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Ventilation Assessment and Comfort Implications in a Student Halls of Residence

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Abstract: Window behaviour is a key driver of energy consumption and has a significant impact on occupant comfort. This study investigated patterns and drivers of window behaviour in a student halls of residence using a mixed-method approach. Twenty-one occupants of Mayflower Halls in Southampton have taken part in the study over the summer of 2017. Occupant surveys include a background interview and a weekly survey (for 6 consecutive weeks) with questions on their perception of the indoor environment as well as a self-reported use of the building controls available in occupant's rooms (e.g. windows, curtain). The environmental monitoring recorded air temperature, relative humidity and window movement. The results showed that a large percentage of participants (67%) were dissatisfied with the ventilation, thermal conditions and noise in their rooms, and would prefer to have more air movement. To address these issues, the paper suggests a series of recommendations for building management and retrofit options.

Keywords: occupants' behaviour, environmental comfort, indoor air quality, building retrofit

1. Introduction

Energy performance of buildings has received an increased amount of attention in recent years with a focus on providing comfortable conditions for occupants (Zero Carbon Hub 2014). This has highlighted that occupants have a significant impact on energy performance (Bonte et al. 2014; Yousefi et al. 2017; Andersen et al. 2009). The impact of occupants on total energy consumption is more significant in recently constructed dwellings due to the lower heat losses resulting from more airtight building fabric. During the summer, this has resulted in overheating and dissatisfaction with ventilation among occupants (Lomas & Porritt 2017).

Often, occupants' behaviour in dwellings is related to achieving thermally comfortable conditions (Raja et al. 2001; Raja et al. 1998) which can vary from person to person. Thermal comfort research provides a framework for understanding perceptions of the indoor environment (Nicol & Humphreys 2002) including standardised questions and guidance on indoor environmental monitoring.

This study aims to investigate ventilation in a newly constructed, multi occupancy building using both occupant surveys and indoor environmental monitoring. This includes factors affecting both occupants' perceptions of the indoor environment and their use of windows.

2. Study Design

This project used a mixed method approach to investigate natural ventilation and the effect of factors, which addressed the behaviour of occupants and their thermal comfort in a new student halls complex of residence in Southampton. A method has been developed that uses a combination of questionnaire surveys and data collection of indoor environment monitoring.

In order to understand the drivers for and the effect of window opening, air temperature, relative humidity and window movement were monitored in participants' rooms. Accelerometers placed on the window monitored window movement and air temperature. Temperature and relative humidity loggers (MadgeTech RHtemp101A) placed inside occupants' rooms provided information on the effect of this behaviour on the thermal environment.

In addition to this, two questionnaires were designed to obtain data on occupant behaviour, satisfaction with the indoor environment, thermal comfort and to analyse which factors would affect the window behaviour. The two questionnaires included a background questionnaire conducted in person and an online questionnaire submitted weekly by participants for 6 consecutive weeks. The online questionnaires were sent to all participants using the iSurvey software created by the University of Southampton.

The background questionnaire includes socio-demographic information, duration of occupancy in Mayflower, use of controls such as heater and fan, country of origin, and satisfaction level of participants to the room and indoor environment such as temperature, ventilation, humidity, lighting and noise level. Weekly questionnaire includes questions on their perception of the indoor environment as well as a self-reported use of the building controls available in their rooms such as window, door and curtain.

3. Case study building

The Mayflower Halls Complex is located at the city centre of Southampton. It divided into three buildings (Block A, B and C), which offer in total 1,104 rooms and a courtyard, which includes the main reception space, shared spaces and some facilities. Student rooms are separated into 7 to 9 rooms as a cluster. Most of the rooms in a cluster are single resident, with ensuite bathroom and shared kitchen area. Each single room has a top opening window to allow natural ventilation and an extract fan in the bathroom.

Figure 1 Sketch of Mayflower Halls of Residence (left) and photograph of internal courtyard design (right)

4. Results

The initial surveys from participants (n=21) gathered socio-demographic characteristics (gender, age, country & city of residence in the last two years), reported occupancy hours, use of heater and fan and satisfaction level with the environmental conditions. For the analysis, prior country & city of residence were divided into two groups - hot and cold climates. Results of this initial survey are shows in Figure 2 and 3.

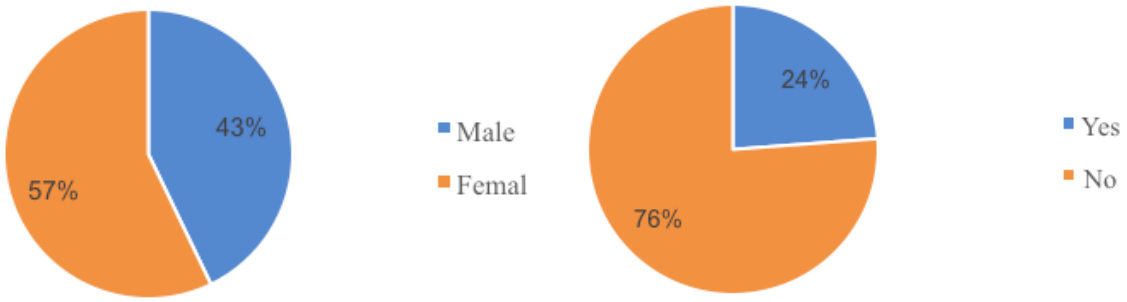

Figure 2 Participants' gender (left). Reported 'use of fan' within the last two weeks of the survey (right).

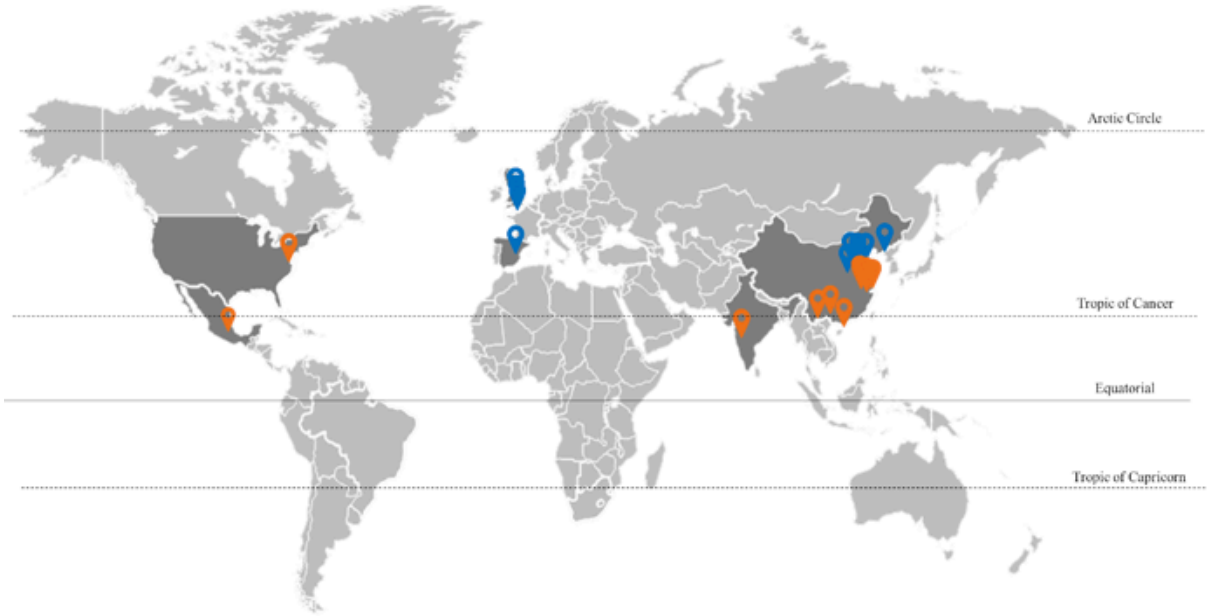

Figure 3 World map showing participants' city of residence in the last two years prior to moving in Southampton

Following the initial survey, participants completed weekly surveys (n=113). This survey included ten questions addressing thermal sensation (TSV) (7-points scale), air movement (AMV), humidity, lighting level, background noise level (NLV), air freshness (AFV), use of windows and use of curtains.

The analysis is formed of four parts; described as follows:

- [Part 1] first, the paper explores relationships between gender, use of fan, prior city of residence, TSV (thermal sensation vote) and AFV (air freshness vote). For this analysis TSV and AFV were transformed into binary variables. TSV 'neutral' was coded as comfortable, while the other categories were coded as uncomfortable. AFV 'very bad', 'bad' and 'slightly bad' were coded as unsuitable, while the other categories were coded as suitable.
- [Part 2] then the paper reviews the reported use of window.

- [Part 3] next the paper explores the relationship between the monitored state of the window at the time of the survey and reported variables from the weekly survey.
- [Part 4] finally the paper reviews a subset of the weekly survey reporting having the window always opened and the monitored state of the window.

Part 1 analysis applied the Pearson's chi-square test with Yate's continuity correction. Results show that there was no significant relationship between (AFV) and (gender, use of fan and prior city of residence), also there was no significant relationship between (TSV) and (gender and prior city of residence). Interestingly there was a significant association between the use of fan and TSV, $\chi2(1)=8.34$, $p<0.05$. Based on the odds ratio, the odds of a participant feeling thermally neutral were 13.75 times higher if the participants did not use a fan. Figure 4 shows that more participants reported to be thermally neutral with no fan. While more participants reported feeling cold, cool, slightly cool, slightly warm, warm and hot with fan. One reason might be that if uncomfortable participants used a fan irrespective of feeling warm or cold; while if feeling neutral participants did not need to use a fan. Future study may explore monitoring the use of fan and other personal control systems (PCS) as predictors of thermal sensation.

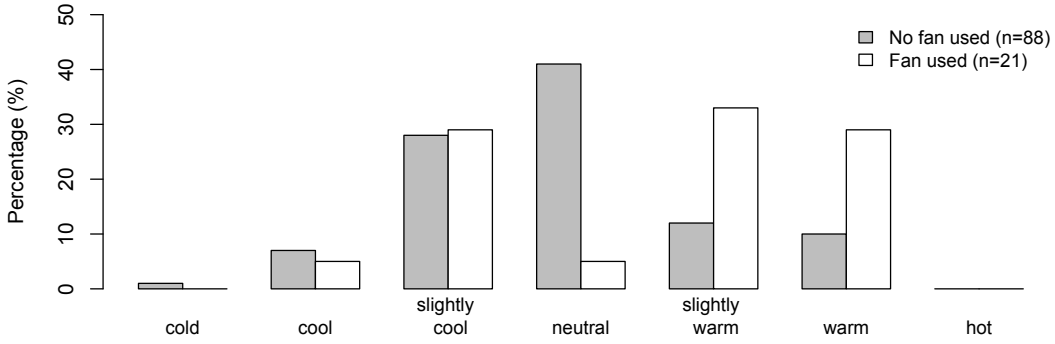

Figure 4 Reported 'use of fan' and TSV

Part 2 reviews the reported use of window during the day of the weekly survey. As shown in Figure 5, 96% of the participants opened their windows on the day of the survey and 66% reported to have their window opened all the time that day. As shown in Figure 6, 29% of the participants felt thermally 'neutral' (TSV) when their window was opened all day; 35% felt 'cool' and 'slightly cool' and 36% felt 'slightly warm' and 'warm'. Therefore having the window opened all day results in balanced TSV. Furthermore as shown in Figure 7, there was no significant relationship between TSV and window opening pattern, $\chi2(1)=3.1$, $p>0.05$.

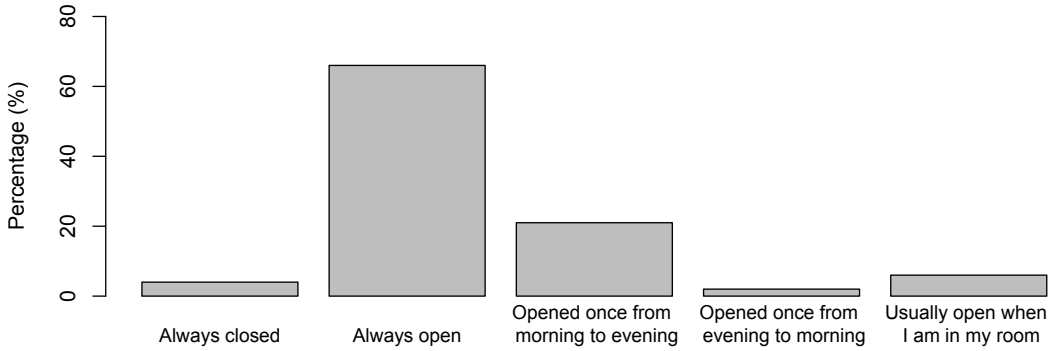

Figure 5 Reported use of window during the day of the weekly survey.

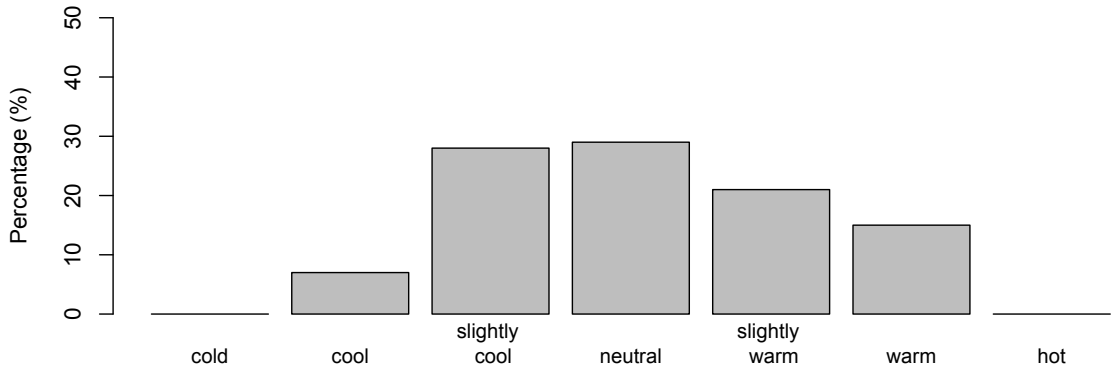

Figure 6 TSV reported by the participants stating having their window always opened during the day of the weekly survey.

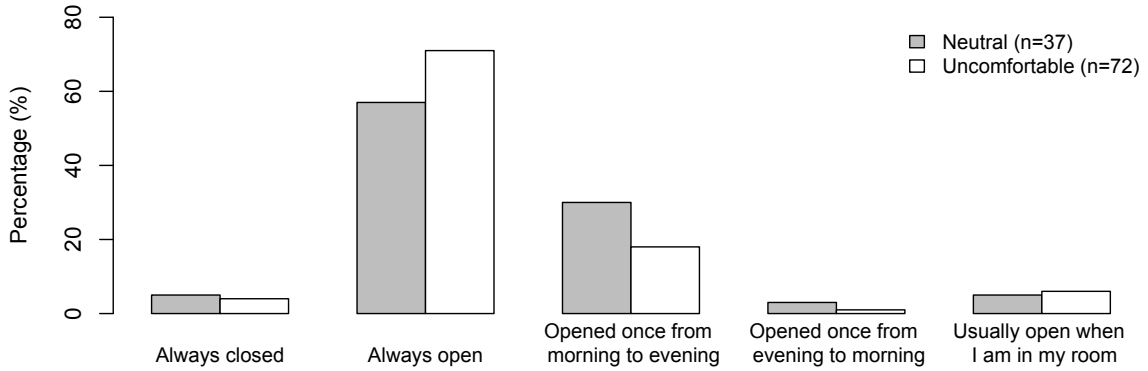

Figure 7 TSV and reported use of window during the day of the weekly survey.

Part 3 explores further the reasons for having a window open. Results show that there was no significant relationship between the monitored state of the window at the time of the survey and reported variables from the weekly survey ($p>0.05$).

Part 4 reviews a subset of the weekly survey reporting having the window always opened and the monitored state of the window from the accelerometer. Interestingly out of the 75 surveys, in 6 surveys the window was closed although the participant reported to have the window opened all day. This shows that there is a gap between reported and monitored responses, which highlight the need for a mixed method approach when studying window opening behaviour.

5. Conclusions

This study has investigated use of windows in a residential building. The study has found that there is a significant association between the use of fan and thermal sensation vote. However, neither gender nor city of previous residence are found to be associated with thermal sensation or air freshness vote. Results also showed that there was a discrepancy between reported and monitored window opening behaviour. Further work could look at personal comfort systems to provide comfort for occupants. As shows in the results, occupants are uncomfortable even when the windows are always open, this could be addressed by increasing the opening angle of the tilt windows. Alternatively, for future university accommodation buildings, flats could be orientated or laid out in a way that allows for cross ventilation.

6. References

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