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 within the UK that may 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 an optimum blind and ventilation strategy is adopted within a renovated block of flats in London. Although shading and ventilation were overlooked at the initial stage of 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 combined with the intended design use of the rooms as in this case study. The authors believe lower indoor temperatures could be achieved if window opening areas were increased in the façade design. In two areas of the building natural ventilation was not possible leading to significant overheating and the retrofitting of mechanical ventilation. This highlights the need for an effective façade management strategy considering the 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, but specifically the glazing system, is the main cause for thermal losses within domestic buildings, improvements of which could lead to substantial energy savings resulting in lower CO2 emissions (IEA, 2013). The UK government have worked towards energy efficient building standards, Part L, which have reduced unwanted air infiltration and improved the insulation standard of existing homes, 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, they observed 90 instances of overheating in domestic buildings in the UK, 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% had been repurposed/refitted buildings into apartments. Within research literature a recent paper published in 2017 (Lomas and Porritt, 2017) reviews 7 papers 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 vary in scale, methodologies in defining overheating and data collection procedure which makes comparisons between studies problematic.

The definition of ‘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) which recommends in summer bedrooms and living areas should remain between 23-25°C and in winter should be between 17- 19°C. 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) recommends that temperatures between 18 – 24°C in air temperature 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 for excess heat and suggests for “… 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 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 issues. 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).

Within residential homes it is recommended to keep noise in bedrooms within the remit of 25 NR, 30 dBA and 55 dBC and living rooms at 30NR, 35 dBA and 60 dBC (CIBSE, 2015). In BS 8233 (BSI, 2014) time restrictions are given for internal ambient noise levels for dwellings between the times of 11pm and 7am a level of 30dBA, in order to prevent health issues in relation to sleep quality. During the day a level of 35dBA is considered acceptable.

It is well documented that blinds and shutters are infrequently used and the motivation 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 occurrence of heat waves becoming more frequent (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).

There is little to encourage the requirement for shading systems to be put in place through Part L building standards, 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 it is important for industry to understand the impact re-fit options have on the energy consumption, comfort of occupants and the building fabric (International Energy Agency, 2013). We look to investigate the impact shading and natural ventilation strategies can have on a newly refitted, urban apartment if optimal user behaviours are encouraged.

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 Hight Street Underground Station. The building was originally used for the manufacture of aircraft parts in the 1930s which was then sold onto a theatrical shoe manufacturer. The last owner of the building was a photographic library. More recently the building has been sold and renovated for residential purposes whilst maintaining the aesthetic of a commercial building (Anello building, 2016). The building has been transformed from a commercial premise into twenty loft apartments and two penthouse suites on the top floor, the apartments are spread over three floors above ground and one lower ground (basement) level. The building is orientated south-west (241.58°) with heavily glazed facades on the south-west and north-east face of the building.

The south-west façade of the building is situated on a busy main road in the heart of Camden with a bus stop directly in front of the property which has 24-hour use. A communal garden area has been created between the front of the building and the pedestrian footpath which consist 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. When the building was left un-occupied for 5-6 weeks before it was fully furnished the building manager found that the waste pipe water had evaporated leaving no protection against ingress from the sewage system. The British Blind and Shutter Association were 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 and in winter should be between 17- 19°C. Noise levels should be below 30DbA to maintain comfort in bedrooms (CIBSE Guide A, 2015).

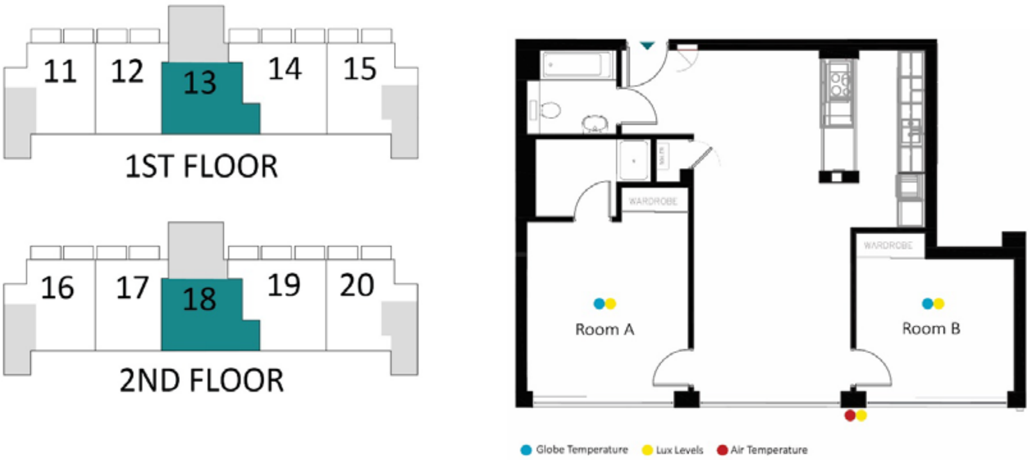
For this case study, we have modelled the behaviour of an occupant who leaves their home vacant between 8am and 4pm, keeping the windows closed for security reasons during the day whilst assessing the thermal impact of closing a blind either internally or externally for the duration of the day and examining 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 a room without solar shading to identify the temperature reduction that is offered through use of internal and external blinds through reducing the operative temperature increase; which would subsequently impact the level of comfort an occupant would experience on their return to the property.

Figure 1. South-West facing building close to Camden High Street Underground Station

2.1 Room Specification

Four rooms were identified within the building to be evaluated, the rooms selected were of similar (if not identical) size, orientation, finish, had the same size glazed area that would be exposed to the same level of solar radiation externally. The bedrooms within apartments 13 and 18 were chosen to be compared, apartment 13 situated on the 1st Floor and apartment 18 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 sensors



The rooms only differ in room depth; Room A extends to 4.5m in depth and Room B extends to 3.5m in depth. Room A and B are both 3.5m wide. Lastly in all the rooms there was no furniture installed and the walls and floors were finished and painted to the same standard, matte white paint on the walls and oak wood flooring (Figure 4.).

2.2 Façade Design

To allow the building to be used for residential purposes the building 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 openings which are approximately 850mm x 450mm situated in the centre column with the first (from bottom) and third segment (from bottom) openable (Figure 4.) 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 however no G-value was given to the building developer but the glazing specifier advised that the glazing alone would be adequate to control the solar gains on all facades (addressed further in the discussions section).

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 composed of 42% Fibreglass & 58% PVC; an internal reflective screen fabric roller blind which is made from 36% Fibreglass and 64% PVC. The 80mm aluminium venetian blind and screen fabric roller were also tested externally. All blinds were tested when positioned fully closed and the external venetian blind was additionally tested at an angle of 45°.

The solar properties of each blind type are presented below calculated to BS EN 14501 (BSI, 2005), as no g-value for the glazing was specified to the building developer by the glazing specifier we were unable to calculate the g-tot of the glazing system.

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

Blind Fabric	**Solar Transmission (T_s / τ_e)**	**Solar Reflectance (R_s / ρ_e)**	**Solar Absorptance (A_s / α_e)**
Screen Fabric	0.10	0.20	0.70
Reflective Screen Fabric	0.05	0.76	0.19
Aluminium Venetian (80mm)	0.00	0.50	0.50
Aluminium Venetian (80mm) at 45° Angle	0.08	0.38	0.55

2.4 Data Collection Procedure

Before each day of data collection, the windows and doors in all bedrooms and the living area were left open overnight to allow for night-time cooling and the blinds were positioned closed or at a 45° angle, except for one room where no blind was installed. All the other rooms had a differing shading system in place. At 8am the windows and joining room doors were then closed to match the user pattern of leaving the home and going to work. External air temperature and internal operative temperature measurements were then recorded every 10 minutes. 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 the door was opened and closed as the individual entered and exited the room being monitored. The black globe thermometer was left positioned in the room throughout testing. At 4pm measurements were stopped and the windows and adjoining room doors were re-opened to allow the building to cool over night for the following days testing.

2.5 Measurements

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 4.). 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 4. Room A and B in Unit 18 with sensor setup

Room A: No Blind Installed — Room B: 80mm Aluminium Venetian Blind

External Air Temperature – A 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.

Noise - Post testing the researcher returned to site to evaluate the sound transmission within each room. The Nor 140 Sound Analyser was positioned at the centre of the room with windows open and in a room with windows closed. LAeq,T values were recorded over the period of 4 days Thursday – Sunday to give an ambient noise level.

3 RESULTS AND ANALYSIS

Data collection started in August 2016 and finished in October 2016 which consisted of twenty days' worth of data, four days were discounted due to variations in testing and were discounted due to quality control. The sixteen days of data comprised of six days where the external air temperature was above 25°C, five days where the external air temperature was between 20 - 25°C and five days where the external temperatures were below 20°C at peak each day.

3.1 Operative Temperature Increase

The operative temperature increase (range) was used for comparison as the starting temperatures in each room were found to differ due to difference in thermal retention between the rooms (as blinds were kept closed overnight) and potential differences in air leakage between rooms. Between 8am and 4pm the range was calculated and the results are presented in Table 2. alongside the minimum (min) and maximum (max) operative temperatures recorded each day and the external air temperature.

The maximum operative temperature in the non-bind room exceeded 25°C on 13 of the 14 cases monitored. Of the 21 cases where internal blinds were monitored 13 of them resulted in operative temperatures over 25°C and of the 18 cases where external blinds were used there were 5 cases.

Table 2. Sixteen days of data collection across four rooms between 8am and 4pm where the solar shading specified are fixed in a closed 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 more than 25°C

3.2 Impact of Blind Position on Operative Temperature Range

The operative temperature increase between 8am and 4pm were statistically compared using a Paired T-Test; to firstly observe whether internal blinds have a significant impact on the operative temperature increase of a room in comparison to a room without a blind; secondly to compare the impact external blinds have on the operative temperature increase of a room in comparison to a room without a blind; and lastly if there is a significant difference in the increase in operative temperature between rooms with internal blinds and rooms with external blinds.

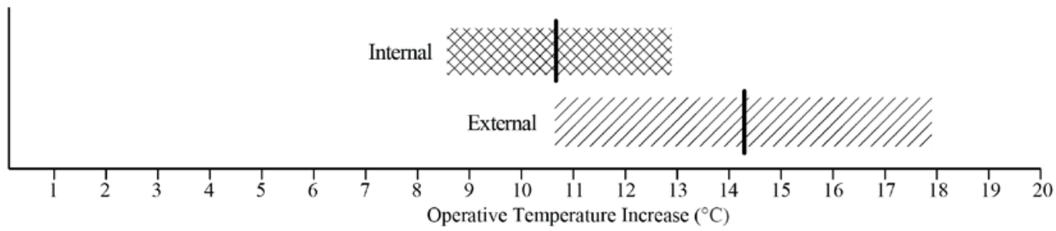
Table 3. Paired T-Test of no blind operative increase (range) values vs internal blind and external blind operative temperature increase (range) and internal blind operative increase (range) vs external operative temperature increase (range).

				95% Confidence Interval of Difference				
Pair	**N**	**Mean (°C)**	**Std. dev (°C)**	**Lower (°C)**	**Upper (°C)**	**t**	**df**	**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. represents the findings from the statistical review which indicates that in all cases there was a significant impact upon operative temperature increase when internal blinds were used and compared to no blind at all. There was also significant impact when external blinds were used in comparison to no blind at all and lastly it was found that there was a meaningful relationship between the operative temperature increase between rooms with internal blinds and rooms with external blinds.

Figure 5. 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 and the external conditions affecting the building were within the same parameters, we can say with 95% confidence that a room with an internal blind and window closed between 8am and 4pm the operative temperature increase within the room would be 8.54°C - 12.88°C lower than a room without a blind, in effect 8.54°C – 12.88°C cooler than a room without a blind. Equally if an external blind was installed the room would be 11.27°C - 18.38°C cooler and the difference in operative temperature between a room with an external blind and an internal blind installed would be between 1.99°C and 4.45°C cooler.

3.3 Impact of Blind Type on Operative Temperature Range

To understand how the different properties of a blind impact the operative temperature a paired T-Test was carried out comparing the operative temperature increase (range) of a room without a blind to that of a room with a specific blind type installed at a closed position or 45° angle.

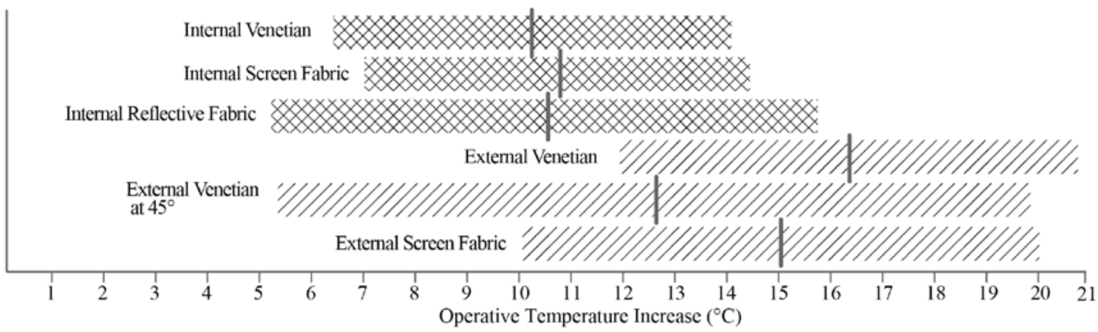
Table 4. Paired T-Test of no blind operative increase (range) values vs specific blind types operative temperature increase (range).

Pair	N	Mean (°C)	Std. dev (°C)	95% Confidence Interval of Difference Lower (°C)	95% Confidence Interval of Difference Upper (°C)	t	df	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

As previous, all blinds were found to have a statistical significant relationship of operative temperature increase when compared to a room without a blind and this has been evaluated for each specific blind type. The mean, lower and upper confidence interval vary dependent on the properties of the blind type and the location of the product (internal or external). Although these results are acknowledged as significant the N values are small which weakens the power in the test.

Figure 6. 95% Confidence interval and mean values of all blind types operative temperature increase (range) compared with a room with no blind.



From Figure.6 we observe how both the external venetian blind and the external screen fabric blind provide the largest mean difference in operative temperature increase indicating that they protect the interior room effectively from unwanted solar gains. With an external venetian blind angled at 45° the operative temperature increase has the broadest range as solar gains are able to penetrate the interior of the room dependant on the angle of solar incidence in relation to the blind.

Between the internal blind types the internal screen reflective fabric (which has a higher solar reflectance (Table 1.) than the internal aluminium venetian blind and screen fabric blind) was hypothesised to be the most effective at reducing operative temperature increase. However, our results show that the reflective screen blind is less effective at reducing operative temperature increase within the room. Reflecting on the data collected this may be due to the intensity of the testing where the Screen Reflective Fabric was tested on days when the no blind room operative temperature peaked between 33.5°C and 45°C where the Screen Fabric and the Aluminium Venetian blinds were tested on days when the operative temperature was between 24.5°C and 47.5°C. The mean values between each internal blind appear very close unfortunately there was not enough power in the test and a reject null hypothesis was obtained between when comparisons were made between blind types

It is important to recognise the extent of the impact that all three internal blinds have on the operative temperature. They can significantly reduce the operative temperature increase by 68 - 73% when compared to the operative temperature reduction achieved by external blinds within this building scenario.

3.4 Noise Transmission

Over the 4 days the noise experienced within the room with windows open was averaged to take into consideration work rush hour traffic and periods of times at night where external noise would be reduced. This resulted in 61Db LAeq,T and 43Db LAeq,T recorded for a room with a window open and a room with the window closed retrospectively.

Considering that even with the windows closed the values exceed 35Db LAeq,T we can assume that occupants would be inclined to keep windows closed in order to improve their acoustic comfort when they are within the building specifically at night when they are trying to sleep

4 DISCUSSION

In the design stage of the building lifecycle the building specifier considered the use of external shading but 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.

Although the glazing system has been evidenced to contribute to overheating in this scenario it is important to note that other design decisions during the refit of the building would also contribute to the extent of the building overheating such as the ceiling height, location and orientation, depth of room, insulation and potential for air leakage, thermal mass of the building, single sided design layout for glazing, hot water distribution layout and the lack of ability to cross ventilate the building.

In the penthouses of the case study building full height glazing has been retrofitted alongside mechanical ventilation. Two types of internal shading have been installed since the study in an attempt to reduce the load on the air conditioning system and improve comfort levels by providing a screen blind to enable daylight penetration, whilst reducing solar gains and a block out blind to provide privacy. External shading has also been installed to the East Façade of the building where the building aesthetics are of lesser value.

5 CONCLUSION

The study described 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 optimal, internal shading in this study demonstrated it can achieve as much as 73% of the operative temperature reduction as external shading. External shading is not widespread practice within the UK as windows are often openable outwards which prevents opening of windows when external shading is positioned closed and situated close to the building facade.

The opening and closing behaviour of windows and blinds has been documented to be poorly understood and underutilised by occupants, initiation of movements can be confounded by a number 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 on the building fabric of a building. The benefits in thermal comfort could also considerably reduce the energy requirement from mechanical ventilation systems if users are educated on the best window opening and blind movement strategies.

Lastly appropriate specification of glazing systems is vital in combatting the issues of overheating, increasing window opening areas is essential for night-time ventilation of buildings particularly in single aspect designed buildings and clarity is needed on the importance of g-value specification at the design stage to ensure buildings are designed so they do not overheat but are also suitable in winter.

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