature and humidity. In these measurements, the reception, medicine room, nurses' break-room, the corridors, and some patient rooms with different bed numbers and different orientations were covered. Air temperature and relative humidity (RH) stratification over 0.1, 1.1, and 1.7 m never exceeded the device accuracies in any of the locations. Therefore, stratification concerns were absent. BMS sensors were not available through out the hospital wards. Hence, we placed our own sensors across the locations of interest.

Preliminary measurements were also carried out in the office building which showed that the difference in measured values between the calibrated sensors and the BMS sensors and air temperature stratification, measured over 0.1, 1.1, and 1.7 m, were within instrument specifications. Therefore, during the surveys, a single temperature sensor was placed close to the participants, at their desk height, and in the hallways, at a height of 1.1 m.

2.2. Subjective survey

2.2.1. Participants

Demography of the nursing staff, who responded to the survey, has