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Adaptive Behaviours and Occupancy Patterns in UK Primary Schools: Impacts on Comfort and Indoor Quality

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Abstract: To improve the quality of school environment and reach state of comfort, it's important that teachers and students take appropriate personal and environmental adaptive behaviours. Studies on adaptive behaviours are mainly focused on adults, especially in residential and office buildings while children's adaptive behaviours at schools are not largely studied. This paper has investigated adaptive behaviours, influential factors and their impact on comfort and indoor quality by doing field studies in 4 primary schools and 15 classrooms in Coventry, UK during July, September, October and November 2017 through observations, subjective and objective measurements. The results are derived from observations on around 400 students aged 9-11 and from more than 600 surveys. Results illustrate that students usually take personal adaptive behaviours after or before breaks, and the number of these behaviours increases during warmer seasons and in afternoon sessions. Students' decisions over appropriate clothing level is related to time of year, however, 27% of students could improve their thermal vote by taking off or taking on jumpers/cardigans. Some environmental adaptive behaviours like door operation are less related to climatic factors, however, window operation is correlated to indoor temperature (R^2=0.29) and outdoor temperature (R^2=0.35). Observations show that around 80% of all environmental adaptive behaviours are done by teachers, teacher assistants or on their request, which can provide conditions that are not comfortable for children. Therefore, it is important to facilitate adaptive behaviour of children to improve their comfort level.

Keywords: Adaptive Behaviors, Comfort, Indoor Quality, Children, Schools

1. Introduction

According to the adaptive approach by Nicol & Humphreys (2002) , "if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort". From the biological perspective, occupants interact with the environment to secure and restore their comfort if appropriate opportunity is provided (Humphreys and Nicol, 1998). Two forms of adaptive behaviours introduced by Nicol et al. (2004) are those which help occupants to feel comfortable in the present situation like removing a jacket or changing postures, called personal behaviours, and those which are taken to make the environment comfortable for the subjects like controlling windows or shadings, called environmental behaviours.

Adaptive behaviours are influenced by climatic factors like temperature, wind speed, air movement, humidity, solar intensity and CO_2 concentration (Humphreys and Nicol, 1998; Nicol, Humphreys and Olesen, 2004; Fabi *et al.*, 2012). The study by Fabi et al. (2012) has suggested other drivers than climatic factors for occupants' behaviour including contextual (e.g., building properties, orientation, heating and ventilation type, season, occupancy patterns and time of day), psychological (expectations, habits, perception, financial and environmental concerns and lifestyle), physiological (age, gender, clothing, activity level, food or beverage intake) and social (occupants' interactions for determining adaptive action).

Occupancy patterns include proximity to the control, the number of occupants sharing a control or type of space (private or shared), arrival and departure patterns or occupancy intervals (just after arrival, intermediate, just before departure) (Gunay, O'Brien and Beausoleil-Morrison, 2013; O'Brien and Gunay, 2014). The study by O'Brien and Gunay (2014) has also identified other contextual factors including availability of controls, accessibility of controls, complexity and transparency of automation systems, presence of mechanical/electrical systems, view and connection with outside, interior design, experience and foreseeable future conditions, visibility of energy use and social constraints (O'Brien and Gunay, 2014). The study by (Humphreys and Nicol, 1998) has discussed circumstances that restrict adaptive actions which are culture, affluence, working conditions, comfort operated by another occupant, conflicting requirements, personality, fashion and health.

To reach comfort and improve environment's quality, many studies have refered to the role of adaptive behaviours (Raja *et al.*, 2001; Nicol and Humphreys, 2002; Rijal *et al.*, 2007; Herkel, Knapp and Pfafferott, 2008; Fabi *et al.*, 2012; Nicol, Humphreys and Roaf, 2012; Gunay, O'Brien and Beausoleil-Morrison, 2013) and its effect on occupants' forgiveness and satisfaction (Baker and Standeven, 1997; Leaman and Bordass, 1999, 2007; Humphreys, 2005; Nicol and Roaf, 2005; Roulet *et al.*, 2006; Frontczak and Wargocki, 2011). According to Dubrul (1988), behaviours are stongly related to comfort perception. Occupants who have the possibility to control their environment, suffer from fewer building related symptoms (Paciuk, 1990; Brager, Paliaga and Dear, 2004; Toftum, Andersen and Jensen, 2009), can tolerate higher temperatures (Brager, Paliaga and Dear, 2004) and discomfort is reported less by them (Raja *et al.*, 2001).

Personal and environmental adaptive behaviors and operation of controls can directly or indirectly affect students' comfort in educational buildings and are related to several factors.

On personal behaviours in educational buildings, studies have shown that students' clothing level usually follows sequence of temperature, running mean temperature and long term fluctuation in temperature (Nicol and Humphreys, 1973; Humphreys, 1974, 1977). Study by Humphreys (1974) shows that clothing level depends on the room temperature; optimum temperature for students with light clothing occurs at 24.5^{o}C, for students with heavy clothing occurs at 21.5^{o}C and for students with winter clothing occurs at 18.5^{o}C (Humphreys, 1974). Humphreys (1977) shows that the effect of temperature changes during day on discomfort was more than its effect on clothing level. On activity type, the study by Raja and Nicol (1997) shows that within the freedom students have for type of activity, more open activities are preferred as temperature increases more.

On environmental adaptive behaviors in educational buildings, studies have shown that window operation is influenced by outdoor temperature (Dutton and Shao, 2010; Stazi, Naspi and D'Orazio, 2017), indoor temperature (Santamouris *et al.*, 2008; Stazi, Naspi and D'Orazio, 2017), humidity (Dutton and Shao, 2010), CO_2 level (Dutton and Shao, 2010), time of day (Stazi, Naspi and D'Orazio, 2017) and noise level (Montazami, Wilson and Nicol, 2012). Blinds are operated to avoid glare or sunlight (Theodorson, 2009; Montazami and Gaterell, 2014), prevent overheating (Montazami and Gaterell, 2014), limit outside distractions (Montazami and Gaterell, 2014), provide outside views (Sanati and Utzinger, 2013) and to darken the room for presentations (Theodorson, 2009). Blinds' ease of use (Sze, 2009; Sanati and Utzinger, 2013) and window design (Sanati and Utzinger, 2013) also affect the operation of blinds.

To provide indoor environment quality in schools and reach state of comfort, it's important that children and teachers take appropriate adaptive behaviours and the chance to exercise those adaptive behaviours should be provided for them. Therefore, the main objectives of the paper are as follows:

- To investigate what factors affect adaptive behaviours of primary school children and how these factors affect students' practice
- To examine the effect of adaptive behaviours and occupancy patterns on environmental variables and state of comfort

2. Methodology

Field studies were carried out in 4 primary schools and 15 classrooms in West Midlands, UK during July, September, October and November 2017, consisting of objective measurements, subjective measurements and observations.

2.1. Climate and weather during data collection

The investigated primary schools are located in Coventry which is the second largest city in the West Midlands region. During the field study time from 17 July to 24 November, highest and lowest average outdoor temperature for occupancy pattern of primary school children were recorded 23^{0}C in July/18 and 6.15^{0}C in November/24, respectively, as shown in Fig 1. Field studies were conducted in a wide range of outdoor temperature from 2.3^{0}C in November/24 to 24.9^{0}C in July/18. During the time field studies were conducted, relative humidity changed from 50-85% in July, from 81-92% in September and from 75-90% in October and November, with one rainy day in July, two rainy days in September and no rainy days in October and November. Outdoor variables were collected from local stations (Weather Observations Website, 2017).

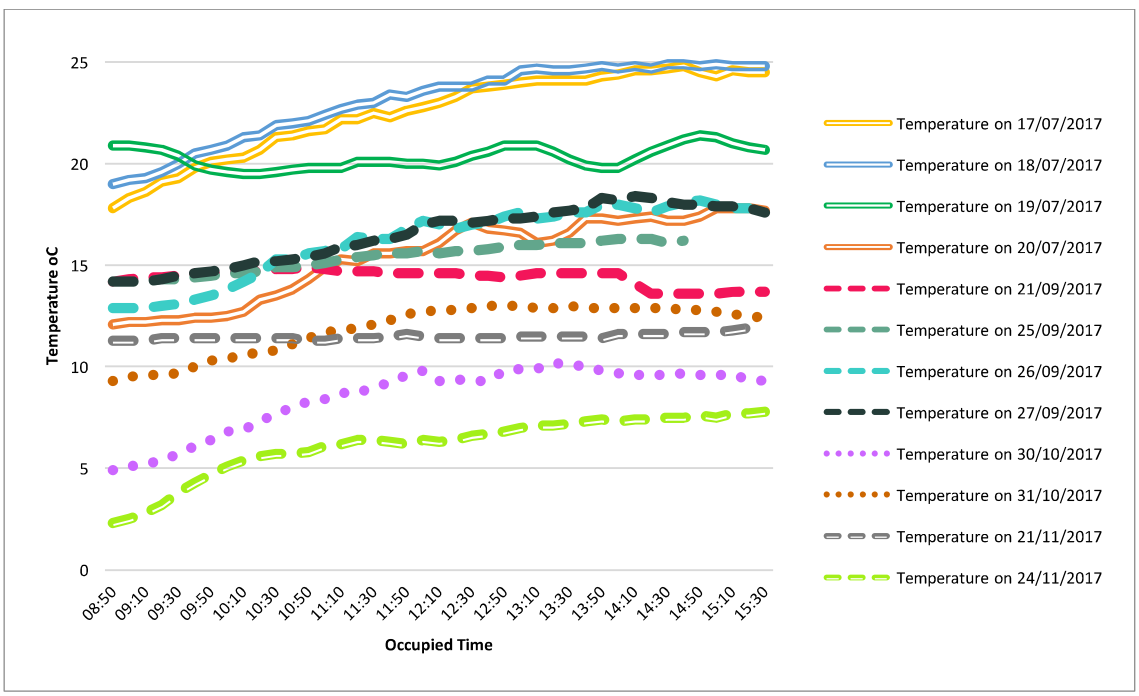
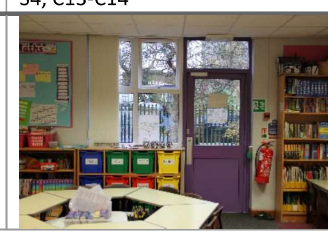


Figure **1**. Outdoor temperature of Coventry during occupied time of field study, retrieved from (Weather Observations Website, 2017)

Table 1. An overview of architectural features of classrooms and controls

School & Class Number	Date	Classroom Orientation	Floor	Area (m^2)	Area of Operable Windows (m^2)	Area of Non-operable Windows (m^2)	Area of door Glazing (m^2)	Total Area of Glazing (m^2)	Number of Operable Windows	Type of Window Operation	Min Height of Operable Window Sill (m)	Exterior Door
S1, C1	17/07/2007	North East	First Floor	60	8	0	0	8	8	Manual	1	No
S1, C2	18/07/2017	South West	First Floor	60	8	0	0	8	8	Manual	1	No
S1, C3	19/07/2017	South West	First Floor	60	8	0	0	8	8	Manual	1	No
S1, C4	20/07/2017	South West	First Floor	60	8	0	0	8	8	Manual	1	No
S1, C5	21/07/2017	North East	First Floor	60	8	0	0	8	8	Manual	1	No
S2, C6	21/09/2017	North West	First Floor	60	8	0	0	8	8	Manual	1	No
S2, C7	25/09/2017	South East	First Floor	60	8	0	0	8	8	Manual	1	No
S2, C8	26/09/2017	South East	First Floor	60	8	0	0	8	8	Manual	1	No
S2, C9	27/09/2017	North West	First Floor	60	8	0	0	8	8	Manual	1	No
S3, C10	30/10/2017	South and West	Ground Floor	65	2.2	8	0	9	6	Manual	1.6	Yes
S3, C11	31/10/2017	South and Northwest	Ground Floor	65	2.2	8	0	9	6	Manual	1.6	No
S3, C12	01/11/2017	North West	First Floor	60	2.5	4	0	6.5	5	Manual with a handle	2.6	No
S4, C13	21/11/2017	West	Ground Floor	45	0.5	0.8	1	2.3	2	Manual	1.8	Yes
S4, C14	22/11/2017	West	Ground Floor	60	0.5	0.8	1	2.3	2	Manual	1.8	Yes
S4, C15	24/11/2017	No window	Ground Floor	60	0	0	1	2.3	0	Manual	1.8	No

Table 2. Several photos of classrooms and windows, Photos by Sepideh Korsavi

S1, C1- S2, C9	S3, C10	S3, C11	S3, C12	S4, C13-C14
				

2.2. Buildings Description

The investigated primary schools are all two-story naturally ventilated buildings with classrooms in different designs and orientations as the study aims to find out how architectural feature affect students' adaptive behaviours. Table 1 shows some architectural features of the classrooms like design of windows play a main role on adaptive behaviours of students. Architectural features of classrooms including their area and orientation, windows' area and characteristics and their type of the operation (i.e. manual or automatic) are listed in Table 1. Controls that can be operated in each classroom include windows, blinds, interior door, exterior door and fan, if any. Several classrooms located in the ground floor might have an exterior door to the playground which is usually operated according to occupancy patterns and on breaks. The only classroom that had cooling fan was Classroom 2 in School 1 and the fan was operated during summer days. Heating systems are operated by caretakers so they are not considered as controls that can be operated in the classroom. Table 2 shows five different window designs, with classrooms 1-9 having the same design; however, classroom 10-14 have different designs and classrooms 15 does not have any window.

2.3. Data acquisition

For the objective of the study, subjective measurements, observations and objective measurements were conducted in 15 classrooms to obtain more reliable data.

2.3.1. Subjective measurements and Observations:

The paper-based survey, which asks about 'personal adaptive behaviours like change in clothing level, fanning and drinking', thermal sensation and preference, comfort and tiredness, is designed for 9-11 years old students (year 5 and year 6) who can read and write easily. More than 600 questionnaires were collected from morning and afternoon sessions, with students filling out surveys once at the end of morning session and once at the end of afternoon session. The design of the study defines transverse sampling in which bias is lowered or avoided, thus, the results are more representative.

Through observations, each student was given a reference number which made observing and recording adaptive behaviours possible. Personal and environmental adaptive behaviours of around 400 students were observed and recorded in a logbook. The results derived from these observations help to verify surveys' results as reference numbers were written on top of each survey. Table 1 provides an overview of the number of students and the number of collected surveys in each school.

Table 3. An overview of the number of students and collected surveys

School Number	Date	Number of observed students	Number of collected surveys during morning and afternoon sessions
School 1	17-21 July 2017	130	200
School 2	21-27 September 2017	110	195
School 3	29-31 October 2017	65	115
School 4	21-24 November 2017	85	115

2.3.2. Objective measurements

Environmental variables like air temperature, radiant temperature, humidity, air speed and CO_2 level were measured at 5-minute intervals by multi-purpose SWEMA 3000, temperature, humidity and Tiny Tag CO2-TGE-0011 data loggers. State of windows, blinds and doors was also recorded by time-lapse cameras at 5 minute intervals.

3. Results

3.1. Personal Adaptive Behaviours

Results of surveys and observations show that personal adaptive behaviours are correlated with occupancy patterns, type of activity, season, outdoor temperature and time of day. However, the time that personal adaptive behaviours happens is more related to occupancy patterns and type of activity, and the frequency and number of those personal behaviours are more related to season, outdoor temperature and time of day, Fig 2 & 3.

Students usually take personal adaptive behaviours like drinking water, fanning and changing clothing level right after or before breaks, especially after breaks, physical Education (PE) and lunch, and that is why the percent of students taking personal adaptive behaviours increases during day, Fig 2 & 3. Percent of students drinking increases up to 92% in July and up to 33% in October. Percent of students fanning increases up to 48% in July and up to 7% in October. Percent of students without jumper increases up to 100% in July and up to 40% in October. According to the results of these two months, percent of students changing clothing level is higher than percent of students drinking and fanning. Among all personal adaptive behaviours, changing seats and fanning are the less frequent ones. Each student is allocated a fixed seat and students can only change seats with teacher's permission and according to type of activity. Fanning was rarely observed in October (7%), however it was more frequent in July (48%). Another personal adaptive behaviour, which was observed in the presence of glare in eyes or on TV, was changing posture or seating direction. According to the above statistics, percentage of personal adaptive behaviours is higher in July than in October which can be attributed to outdoor and indoor temperature and time of year. The pattern of taking personal behaviours is almost similar, however, their frequency is different in different seasons.

Less personal behaviours were observed during teaching activities which is mainly due to the fact that students are not free to move around in the classroom to drink or change seats, Fig 2 & 3. Several other studies (Santamouris *et al.*, 2008; Stazi, Naspi and D'Orazio, 2017) show that less adaptive behaviors are taken during teaching activities than during breaks as pupils are concentrating on lessons. Students' freedom to change clothing level, seating position and posture is higher in art classes which can help provide a more comfortable environment for them as the study by Nicol & Humphreys (1973) in educational buildings in UK has shown that students can make a more comfortable environment for themselves by changing posture and activity.

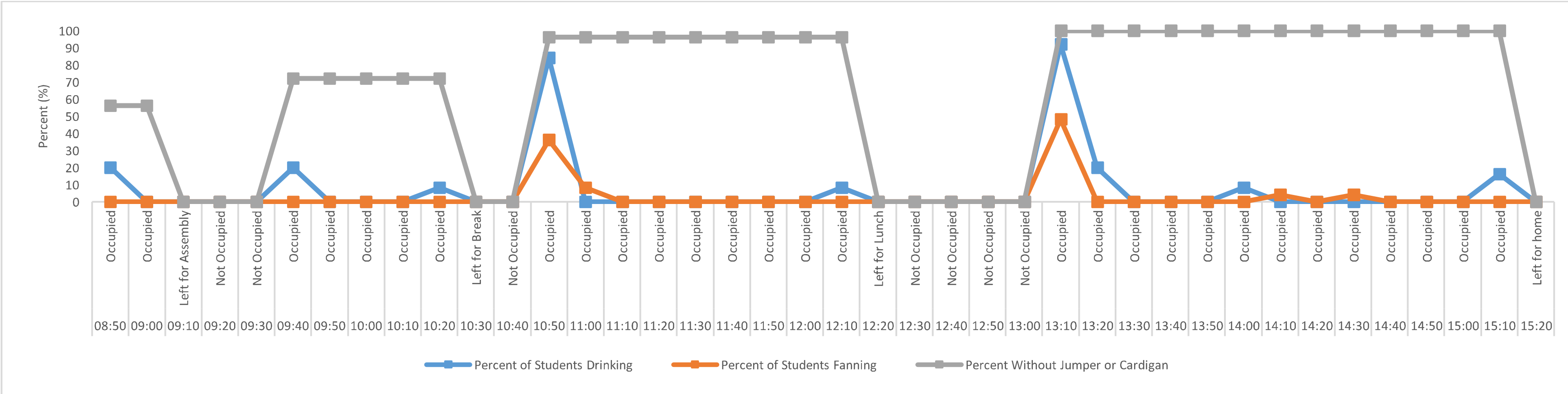


Figure **2**. Percent of students drinking, fanning and without jumper in a single day in July

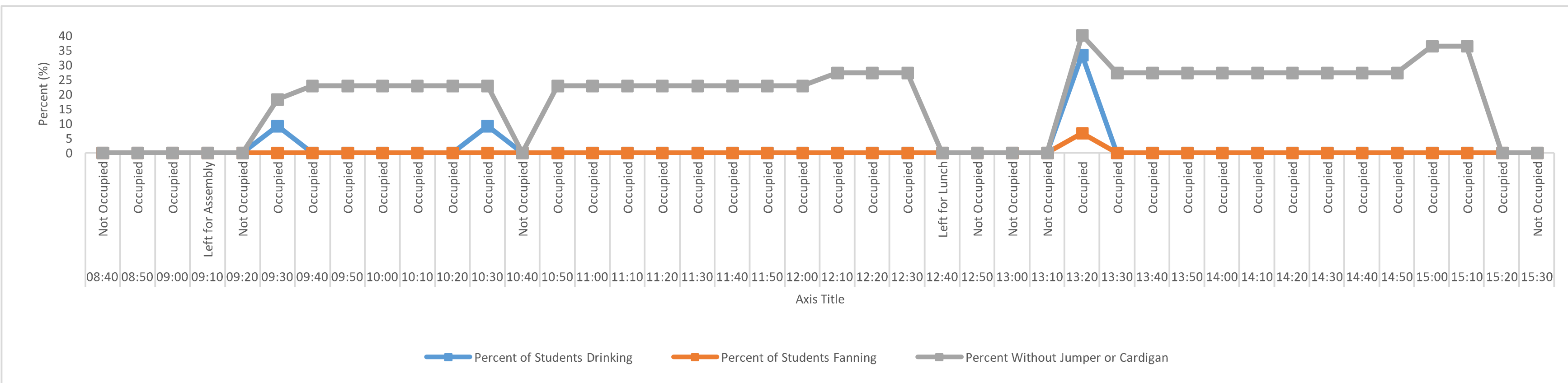
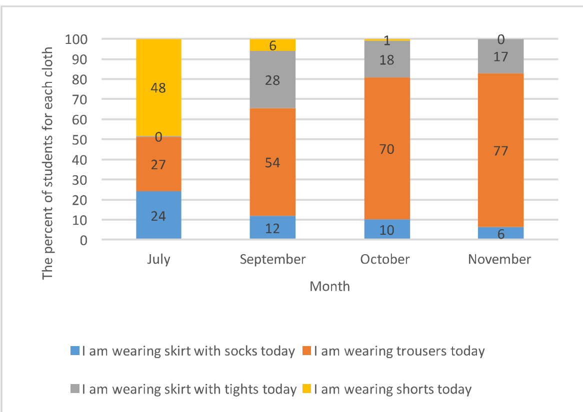


Figure 3. Percent of students drinking, fanning and without jumper in a single day in October

3.1.1. Clothing Level and Comfort Vote

Students' decisions on what to wear mostly depend on time of year, as shown in Fig 4 & 5. Fig 4 shows that most students wear shorts in July (48%), however, girls and boys mostly wear trousers in October and November, 70% and 77%, respectively. The percent of girls wearing skirt with socks decreases from July to November and the percent of students wearing skirt with tights increases from July (24%) to September (12%) and then decreases again from September to October (10%) and November (6%); girls start to wear more trousers in these two months. This adaptive behaviour which starts even before getting to school shows students' perception of outdoor temperature and seasons. Results show that 94 students do not even take their jumper/cardigan to school in July and this number decreases in other months, as shown in Fig 5. Several other studies have already shown that students' clothing level usually follows sequence of temperature, running mean temperature and long term fluctuation in temperature (Nicol and Humphreys, 1973; Humphreys, 1974, 1977).



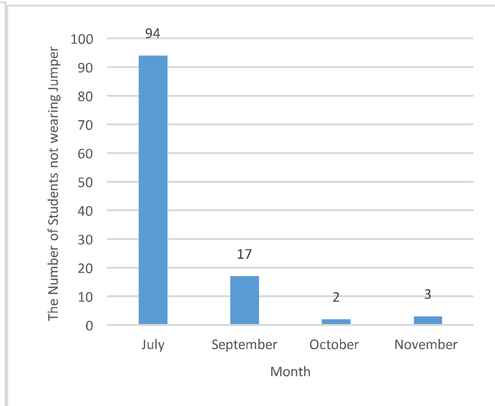


Figure 4. Students' decision on clothing. Fig 5. The number of students not wearing jumper/cardigan in different seasons

Results of the surveys show that 27% of students could improve their thermal preference vote by putting on or off jumper/cardigan. Indeed, 17% of students preferred a cooler and colder environment and had jumpers or cardigans on, as shown in Fig 6. Similarly, 10% students preferred warmer and hotter environment and did not have jumper/cardigans on, as shown in Fig 6. Similarly, The study by Nicol & Humphreys (1973) on educational buildings in UK shows that constraints on clothing at schools can cause discomfort equivalent to a departure of 4°C from the optimum temperature (Nicol and Humphreys, 1973).

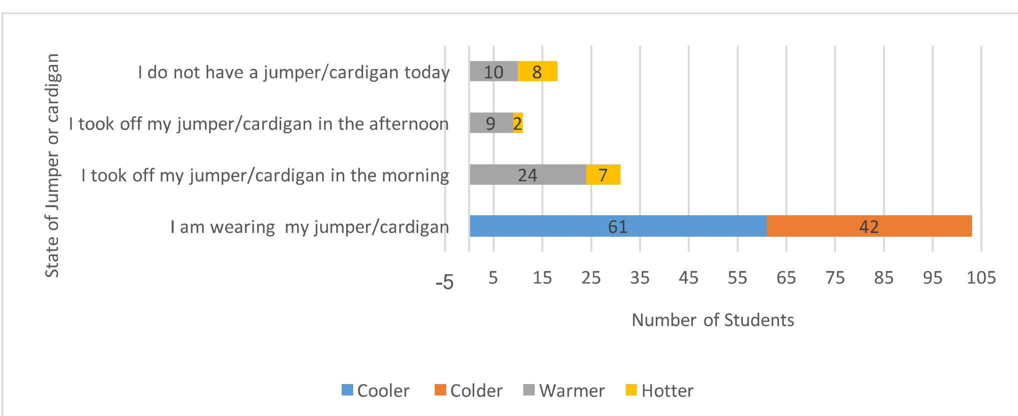


Figure 6. The number of students who could improve their thermal state by taking on or off jumper/cardigan

3.2. Environmental Adaptive Behaviours

3.2.1. Who does operations?

Observations show that around 80% of all operations are done by teachers, teacher assistants or on teachers' request and less than 20% are done by students or on students' request, as shown in Fig 7. Therefore, there is a risk that environmental conditions are mainly adjusted based on teachers' perceptions and preferences, and consequently classrooms' conditions might not suit the state of comfort of students. Results of the observation show that those students who decide to do environmental adaptive behaviours or are asked to do environmental behaviours, are usually seating close to the means of controls, either door, window or blind.

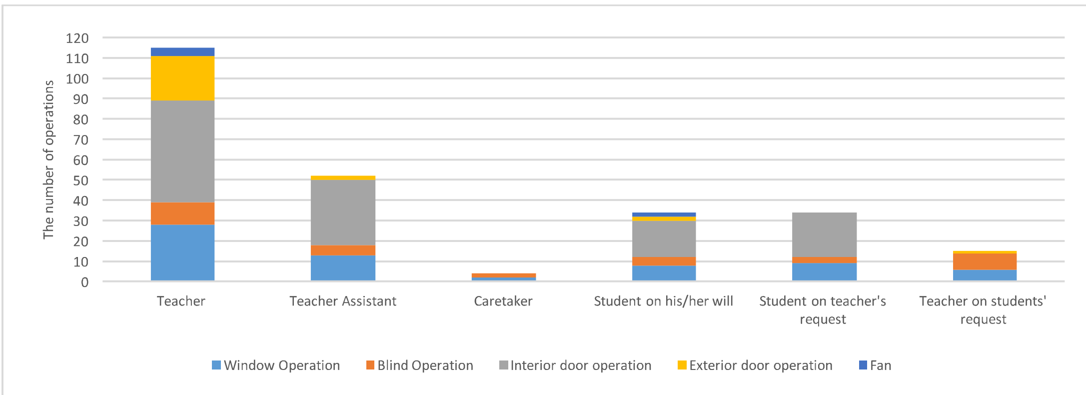
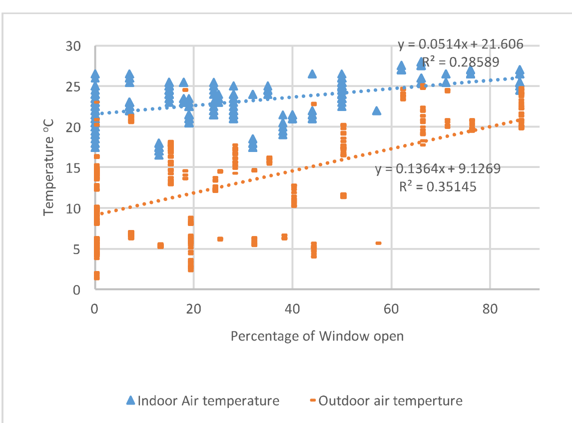


Figure 7. Who has operated different controls?

3.2.2. What factors affect operations?

The results of the study show that the percentage of open window is related to indoor temperature (R^2=0.29) and outdoor temperature (R^2=0.35), as shown in Fig 8. Similarly, the number of window adjustment is correlated with indoor temperature (R^2=0.24) and outdoor temperature (R^2=0.33), Fig 9. These results are supported by the evidence available in literature reviews (Dutton and Shao, 2010; Stazi, Naspi and D'Orazio, 2017) (Santamouris *et al.*, 2008; Stazi, Naspi and D'Orazio, 2017). In addition, this study shows that operation of openings (i.e. windows and doors) is not only affected by climatic factors and it is also affected by occupancy patterns and background noise level.



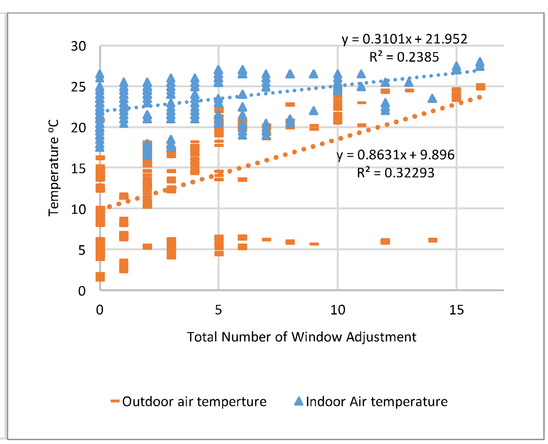


Figure 8. The relation between percentage of open window and indoor & outdoor temperature. Figure **9**. The relation between the number of window adjustment and indoor & outdoor temperature

3.2.3. How do operations and occupancy patterns affect environmental variables?

Providing an opportunity for students to practice adaptive behaviours in classrooms is important as all personal and environmental adaptive behaviours, students' occupancy patterns and the number of them can affect climatic variables and their state of comfort. Fig 10 shows an example of how operation of controls and occupancy patterns can affect environmental variables in a single day in summer. Not only opening windows and door affects temperature and indoor air quality, the number of students and their type of activity also affects these variables. A noticeable difference can be seen at 9:30 and 10:00 when the number of students increased from 28 to 53 for practicing singing. By an increase in the number of students and change in their type of activity, radiant temperature increased more than two degrees (from 24.6 at 9:00 to 26.8 at 10:00) and CO_2 level increased up to around four times (from 658 ppm at 9:00 to 2331 ppm at 10:00). The state of windows, type of activity and the number of students do not change from 9:30 to 10:00, yet, radiant temperature, air temperature and CO_2 level increase which can be attributed to door being closed and the longer period that the activity is taking place, Fig 10. At 10:30, when more windows were left open and students left the classroom, radiant temperature dropped three degrees (3°C) and CO_2 level decreased to around four times, Fig 10. The state of windows at different times by time lapse camera and the percentage of window open is presented in Table 4.

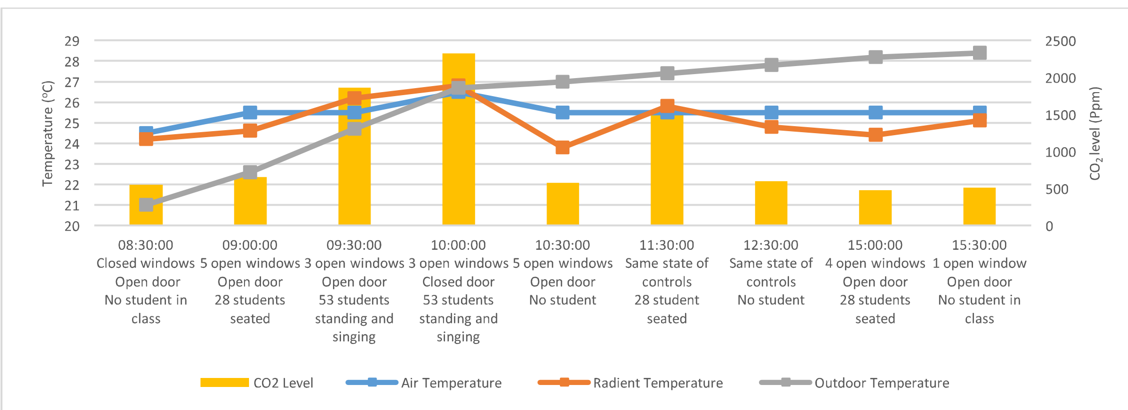


Figure 10. The effect of state of controls and occupancy patterns on environmental variables

Table 4. State of windows at different times in the classroom, Photos by Time-lapse cameras

Time	**08:30**	**09:00**	**09:30**
Open window (%)	**0%**	**66%**	**50%**
State of windows			
Time	**10:00**	**10:30**	**15:30**
Open window (%)	**50%**	**86%**	**18%**
State of windows			

3.2.4. How to facilitate adaptive behaviours for children?

To provide appropriate opportunities for students to operate controls and according to their own preference, controls especially windows and blinds should be carefully designed. Students in [S3, C10], [S3, C12], [S4, C13] and [S4, C14] do not have an opportunity to operate windows and blinds due to their design and type of access to them, Table 2. In [S3, C10], [S4, C13] and [S4, C14], small windows can only be operated by teacher or teacher assistant as the height of window sill is 1.6-1.8 (m) and they are out of reach of students, Table 1.

Moreover, windows are located at the end of the classroom and next to teacher's desk, which makes children's access to them difficult, 2nd and 5th photo in Table 2. In [S3, C12], access to windows is not difficult, however, windows at the height of students are not operable. Therefore, only upper windows are operated by a handle which is done by teacher or teacher assistant, Table 2. The interaction of students with windows and blinds was observed more frequently in classrooms 1-9 in schools 1 & 2 since windows were different in design and size, lower in height (the height of window sill is 1m) and easy to access. Two more studies in educational buildings have shown that blinds' ease of use and window design affect the frequency of blind operation (Sze, 2009; Sanati and Utzinger, 2013).

4. Conclusion

Adaptive behaviours of around 400 students aged 9-11 were studied in four UK primary schools. The study was carried out during July, September, October and November 2017 through observational field studies, subjective and objective measurements and more than 600 questionnaires were collected.

Results reveal that the time that personal adaptive behaviours takes place is more related to occupancy patterns and type of activity, however, the frequency of personal adaptive behaviours is more related to season, outdoor temperature and time of day. Personal adaptive behaviours like drinking water, fanning and taking off or on jumper/cardigan usually happens right after and before breaks, especially after breaks, Physical Education (PE) and lunch with fewer personal behaviours during teaching activities. Percent of students displaying personal adaptive behaviours is higher in summer than in autumn which can be attributed to outdoor and indoor temperature. Students' decisions over clothing mostly depends on time of year, with boys wearing more shorts and girls wearing more 'skirts with socks' in July; however, both girls and boys wear more trousers in October and November. Many students do not take their jumpers/cardigans when outdoor temperature is warmer. Surveys' results show that 27% of students could improve their thermal preference vote by taking off or taking on jumpers/cardigans.

On environmental adaptive behaviours, the operation of some of them like doors is less related to climatic factors, however, operation of windows is correlated with indoor temperature (R^2=0.29) and outdoor temperature (R^2=0.35). Around 80% of all operations are done by teachers, teacher assistants or on their request, therefore, provided environmental conditions can be inappropriate according to students' state of comfort. It is important that design of controls facilitate adaptive behaviours of children according to their physiology. Easy to access and easy to operate controls that are safe for children can help them practice adaptive behaviours. Adaptive behaviours and occupancy patterns influence environmental variables, so it is important to consider the extent to which students can practice adaptive behaviours, their arrival and departure patterns, the number of them in the classroom and their type of activities.

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