A Case Study assessing the impact of Shading Systems combined with Night-Time Ventilation strategies on Overheating within a Residential Property.

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ABSTRACT

Overheating in domestic homes, specifically in built up urban areas, has become a pressing problem throughout the UK. It is likely to become a costly energy problem in years to come if passive design strategies are not fully understood and integrated. This research looks to investigate how internal and external solar shading systems impact on operative temperatures when differing blinds together with a night time natural ventilation strategy are adopted within a renovated block of flats in North London. Although shading and ventilation were overlooked at the initial stage of the building design, the implementation of solar shading has been found to be beneficial in maintaining thermal comfort within the building when external temperatures were recorded both above and below 20 - 25°C.

During the study shading was combined with a night-time natural ventilation strategy which enabled most rooms to cool when external temperatures were at their lowest. However, night time ventilation may not be desirable to the occupants due to external traffic noise and security issues in relation to the intended design use of the rooms such as those in this case study. The authors believe lower indoor temperatures could be achieved if the areas of opening were increased in size in the façade design. In two areas of the building natural cross-ventilation was not possible leading to significant overheating issues and the retrofitting of mechanical ventilation. This highlights the need for an effective façade management strategy that considers the inter-relationship between glazing, shading and ventilation collectively at the design stage.

KEYWORDS

Overheating, Night-Time Ventilation, Internal Blinds, External Blinds, Shading.

1 INTRODUCTION

The UK is a predominantly heating reliant nation and it has been identified that the façade, and specifically the glazing system, is the main cause for fabric thermal losses within domestic buildings, improvements of which could lead to substantial energy savings resulting in lower CO_2 emissions (IEA, 2013). The UK government has worked towards energy efficient building standards, Building Regulation - Part L1A, which have reduced unwanted air infiltration and have improved the insulation standard of new homes. Schemes such as the Green Deal in conjunction with Building Regulation – Part L1B have encouraged homeowners to refurbish existing homes to a similar standard. However, through these improvements the number of reported thermal discomfort issues relating to overheating in summer has risen.

The Zero Carbon Hub (2015) has found that up to 20% of the housing stock is subject to overheating alone and in the healthcare sector 90% of hospitals are susceptible to overheating (Seguro and Palmer, 2016). The Good Homes Alliance (2014) identified that urban apartments tend to overheat most frequently. Overall, they identified 90 instances of overheating in domestic buildings in the UK and 73% of these were located in urban locations. 78% (of the 90) of these occurrences were reported in apartments, 48% (of the 90) were new builds (30% had been built post 2000) and 30% were buildings repurposed/refitted into apartments. Within research literature a recent paper by Lomas and Porritt, (2017) reviews 12 studies where overheating has been evidenced across the UK in domestic homes in a mix of building types that vary in age and construction type. However, these studies conducted by different research teams vary in scale, methodologies in defining overheating and data collection procedures which makes comparisons between them problematic.

The term 'overheating' is not clearly defined for post-occupancy evaluations. Recommended operative temperatures for different room purposes are given within CIBSE Guide A (2015), ASHRAE Standard 55 and BS EN 15251:2007 (BSI, 2008). These recommend bedrooms and living areas should remain between 23 - 25°C in summer and between 17 - 19°C in winter. It is important to realise that these temperatures represent the upper and lower limits of thermal comfort and are not representative of long-term temperatures that may cause serious health issues for vulnerable groups. The World Health Organisation (1990) recommended that air temperatures between 18 - 24°C are suitable for healthy sedentary people but for vulnerable groups air temperatures should be maintained at 20°C. The Housing Health and Safety Rating System gives guidance on excess heat and suggests "… temperatures (which) exceed 25°C, mortality increases and there is an increase in strokes" (Department for Communities and Local Government, 2006). This issue was highlighted in 2003, when 2,000 premature deaths occurred in relation to a 10-day heatwave experienced in the UK. These 'heatwave' temperatures are likely to become common summer temperatures as early as 2040 (Public Health England, 2015).

Increased ventilation and solar shading are the recommended strategies for combatting overheating (Zero Carbon Hub, 2015, Serguro & Palmer, 2016, Public Health England, 2015, BRE, 2016, Lomas and Porritt, 2017). However, the barriers to these solutions are those of human behaviour. It has been suggested in the UK Climate Change Risk Assessment 2017 that "…people lack a basic understanding of the risks to health from indoor high temperatures, and are therefore less likely to take measures to safeguard their and their dependents' wellbeing." Natural ventilation in urban areas can be problematic due to issues arising from external noise and security concerns. In a survey given to 89 householders in London windows were also found to be infrequently used with more than half of respondents stating they were unable to open windows due to security reasons and one third asserting they were unable to open them due to high external noises. Furthermore, over the course of a very hot day one in five respondents would not tend to open any windows at night and one in ten would keep all windows closed all day. In total 70% of respondents suggested they would either open one or no windows at night, which limits the potential for night-time ventilation (Mavrogianni et al., 2016).

It is well documented that blinds and shutters are used infrequently and the motivations to instigate blind movements are often related to a number of factors inclusive of lighting conditions, exposure to glare, preference for a view and the associated thermal affects which are then defined by the priorities of the user (Paule et al., 2015, Van Den Wymelenberg, 2012). Within the previously mentioned study conducted in London, even on seemingly hot days one quarter of occupants reported that they did not close blinds during the day (Mavrogianni et al., 2016).

In the UK air conditioning systems are still rarely used within domestic homes however this may change with the increasing frequency of heat waves (BRE, 2016) and the predicted rise of 5°C in annual average temperature in the South-East of England by the end of the century (Hulme et al., 2002). The Energy Performance Building Directive has identified overheating as a concern across Europe and a cause for increasing energy consumption in relation to air conditioning costs. Passive measures, such as solar shading, are recommended to reduce the need and size of air conditioning units which will subsequently reduce energy consumption (Publications Office, 2010, Wouter et al., 2010).

There is little to encourage the requirement for shading systems to be put in place through Part L building regulations, and compliance tools such as BREEAM are ineffective in capturing the benefits solar shading can offer as they are based on averaged weather data sets that pay little attention to the solar heat gains within a building (Seguro and Palmer, 2016). However as 75 - 90% of the buildings have already been built and will still be standing in 2050 (International Energy Agency, 2013), it is also important for industry to understand the impact re-fit options have on the energy consumption, comfort of occupants and the building fabric.

In this study, we aim to investigate the impact that shading and natural ventilation strategies combined can have on a newly refitted, urban apartment taking into consideration user behaviours.

2 FIELD STUDY METHODOLOGY

The case study building is situated in the centre of Camden, London less than a 5-minute walk away from Camden High Street Underground Station. The building was originally constructed for the manufacture of aircraft parts but has now been renovated for residential purposes whilst maintaining the aesthetic of a commercial building. The top part of the building has been transformed from a commercial premises into twenty loft apartments and two penthouse suites on the top floor. The rest of the apartments are spread over three floors above ground and one floor at lower ground (basement) level. The building is south-west orientated (241.58°) with heavily glazed façades on the south-west and north-east face of the building. Overall the building has a medium thermal mass as the walls are constructed from brick with a mix of concrete and timber flooring throughout the building.

The south-west façade of the building is situated on a busy main road in the heart of Camden with a 24-hour use bus stop directly in front of the property. A communal garden area has been created between the front of the building and the pedestrian footpath which consists of a 1.8m wooden fenced surround containing newly planted young evergreen oak trees which will provide privacy from passers-by to the ground floor and provide shading for the ground floor and potentially first floor of the building in years to come (Figure 1.).

In the original building specification, no shading was specified, however during the construction it was reported how some of the apartments appeared to be overheating above acceptable comfort levels. This was causing issues for workers carrying out the re-fit, affecting materials and methods during construction and subsequently created issues with the plumbing system. For example, when the building was left unoccupied for 5-6 weeks, the building manager found that the waste pipe water had evaporated leaving no protection against odour ingress from the sewage system. A member of the British Blind and Shutter Association was approached to give further recommendations of the impact differing shading strategies could have on comfort levels within the building.

The comfort boundaries in this study have been defined by operative temperature recommended by CIBSE Guide A (2015), ASHRAE Standard 55 and BS EN 15251:2007 (BSI, 2008) where bedrooms should remain between 23 - 25°C in summer and between 17-19°C in winter.

For this case study, we have modelled the real-time behaviour of an occupant who leaves their home vacant between 8am and 4pm, keeping the windows closed for security reasons during the day whilst assessing the thermal impact of closing a blind either internally or externally for the duration of 24-hours. We examined what effect this has on the operative temperature increase of a room during the day. This is then statistically compared with the operative temperature increase of an almost identical room without solar shading, the control room, to identify and quantify the temperature reduction achieved through the use of internal and external blinds. It is hypothesised that the operative temperature increase will be reduced when shading is used and this would lead to a positive impact on the level of comfort when an occupant returns to the property in the afternoon.

Figure 1. South-West facing building close to Camden High Street Underground Station (Photograph taken with a wide-angled lens).

2.1 Room Specification

Four bedrooms in two apartments were identified within the building to be evaluated. All the rooms selected were identical in orientation, finish and the amount of glazed area. The bedrooms within apartments 13 and 18 were chosen to be compared (apartment 13 situated on the 1st floor and apartment 18 directly above on the 2nd floor). These two units have identical room layouts (see Figure 2.) with each apartment containing a living room, kitchen, bathroom and two rooms designed as bedrooms.

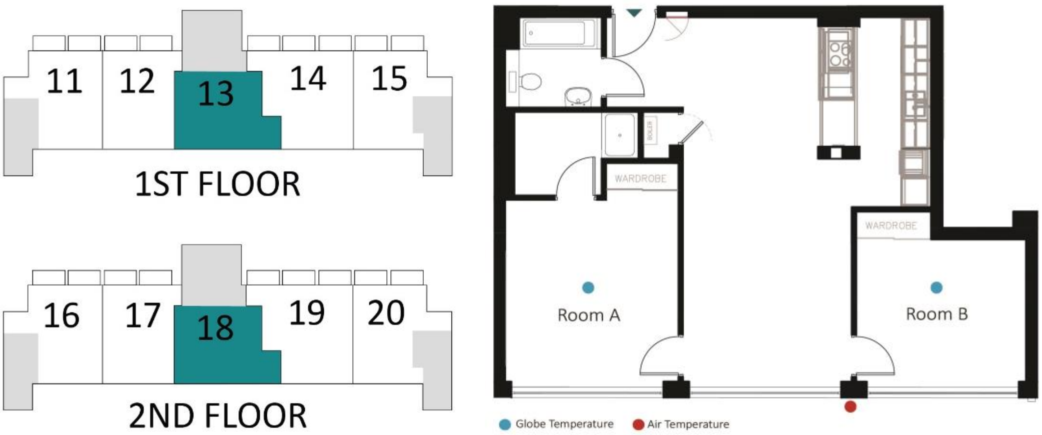

Figure 2. Building floor layout and Unit 13 and 18 layouts with sensor positions.

The bedrooms only differ in room depth; Room A extends to 4.5m and Room B extends to 3.5m. Both Room A and B are 3.5m wide. There was no furniture in either apartment and the walls and floors were finished and painted to the same standard - matt white paint on the walls and oak wood flooring (Figure 3.).

2.2 Façade Design

To allow the building to be used for residential purposes, it has been refitted with double low-e argon filled glazing (4-16-4) with a black/grey spacer which fits into steel window mullions. Both bedrooms (Room A and Room B) have a glazed façade on the south-west wall; the glazed areas are of equal size covering 3.2m x 1.85m and each window is split into three columns which is segmented into four rows. There are two areas of opening which are approximately 850mm x 450mm situated in the centre column with the first (from bottom) and third segment (from bottom) openable (Figure 3.) The glazing sits 1.1m above floor level in all rooms and has been specified to have a U-value of 1.1 W/m^{2}K. No g-value was given by the building developer but the glazing specifier advised that the glazing alone would be adequate to control the solar gains on all façades.

2.3 Solar Shading Selection

We evaluated the impact of three internal and two external solar shading products; an internal 80mm aluminium venetian blind, an internal screen fabric roller blind and an internal reflective screen fabric roller blind. The 80mm aluminium venetian blind and screen fabric roller were also used externally. All types of blinds were tested when fully closed for the period of 8 hours and in addition the external venetian blind was also tested with louvres at an angle of 45°.

The solar properties of each blind type are presented below calculated to BS EN 14501:2005 (BSI, 2005). Even though g_{tot} could not be calculated due to lack of glazing data, this has not compromised the study as the same type and size of glazing was used in each of the rooms.

Table 1: Blind Fabric Specifications according to BS EN 14501.

Blind Fabric	**Material Composition**	**Solar Transmission (Ts or τe)**	**Solar Reflectance (Rs or ρe)**	**Solar Absorptance (As or αe)**
Screen Fabric	42% Fibreglass / 58% PVC	0.10	0.20	0.70
Reflective Screen Fabric	36% Fibreglass / 64% PVC	0.05	0.76	0.19
Aluminium Venetian (80mm)	Aluminium	0.00	0.50	0.50
Aluminium Venetian (80mm) at 45° Angle	Aluminium	0.08	0.38	0.55

2.4 Data Collection Procedure and Measurements

Before each day of data collection, the windows and joining room doors in all bedrooms and the living area were left open overnight to allow for night-time cooling. Blinds were also installed the day previous and positioned fully closed or closed at a 45° angle, for the Venetian blinds. A different shading strategy was installed in each room except for the control room where no blind was installed. The readings were taken manually which required a researcher to enter each room and record the readings on the sensors; each time this was done in the same way; the door was opened and closed as the individual entered and exited the room being monitored and the instrumentation was left in the same position throughout testing.

The data collection procedure was conducted as follows:

- 8am – Windows and Doors Closed, Measurements Start.
- Measurements taken every 10 minutes.
- 4pm – Windows and Doors Opened, Measurements Stopped.

Internal Operative Temperature – A black globe thermometer (40mm Ø) was used with a mercury thermometer as the temperature probe. The sensor was set up on a tripod and positioned 1.8m from the glazed façade and set at 1.2m from floor level within all four rooms being monitored (Figure 3.). The size of the globe used closely correlates with measurements of operative temperature within the indoors, which relates to the temperature humans feel when clothed (Humphreys, 1977).

Figure 3. Room A and B in Unit 18 with sensor setup.

External Air Temperature – An air temperature sensor was situated on the ground floor outside. The handheld air temperature sensor was positioned away from direct solar radiation to prevent the metal probe being affected by radiant heat.

3 RESULTS AND ANALYSIS

Data collection took place over a period of twenty days between August and October 2016. Out of these, data from sixteen of the twenty days met the quality requirements and were used for analysis. On six days (of the sixteen) the peak external air temperature was above 25°C. On five days, the external air temperature peaked between 20 - 25°C and on the remaining five days the temperature peaked below 20°C. Overall external wind velocities were considered calm and the weather conditions were considered typical for summer in London.

3.1 Operative Temperature Increase

The operative temperature increase (range - the difference between lowest and highest operative temperature values recorded in one day) was statistically analysed as the starting temperatures in each room were found to fluctuate due to different thermal retention between different rooms (as different blinds were kept closed) and there were potential differences in air leakage. The ranges were calculated for each individual day and the results are presented in Table 2. alongside the minimum (min) and maximum (max) operative temperatures and the external air temperatures (min, max and range).

The peak operative temperature in the non-blind room exceeded 25°C on 13 of the 14 days monitored. Internal blinds were monitored on 21 occasions, on 13 of these occasions the peak operative temperature reached above 25°C. On 18 of the occasions where external blinds were monitored peak operative temperatures rose above 25°C on 5 occasions.

It is also noted that on several occasions the minimum operative temperature exceeded 25°C as the rooms were unable to naturally cool overnight, due to the small area of opening and lack of cross-ventilation. If the minimum operative temperatures were lower then shading would have been able to maintain temperatures within the comfort threshold.

Table 2. Data collection of indoor temperatures over 16 days across four rooms between 8am and 4pm. The solar shading specified were fixed in either at closed/ lowered position or at a 45° angle for the entirety of the day.

				No Blind			**Internal Blind**									**External Blind**								
							Aluminium Venetian			**Screen Fabric**			**Reflective Screen Fabric**			**Aluminium Venetian**			**Aluminium Venetian at 45°**			**Screen Fabric**		
	External Air Temperature (°C)			**Operative Temperature (°C)**			**Operative Temperature (°C)**			**Operative Temperature (°C)**			**Operative Temperature (°C)**			**Operative Temperature (°C)**			**Operative Temperature (°C)**			**Operative Temperature (°C)**		
Testing Day	Min	Max	Range	Min	Max	Range	Min	Max	Range	Min	Max	Range	Min	Max	Range	Min	Max	Range	Min	Max	Range	Min	Max	Range
Day 1	22.4	34.2	11.8	26.5*	45.0*	18.5	23.5	31.0*	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Day 2	22.5	31.1	8.6	25.0	40.0*	15.0	-	-	-	28.0*	31.0*	3.0	-	-	-	28.0*	28.0*	0.0	-	-	-	-	-	-
Day 3	20.8	27.9	7.1	27.0*	47.5*	20.5	28.5*	34.5*	6.0	27.0*	32.0*	5.0	-	-	-	-	-	-	27.0*	29.5*	2.5	-	-	-
Day 4	17.3	28.3	11.0	-	-	-	27.5*	34.0*	6.5	27.0*	32.0*	5.0	-	-	-	-	-	-	26.0*	29.0*	3.0	-	-	-
Day 5	16.7	28.4	11.7	-	-	-	26.0*	30.0*	4.0	-	-	-	27.0*	32.0*	5.0	-	-	-	-	-	-	26.0*	28.0*	2.0
Day 6	19.7	25.5	5.8	27.0*	36.0*	9.0	21.0	26.0*	5.0	-	-	-	27.0*	31.0*	4.0	-	-	-	-	-	-	-	-	-
Day 7	14.3	23.2	8.9	23.0	39.0*	16.0	-	-	-	21.5	27.0*	5.5	21.0	26.5*	5.5	-	-	-	-	-	-	-	-	-
Day 8	16.9	20.4	3.5	23.0	33.5*	10.5	-	-	-	-	-	-	22.5	25.0*	2.5	21.0	22.5	1.5	-	-	-	22.0	24.0	2.0
Day 9	13.2	20.1	6.9	22.5	42.0*	19.5	-	-	-	-	-	-	21.0	26.5*	5.5	20.0	21.5	1.5	-	-	-	20.5	23.0	2.5
Day 10	10.5	21.4	10.9	22.0	45.0*	23.0	-	-	-	-	-	-	20.5	28.0*	7.5	20.0	22.5	2.5	-	-	-	19.0	26.0*	7.0
Day 11	13.0	20.5	7.5	23.0	44.0*	21.0	-	-	-	-	-	-	-	-	-	20.0	21.0	1.0	-	-	-	20.0	22.0	2.0
Day 12	13.5	18.7	5.2	22.5	39.0*	16.5	-	-	-	-	-	-	-	-	-	20.0	20.5	0.5	-	-	-	19.5	21.0	1.5
Day 13	9.9	18.2	8.3	19.5	38.0*	18.5	18.5	24.0	5.5	18.0	23.0	5.0	-	-	-	-	-	-	19.5	21.5	2.0	-	-	-
Day 14	12.3	16.4	4.1	21.0	37.0*	16.0	19.5	24.0	4.5	18.5	22.5	4.0	-	-	-	-	-	-	20.0	21.5	1.5	-	-	-
Day 15	11.1	16.0	4.9	20.0	32.5*	12.5	-	-	-	18.0	21.5	3.5	-	-	-	-	-	-	19.0	21.0	2.0	-	-	-
Day 16	4.5	15.3	10.8	20.5	24.5	4.0	-	-	-	19.0	20.0	1.0	-	-	-	-	-	-	20.0	20.5	0.5	-	-	-

* Operative Temperature higher than 25°C

3.2 Impact of Blind Position on Operative Temperature Range

The operative temperature increases between 8am and 4pm were statistically compared using a Paired T-Test in SPSS to observe whether:

a) Internal blinds have a significant impact on the operative temperature increase in comparison to the control room.
b) External blinds have a significant impact on the operative temperature increase in comparison to the control room.
c) Whether there is a significant difference on the operative temperature increase between rooms with internal and external blinds.

Table 3. Paired T-Test of no blind operative increase (range) values vs internal blind and external blind operative temperature increase (range) and internal blind operative increase (range) vs external operative temperature increase (range).

				95% Confidence Interval of Difference				
Pair	**No. of Paired Samples**	**Mean (°C)**	**Std. dev (°C)**	**Lower (°C)**	**Upper (°C)**	**t - statistic (°C)**	**Degrees of Freedom**	**Sig. (2 tailed)**
No Blind vs Internal Blind	14	10.71	3.75	8.54	12.88	10.68	13	<0.05
No Blind vs External Blind	10	14.25	5.11	10.60	17.90	8.82	9	<0.05
Internal Blind vs External Blind	12	3.13	1.74	2.02	4.23	6.23	11	<0.05

* Level of Significance 0.05

Table 3. and Figure 4. represent the findings from the statistical review. These indicate that in all cases there was a significant impact on operative temperature increase when both internal and external blinds were used and compared to the control room. It was found that there was a significant relationship between the operative temperature increase between rooms with internal blinds and rooms with external blinds.

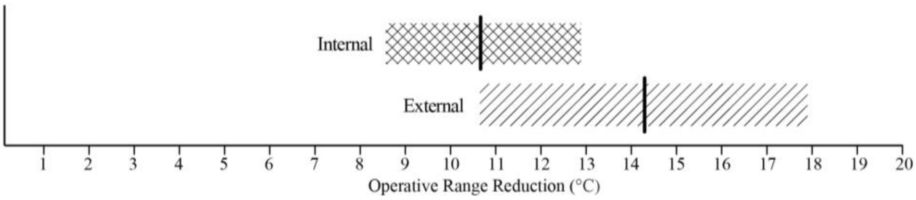

Figure 4. 95% Confidence interval and mean values of internal blind rooms and external blind rooms operative temperature increase (range) compared with a room with no blind.

If the experiment was to be carried out again in the same location, with external conditions within the same parameters and with the same window and blind opening and closing actions, we can say with 95% confidence that:

a) Internal Blinds will reduce the operative temperature increase by between 8.54°C - 12.88°C. The room with an internal blind would therefore be 8.54°C – 12.88°C cooler than a room without a blind.

b) External Blinds would reduce the operative temperature increase in the room by between 10.60°C – 17.90°C. The room with an external blind would therefore be 10.60°C – 17.90°C cooler than a room without a blind.
c) The difference in operative temperature increase between a room with an internal blind and an external blind installed would be between 2.02°C and 4.23°C. In effect the external blind room would be 2.02°C – 4.23°C cooler than a room with an internal blind.

External blinds, as hypothesised, have been found to reduce operative temperature increase more than internal blinds.

3.3 Impact of different blind types on Operative Temperature Range

To understand how different blind types and their properties impact the operative temperature, a paired T-Test was carried out comparing the operative temperature increase of the control room to that of a room with a specific blind type installed at a closed position or in the case of external aluminium venetians with louvres at a 45° angle.

Table 4. Paired T-Test of no blind operative increase (range) values vs specific blind types operative temperature increase (range).

				95% Confidence Interval of Difference				
Pair	**No. of Paired Samples**	**Mean (°C)**	**Std. dev (°C)**	**Lower (°C)**	**Upper (°C)**	**t - statistic (°C)**	**Deg. of Freedom**	**Sig. (2 tailed)**
No Blind vs Int. Aluminium Venetian	5	10.30	3.07	6.48	14.12	7.49	4	< 0.05
No Blind vs Int. Screen Fabric	7	10.79	4.01	7.08	14.49	7.12	6	< 0.05
No Blind vs Int. Reflective Screen Fabric	5	10.60	4.29	5.27	15.93	5.52	4	< 0.05
No Blind vs Ext. Aluminium Venetian	6	16.42	4.22	11.98	20.85	9.52	5	< 0.05
No Blind vs Ext Aluminium Venetian at 45°	5	12.60	5.81	5.38	19.82	4.85	4	< 0.05
No Blind vs Ext. Screen Fabric	5	15.10	3.97	10.16	20.04	8.49	4	< 0.05

* Level of Significance 0.05

The results of the T-Test are presented in Table 4. Once again, all blinds were found to have a statistically significant relationship with the operative temperature increase. The mean, lower and upper confidence intervals vary depending on the properties of the blind type and the location of the products (internal or external).

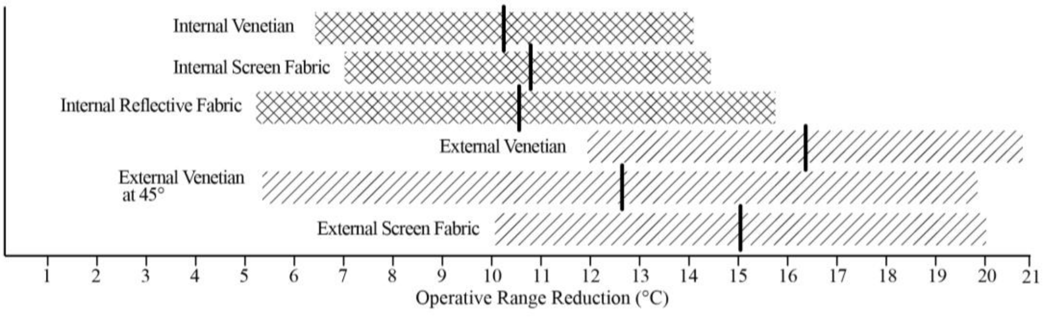

Figure 5. 95% Confidence interval and mean values of all blind types operative temperature increase (range) compared with a room with no blind.

From Figure 5. we observe how the external blinds provide the largest mean difference in operative temperature increase indicating that they limit solar gain effectively.

It is important to recognise the extent of the impact that the internal blinds have on the operative temperature. They have also been able to significantly reduce the operative temperature increase - by 68 - 73% when compared to the operative temperature reduction achieved by external blinds. This means that internal blinds are almost three quarters as effective as external blinds within this building scenario.

4 DISCUSSION

In the design stage of the building external shading was discouraged by the planning authority on the basis it would not be a necessity and therefore would not justify the impact on the aesthetics of the building. This was further supported by the glazing specifier where the developer was informed the glazing alone would obviate the requirement for solar shading.

This only proves that there are a number of design decisions during the refit of a building that may contribute to issues of overheating which are not fully understood.

Solar shading combined with night-time ventilation in this case has been evidenced to reduce operative temperature increase. There are several other design factors that can also contribute to overheating and these need to be considered and evaluated before construction or re-fit. These are: the location and orientation of the building, ceiling height, room depth, insulation and potential for air leakage, thermal mass of the building, façade design layout, hot water distribution layout and the ability to cross ventilate the building.

5 CONCLUSION

The study conducted has demonstrated how solar shading when combined with night-time ventilation can be an effective method in reducing operative temperature increase in an urban flat. Although external shading is observed to be most efficient, internal shading in this study demonstrated that it can achieve as much as 73% of the operative temperature reduction as that of as external shading. The use of external shading is not widespread practice in the UK as windows are often outward opening. This would prevent opening of the windows when external shading is extended and situated close to the building façade.

The behaviour behind opening and closing of windows and blinds has been documented to be poorly understood and underutilised. Initiation of movements can be confounded by a number of behavioural factors, particularly in urban areas, where noise pollution, security and availability of daylight are often prioritised over thermal comfort. Within unoccupied rooms changes in solar shading and window opening behaviour could have a beneficial impact on the thermal conditions experienced in a living space later in the day and over a period of time also on the building fabric of a building. The benefits of improved thermal comfort could also considerably reduce the energy requirement from mechanical ventilation systems, especially if users are educated on the best window opening and blind movement strategies and apply these to their daily lives.

Lastly, appropriate specification of glazing systems is vital in combatting the issues of overheating. Increasing the area of openings in a façade design is essential for night-time ventilation of buildings particularly in single aspect designed buildings. Also, clarity is needed on the importance of g-value specification at the design stage to ensure buildings are designed so they do not overheat.

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