University of Southampton

Faculty of Environmental and Life Sciences

School of Geography and Environmental Sciences

Sustainability benefits of energy behaviour change in a NHS Trust

by

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Thesis for the degree of Doctor of Philosophy

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Abstract

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In 2015/16 National Health Service (NHS) hospitals in England spent over £570 million on energy, consumed over 10,983,151 megawatt hours of energy and produced 4.6 million tonnes of carbon dioxide equivalent ($MtCO_2e$) from energy. In a survey of 70 NHS energy managers, it was reported that energy conservation is important to NHS organisations. However, to NHS healthcare staff energy conservation is a low priority and sometimes considered to be in conflict with their primary driver, which is delivering excellent patient care. This study assessed the implications of running a behaviour change intervention in a NHS hospital designed to reduce energy whilst putting patients first.

To the researcher's knowledge to date, there has not been a published academic study that has directly measured the sustainability (economic, environmental and social) benefits of running an energy behaviour change intervention in a hospital. In addition, all published information on energy behaviour change in hospitals relates to general acute-care hospitals. Therefore, this study addresses current research gaps by undertaking an academic study using mixed method data collection to directly measure the potential sustainability (economic, environmental and social) benefits to patients, staff and the organisation of running an energy behaviour change intervention in a NHS community hospital.

The study was run in three older persons' in-patient acute-care wards in a NHS community hospital (the Trust) in the South of England over a nine month period. The quantitative data collection methods used in this study included the use of air temperature, relative humidity, sound, carbon dioxide and light monitors together with window movement sensors to directly measure and monitor the ward environment.

Other quantitative data collection methods used include the use of Trust management information to measure and monitor patient length of stay and movement sensors on patient beds to measure and monitor patient wellbeing in relation to rest and recovery. Together with Trust management information on staff satisfaction in relation to sickness levels and staff retention. The qualitative data collection methods used in this study included staff comfort surveys (n = 30 participants, 463 surveys) and staff focus groups (n = 30 participants, 6 focus groups) to directly measure the staffs' experience and indirectly measure the patients' experience.

The study produced an economic and environmental saving of 13% in electricity consumption. Other environmental savings included an 11% decrease in artificial lighting loads, a 1 decibel reduction in mean noise levels, 0.6 degree Celsius reduction in median air temperature and 27% reduction in window movements during the heating season. Social savings included a 22% increase in patient rest when compared to the control group.

In addition, this nurse led behaviour change intervention created the quieter periods required for better patient outcomes, which continued for at least a month after the intervention before gradually tailing off but not stopping during the monitoring period. It took up to a month to implement quieter periods showing a delay in the effect. Switching off small power equipment took effect immediately and continued for a month after the intervention, before tailing off over the next month and completely stopping the following month.

The study also showed that the nursing staff had a heightened awareness of the environmental impacts on the wards as a result of the evidence based information used during the intervention, particularly in relation to noise and temperature, which creates risks in terms of acceptability of the approach to the nursing staff participating in the intervention, who reported their wards were cold as a result of controlling temperatures to remain within the CIBSE recommended levels (22-24^{o}C) during the heating season.

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Research Thesis: Declaration of Authorship

Print name: Louise Kathleen Sawyer

Title of thesis: Sustainability benefits of energy behaviour change in a NHS Trust

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission.

Signature: Date:

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Finally, I would like to thank the other stakeholders involved in this study including the PFI owner, PFI management company, Hard and Soft facilities suppliers and their teams on site who readily joined in with the project.

Definitions and Abbreviations

°C: Degree Celsius

AC: Alternating current

ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers

Cfb: Warm temperature (C), fully humid (f), with warm sunshine (b)

CHP: Combined heat and power

CIBSE: Chartered Institute of Building Engineers

Clo: Clothing insulation

CO_2e: Carbon dioxide equivalent

dB: Decibel

DC: Direct current

DoH: Department of Health

EV: Expectancy value

GAP: Global Action Plan

HTM: Health Technical Memorandum

HVAC: Heating, ventilation and air conditioning

IEQ: Indoor environmental quality

kW: Kilowatt

kWh: Kilowatt hour

m/s/s: Meters per second per second

Met: Metabolic rate

MRT: Mean radiant temperature

MWh: Megawatt hour

Definitions and Abbreviations

NHS: National Health System

NMC: Nursing and Midwifery Council

PFI: Privately Financed Initiative

PMV: Predicted Mean Vote

PPD: Predicted Percentage of Dissatisfied

ppm: Parts per million

Q-Q Plot: Quartile-quartile plot

RH: Relative humidity

SDU: Sustainable Development Unit

SEM: Structural equation modelling

SPS: Samples per second

TIB: Theory of Interpersonal Behaviour

TPB: Theory of Planned Behaviour

V: Volts

U-value: Thermal transmittance of materials

VBN: Value Belief Norm

WGBT: Wet bulb globe temperature

Chapter 1 Introduction

This chapter presents the relevant background information in section 1.1 and rationale for undertaking this study in section 1.2. Section 1.3 defines the main research aim and objectives of this study and section 1.4 outlines the main structure and chapter layout of the thesis in order to provide the reader with guidance on the content of this thesis.

1.1 Background to the study

As a result of the Climate Change Act 2008, which imposes a mandatory target for the UK to reduce its greenhouse gases by 80% by 2050 from a 1990 baseline (Climate Change Act 2008) and increasing concerns about the effects of a changing climate on our health and care system (Gill and Stott 2009, Watts et al. 2015), the National Health Service (NHS) in England has publically committed to reduce its carbon footprint (scopes 1, 2 and 3) by 28% by 2020 from a 2007 baseline (NHS Sustainable Development Unit 2016a). This target is designed to bring NHS England's reduction of greenhouse gases in line with the 2020 carbon budget set by UK Government (NHS Sustainable Development Unit 2016b) as part of the Climate Change Act 2008 (Committee on Climate Change 2008).

NHS Sustainable Development Unit (NHS SDU) reported that NHS England's 2015 carbon footprint was 22.8 million tonnes of carbon dioxide equivalent ($MtCO_2e$) with energy accounting for 20% of the footprint or 4.6 $MtCO_2e$ (NHS Sustainable Development Unit 2016b). In 2016, the NHS SDU reported an 11% reduction in NHS England's carbon footprint between 2007 and 2015, equating to a reduction of 2.9 $MtCO_2e$ despite an 18% increase in activity during this period (NHS Sustainable Development Unit 2016b).

Between 2007 and 2015 NHS England reduced its energy by 4% or 0.2 $MtCO_2e$ (NHS Sustainable Development Unit 2016a). Energy improvement interventions in the NHS have traditionally focused on building efficiency and technical solutions such as insulation, low energy lighting, improved heating and lighting controls, and improvements in building management systems (NHS Sustainable Development Unit 2010). In 2015 the NHS SDU reported that other building energy improvements such as combined heat and power (CHP) systems, increased use of renewable energy and staff engagement had contributed to energy savings of £30 million (NHS Sustainable Development Unit 2016a).

Despite these improvements, in 2015/16 NHS Trusts in England spent over £570 million on energy and consumed over 10,983,151 megawatt hours (MWh) of energy (HSCIC 2016a). To help facilitate energy reduction and put climate change mitigation at the heart of the health service, the Department of Health (DoH) published Health Technical Memorandum (HTM) EnCO_2de 2015 (EnCO_2de 2015). EnCO_2de 2015 provides advice and guidance to healthcare organisations on how to consider the implications of energy use and carbon reduction whilst putting patients first (Department of Health 2015).

Behaviour change features more prominently in EnCO_2de 2015 than in previous versions with the publication acknowledging the importance of staff behaviour change and motivation on the impact of healthcare organisations' ability to save energy, particularly where energy savings are not the staffs' main priority (Department of Health 2015). The Carbon Trust (2013) states that a well implemented staff engagement scheme can lead to energy savings of between 5-10%, which using the HSCIC 2016 figures, could equate to annual energy savings for NHS England of between 549,157 to 1,098,315 MWh, together with between 230,000 to 460,000 tCO_2e of carbon emissions savings and between £28.5 to £57 million of financial savings.

Since the beginning of the financial year 2012/13, forty eight NHS general acute-care hospitals have reported implementing a staff centred energy conservation initiative, however only eight could provide an estimated cost saving from their initiative, which ranged between 1-5% of the total energy cost (Morgenstern, Raslan, et al. 2016) although none of these savings were verified.

Operation TLC is an energy behaviour change programme developed by Global Action Plan (GAP), an environmental behavioural change charity and St Bartholomew's Health NHS Trust (Bart's). Operation TLC stands for **T**urn equipment off, **L**ight out & **C**ontrol temperatures and was developed to deliver an improved experience for staff and patients, improved environments and cost efficiencies in NHS organisations (Trusts) (Daly and Large 2016).

When Operation TLC was run at two of Bart's general acute-care hospitals it was reported that this energy behaviour intervention produced 3% annual energy savings, which equated to £428,000 of financial savings and 1,900 tCO_2e of carbon emission savings (Daly and Large 2016). It also reported that patients' experienced a third fewer sleep disruptions, a 38% reduction in patient requests for room temperature to be changed and an improved experience for both staff and patients (Daly and Large 2016).

GAP used a mixed methods approached to gather the data during the intervention at the two Bart's hospitals, including 14 post-intervention interviews with employees, 70 pre-intervention patient questionnaires, 88 post-intervention patient questionnaires and observations of employees' actual environmental behaviour (Manika et al. 2016). However, the data collection methods and consequently the reported benefits were not subjected to academic or independent scrutiny, and therefore cannot be verified.

In addition the relatively low sampling size meant the results may not have reflected the differences in treatments, patients, environments and medical equipment that are found in the two hospitals (Manika et al. 2016). A full analysis of these Operation TLC findings and the subsequent research carried out by Manika et al. (2016) using secondary data, originally gathered by GAP can be found in later chapters.

1.2 Rationale for the study

NHS England has 771 hospital sites, comprising 217 general acute-care hospitals, 54 specialist acute-care hospitals, 100 mixed service hospitals, 113 other in-patient sites and 287 community hospitals (HSCIC 2016b). In 2015/16 NHS England community hospitals accounted for £15,259,905 and 288 MWh of energy, which is approximately 3% of NHS England's total energy budget (HSCIC 2016a).

As a community and mental health Trust, the in-patient acute-care wards in the NHS hospital participating in the study comprises primarily of elderly (aged over 65 years[1]), often vulnerable patients some with dementia and other mental health conditions (on average 27.5%[1]). Two of the most current challenges for the NHS is the growth of mental health illness in society (The King's Fund 2015) and an ageing population (Appleby 2013), so it is likely these type of in-patient facilities will become increasingly important in the future.

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987). When organisations incorporate sustainable development into their operation(s) it is called corporate sustainability (Baumgartner and Ebner 2010) and is based on the three pillars of sustainable development, namely economic, environmental and social (Ebner and Baumgartner 2006). Corporate sustainability requires balanced consideration of these pillars in business activities (Figge et al. 2002).

[1] Figures obtained from Trust's Tableau management information reporting system (Tableau 2003), accessed on 01/08/2018

Organisations are becoming increasing committed to embedding sustainability into their operation(s) and measuring the sustainability impacts (economic, environmental and social) of their activities (Baumgartner and Ebner 2010). As the participating Trust sponsored this study as a corporate sustainability project, balanced consideration of the sustainability (economic, environmental and social) benefits of running a behaviour change intervention was measured.

To the researcher's knowledge date, there has not been a published academic study that has independently measured the sustainability (economic, environmental and social) benefits of running an energy behaviour change intervention in hospitals and all reported information on energy behaviour change interventions in hospitals has only been reported in relation to general acute-care hospitals (Morgenstern, Raslan, et al. 2016).

Therefore, this study addressed these current research gaps by undertaking an academic study using mixed method data collection to measure the potential sustainability (economic, environmental and social) benefits to patients, staff and the organisation of running an energy behaviour change intervention, adapted from Operation TLC, in an NHS community hospital.

1.3 Research aim and objectives

This study uses qualitative and quantitative data collection methods to measure the potential sustainability (economic, environmental and social) benefits for patients, staff and the organisation of running an energy behaviour change intervention, adapted from Operation TLC in older persons' acute-care wards in a NHS community hospital with the aim of academically verifying the theory that:

"Running a behaviour change intervention in a hospital saves energy whilst creating a healthy environment that improves patient wellbeing and staff satisfaction"

This study also examines research gaps identified during the literature review, so consequently has the following objectives:

1. To run a behaviour change intervention in a hospital and measure how much energy and carbon dioxide equivalent (CO_2e) it saves.
2. To link the energy behaviour intervention to the respective hospital building, processes and interfaces with the occupants.
3. To identify, quantify and critically discuss the applicability and limitations of running an energy behaviour change intervention in a hospital.
4. To identify, measure and analyse the sustainability (economic, environmental, social) benefits of running an energy behaviour change intervention in a hospital.

Consequently, this study will statistically analyse the following research questions and null hypotheses:

RQ1: In what ways and to what extent does running a behaviour change intervention in a hospital reduce energy consumption?

- H1: The intervention group did not switch off equipment more than the control group
- H2: The intervention group did not switch off lights more than the control group
- H3: The intervention group did not implement night time switch off
- H4: The intervention group did not save more energy than the control group

RQ2: In what ways and to what extent does running a behaviour change intervention in a hospital improve patient well-being?

- H5: The intervention group did not reduce noise levels more than the control group
- H6: The intervention group did not control temperature more than the control group
- H7: The intervention group did not implement quiet time
- H8: The intervention group did not have more patient rest than the control group
- H9: The intervention group did not have lower patient length of stay than the control group

RQ3: In what ways and to what extent does running a behaviour change intervention in a hospital improve staff satisfaction?

- H10: The intervention group did not have lower staff sickness than the control group
- H11: The intervention group did not have lower staff turnover than the control group

1.4 Publications

The formal publication from this work comprises a journal paper published in Building and Environment, listed below:

Sawyer, L. K., Kemp, S., James, P. A. B., and Harper, M., 2020. Noisy and restless: 24 h in an NHS community hospital ward, a qualitative and quantitative analysis of the patient environment. *Building and Environment* [online], 175 (January), 106795. Available from: https://doi.org/10.1016/j.buildenv.2020.106795.

The focus of this paper was the study pilot discussed in Chapter 3, section 3.11.

1.5 Thesis structure

This thesis consists of nine chapters, which provide details of the holistic approach to researching the sustainability benefits of running an energy behaviour change intervention in a NHS community hospital. Figure 1 shows a flowchart of the thesis structure.

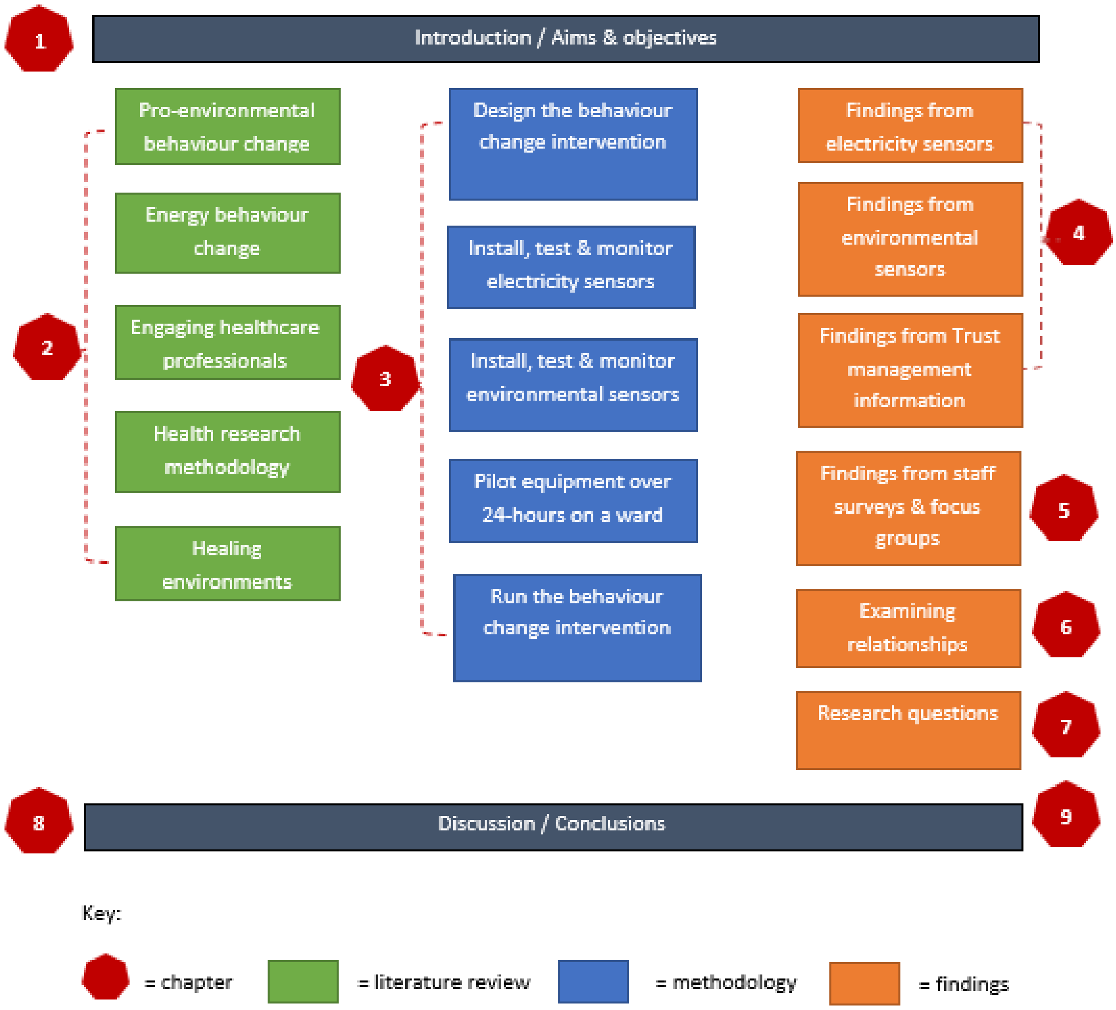

Figure 1. Flowchart of the behaviour change thesis

Chapter 2 Literature review

This chapter presents the results of a scoping review of published academic literature relating to this study. Munn et al. (2018) recommends using a scoping review when the purpose of the review is “to identify knowledge gaps, scope a body of literature, clarify concepts or to investigate research conduct”. Section 2.1 presents an overview of the different disciplinary approaches to pro-environmental behaviour change. Section 2.2 presents an overview of the different disciplinary factors and approaches to energy behaviour change. This section also includes a review of published academic literature relating to energy behaviour change in healthcare organisations, including Operation TLC.

Section 2.3 focuses on the factors previously identified as important influences for engaging healthcare professionals and section 2.4 focuses on the research methods previously identified as successful in a healthcare environment. Section 2.5 focuses on the factors that create a healing environment, including the impacts of light, sound, temperature and thermal comfort on staff and patients in a healthcare environment. A summary of the key findings from the literature review is presented in section 2.6.

2.1 Pro-environmental behaviour change

Psychologists and sociologists have attempted to understand what drives, limits and consequently changes pro-environmental behaviour (Staddon et al. 2016), such as reducing energy consumption. In a review of sixty behaviour change approaches Darnton (2008) made the distinction between (1) behaviour models, which show the underlying factors that influence the behaviour, and (2) theories of change, which show how behaviours change over time. Whilst behaviour models and theories of change have different purposes Darnton (2008) concludes a successful behaviour change intervention requires an understanding of both concepts. See Appendix A for a summary table of the behaviour models and change theories identified by Darnton (2008).

Behaviour change models and theories can assist with the exploration of pro-environmental behaviour and identification of potential influences on it (Darnton 2008, Chatterton 2011). These range from linear rational choice theories and models, for example Kollmuss and Agyeman (2002) model, which uses the rational choice theory that environmental information generates environmental knowledge, which then shapes a person’s environmental attitude and leads to pro-environmental behaviour, shown in Figure 2.

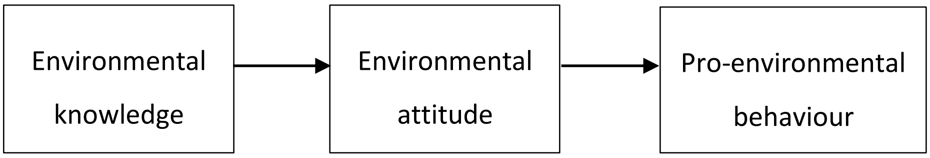

Figure 2. Model of the linear rational choice model of pro-environmental behaviour reproduced from Kollmuss and Agyeman 2002

To simple socio-psychological theories and models that address the gap between a person's attitudes and their actions, such as Blake's Value Action Gap (1999) shown in Figure 3, which includes potential barriers between environmental concern and pro-environmental action (Kollmuss and Agyeman 2002).

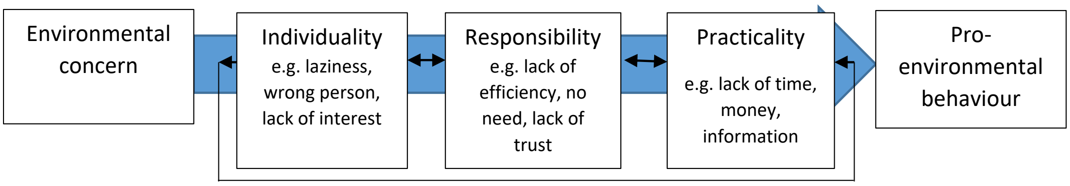

Figure 3. Model of Blake's Value Action Gap behaviour change model (1999) reproduced from Kollmuss and Agyeman 2002

To Fishbein and Ajzen (1975) Theory of Reasoned Action, which uses Expectancy Value (EV) Theory; a cognitive-motivational theory that relates the motivation required to achieve a goal to the perceived value or attributes of that goal and the expectancy of achieving the goal (Kominis and Emmanuel 2007), to bridge the gap between people's beliefs and their behavioural outcomes by incorporating a factor of 'behavioural intention' into the model (Darnton 2008), shown in Figure 4.

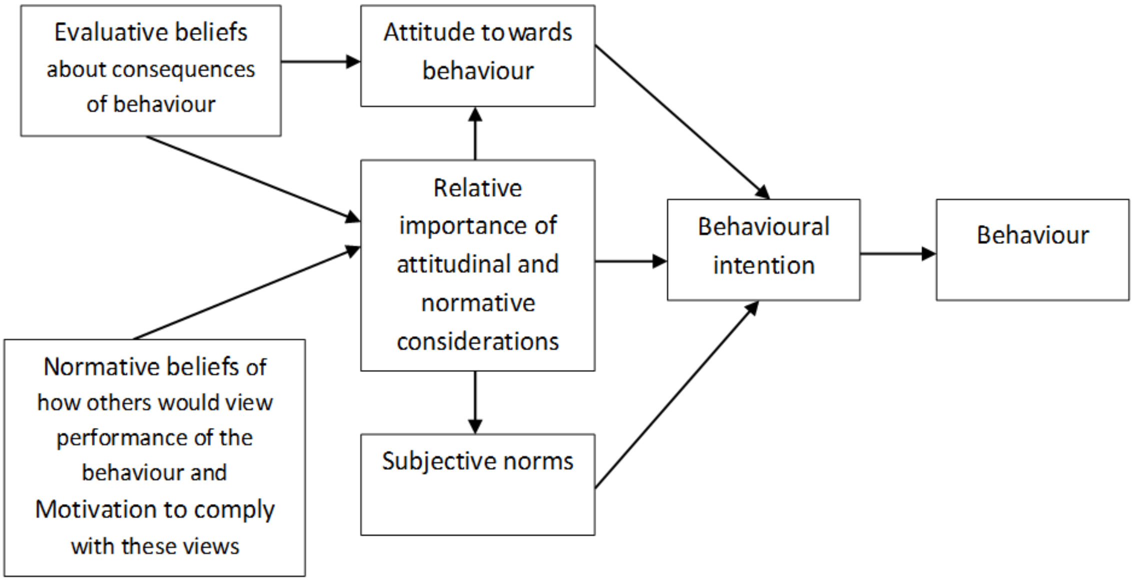

Figure 4. Fishbein and Ajzen Theory of Reasoned Action (1975) behaviour change model

To more complex EV theories and models, include Triandis' Theory of Interpersonal Behaviour (1979), Ajzen's Theory of Planned Behaviour (1991) and Stern's Value-Belief-Norm (2000) model. The Theory of Planned Behaviour (TPB) model identified that attitude, subjective norms and perceived control were highly accurate factors at predicting behavioural intention (Ajzen 2011). Theory of Interpersonal Behaviour (TIB) encompasses the factors included in the TPB but also incorporates cultural, social, and moral factors within the framework as predictors of behavioural intention (Gagnon et al. 2003).

Stern's Value-Belief-Norm (VBN) model was developed specifically to identify factors that influence pro-environmental conservation behaviour (Kaiser et al. 2005). The factors identified include attitudes, subjective norms, cultural, social and moral factors together with other contextual factors such as financial resources and costs, and available technologies (Stern 2000).

Following the review of various psychological and social models of pro-environmental behaviour Kollmuss and Agyeman (2002) found that pro-environmental behaviour was created by the interaction of complex and multiple factors, including internal factors such as attitude and knowledge, external factors such as economic, social and culture, and demographic factors such as age, gender and status to name a few.

More recently a range of theories and models have been developed to change behaviour associated with energy use (Chatterton 2011); many often overlap or build on other behaviour change frameworks for example, Figure 5 shows a revised version of Triandis' TIB adapted by Chatterton (2011) to model an energy behaviour change framework.

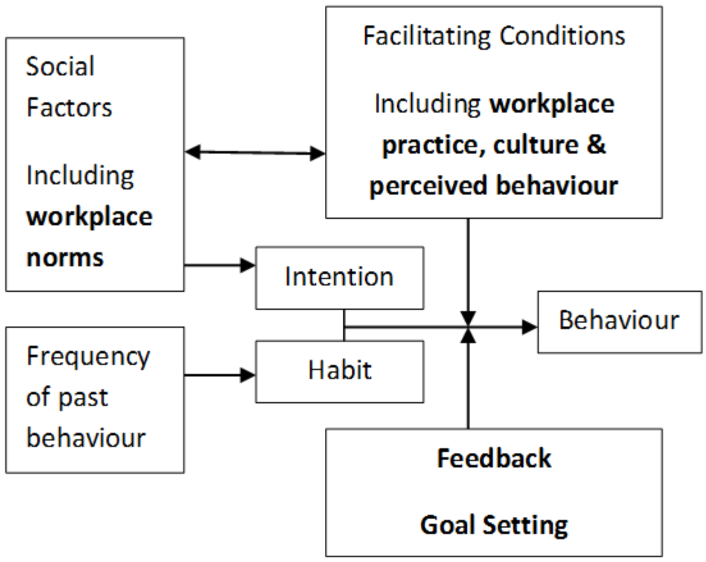

Figure 5. Revised version of Triandis' Theory of Interpersonal Behaviour model reproduced from Chatterton 2011

Behaviours continued over time form habits (Chatterton 2011) or "locked-in behaviours" (Maréchal 2010), which may be modified in the short term through conscious effort but will not continue unless they become a habitual change (Maréchal 2010). It takes around sixty-six days for a behaviour to become a habit (Lally et al. 2010), which may explain why some behaviour change interventions have not been able to successfully deliver long term energy conservation (Fisher and Irvine 2016).

Michie et al. (2011, p.1) defines a behavioural change intervention as "co-ordinated sets of activities designed to change specified behaviour patterns". Following an examination of nineteen frameworks of behavioural change interventions Michie et al. (2011) concluded that a behavioural change intervention typically starts with deciding what approach to take and then designing the specifics of the intervention itself (Michie et al. 2011), to ensure an effective intervention design.

Michie et al. (2011) discusses that the approach requires a systematic method for understanding the nature of the behaviour to be changed, identifying appropriate systems and their components for changing the behaviour, and then assessing in what circumstances the different systems and their components are likely to be effective and will consequently form the final intervention design.

Energy behaviour change will be explored in more detail in the next chapter, including an examination of the multiple energy behaviour change factors and approaches that have been studied in different environments from households to healthcare organisations, in order to decide which behaviour change factors and approach to use for this study.

2.2 Energy behaviour change

2.2.1 Energy behaviour change factors

Energy behaviour change in households has been considerably studied (Abrahamse et al. 2005, 2007, Steg 2008, Manika et al. 2016) and researchers have concluded there are several factors that influence energy conservation; firstly people must be aware there is a need for energy conservation and possible ways to reduce energy consumption. Secondly, they need to be motivated to conserve energy and adopt the relevant behaviours to make it happen (Steg 2008).

People are generally aware of the problems related to energy use (Abrahamse et al. 2007) and are becoming more aware as communication on climate change intensifies (Wibeck 2014). As a consequence people are becoming increasingly concerned about climate change and the potential impacts associated with a changing climate (Dunphy 2014). However, despite increasing awareness and concern, people do not always act in line with their concerns, values or attitudes (Kollmuss and Agyeman 2002, Steg 2008, Chatterton 2011).

In other words, what people say is not necessarily what they do (Frederiks et al. 2015). Studies have found a gap between knowledge and action (Sligo and Jameson 2000, Courtenay-Hall and Rogers 2002, Kennedy et al. 2004), values and action (Blake 1999, Boulstridge and Carrigan 2000, Flynn et al. 2009, Kennedy et al. 2009), and attitude and action (Boulstridge and Carrigan 2000). This has been found to be evident in energy conservation at home (Kollmuss and Agyeman 2002, Abrahamse and Steg 2011).

It has been assumed that the behaviours that influence energy conservation at home are transferable to the workplace (Mulville et al. 2017), however whilst energy behaviour change in organisations has been studied to a lesser extent (Lo et al. 2012, Gulbinas and Taylor 2014, Staddon et al. 2016) the studies have concluded that an individual's attitudes, beliefs and approach may be transferrable to the workplace (Mulville et al. 2017). Although, a study by Menzes et al. (2012) found that attitude did not significantly impact energy use, which confirms studies in non-domestic settings that changes in habit may occur without a change in attitude (Siero et al. 1996, Tetlow et al. 2015).

In non-domestic settings other key factors influence energy conservation including organisational, contextual and social factors (Carrico and Riemer 2011, Lo et al. 2012, Littleford 2013, Morgenstern, Raslan, et al. 2016) and the complex interactions between these factors (Coleman et al. 2013) have the potential to both provide leverage to encourage energy efficient behaviours and create barriers to hinder energy efficiency behaviours (Littleford 2013).

Organisational factors include organisational culture, policies and practices. Siero et al. (1996) and Mulville et al. (2016) found it was more effective to focus on workplace culture and practices than the attitude of the employees involved in the intervention. As a captive audience, employees are subject to organisation policy (Carrico and Riemer 2011), although De Groot and Steg (2009) found energy conservation polices are generally more acceptable to people who value the environment or feel obliged to reduce energy use and Steg (2008) found energy policies were also more acceptable to people when they promote energy efficiency rather than restrict behaviours.

Djordjevic and Cotton (2011) identified potential barriers around communicating organisational sustainability policies and practices, including the complexity of the individual sustainability issue and potential differing views about the desired outcome of the behaviour change intervention. Consequently, emphasising the importance of effective communication during a behaviour change intervention.

Energy Managers interviewed during a study by Morgenstern, Raslan, et al. (2016) strongly felt that senior management commitment is an essential part of organisational culture when implementing a successful pro-environmental intervention, which is confirmed in a report by Cox et al. (2012). Active engagement of middle managers was also found to create a successful energy behaviour change intervention (Lo et al. 2012).

Within an organisation different people have different organisational priorities and objectives, which may lead to tensions between those running the energy conservation intervention, primarily energy managers and those participating, particularly if energy conservation priority is perceived to be counterproductive to other primary objectives (Bedwell et al. 2014, McGain and Naylor 2014, Morgenstern, Raslan, et al. 2016). For example, in healthcare organisations energy conservation is a low priority for healthcare professionals and in some cases is perceived as being in conflict with their main priority of delivering excellent patient care (McGain and Naylor 2014, Morgenstern, Raslan, et al. 2016). Consequently a narrow professional focus may be a barrier to running an energy behaviour change initiative (Dunphy 2014).

Other organisational factors that may impact on an energy conservation intervention include workload and resources (Ryan-Fogarty et al. 2016). If workloads are high and/or resources are low then employees may not have time to become fully engaged with or get involved in energy conservation interventions (McGain and Naylor 2014, Morgenstern, Raslan, et al. 2016).

Regarding contextual factors, unlike their home, staff have little, if no control over their environment in organisations and consequently feel a detachment from their work space (Bull et al. 2014, Dunphy 2014, Ornaghi et al. 2018) and disconnected with energy conservation at work (Mulville et al. 2017). Energy is often controlled by building management systems operated by the facilities team who don't necessarily occupy the work space where the intervention will be run (Goulden and Spence 2015), so there is limited control for staff occupying the targeted work spaces over most of the energy consuming systems (Staddon et al. 2016).

Also, bills are often paid by the energy manager (Morgenstern, Raslan, et al. 2016), so there is no direct financial incentive to reduce energy use (Bedwell et al. 2014). Lack of direct control and accountability in the workplace may also offer a justification for acting in a way that may contradict their personal values (Dunphy 2014).

Likewise, those who operate the building management systems and pay the bills often don't have control over the energy consuming equipment in the targeted work spaces (Goulden and Spence 2015), therefore collaboration between all the different stakeholders (engineers, facilities managers, sustainability teams and others depending on the organisation such as healthcare professionals, office workers, students etc.) in an organisation is essential (Tudor 2013, McGain and Naylor 2014). A study undertaken by Menzes et al. (2012) found a direct relationship between perceived behavioural control and energy use, in that people who had high perceived control saved more energy than those who did not, although in later studies Mulville et al. (2016) found this relationship was not as significant as previously expected.

Equipment is also often shared which may lead to a disconnect in responsibility, in terms of who is responsible for switching the equipment off when it's not in use, resulting in diffusion of responsibility, i.e. 'it's someone else's job' and the equipment remaining permanently on (Topf 2005, Littleford 2013, Mulville et al. 2017). Although energy efficiency of equipment is likely to have improved over recent years (Mulville et al. 2014) the increased range of equipment being used means that small power consumption in the workplace is likely to continue to have significant impact on energy conservation interventions (Jenkins et al. 2009).

In addition to organisational and contextual factors, social factors also affect energy efficiency behaviours in the workplace, such as social or group norms, knowledge and values. There is evidence that social or group norms may motivate employees to save energy (Bedwell et al. 2014, Staddon et al. 2016), particularly when they seek praise or reward (Chatterton 2011). Research shows that staff are more likely to adopt pro-environmental behaviour when encouraged by peers (Bedwell et al. 2014, Staddon et al. 2016) particularly when the behaviour, in this case energy conservation is visible to peers (Bedwell et al. 2014). However, if the culture of the social or group norm is anti-environmental then this may discourage energy conservation (Bedwell et al. 2014).

Studies have also revealed that social or group norms can create separation between personal and professional values and actions, which may lead to cognitive dissonance (Topf 2005, Harris et al. 2009, Dunphy 2014). Festinger's (1957) cognitive dissonance is conflict between opposing elements in this case a person's values and the group's norm.

In addition to social or group norms ignorance or lack of knowledge has been found to be a barrier to pro-environmental behaviour (Rothenberg 2003, Topf 2005) with some organisations relying on employees' self-policing pro-environmental behaviour based on assumed knowledge that in practice may be lacking (McDiarmid 2006, Cotton et al. 2015). Tudor et al. (2008) found that employee attitude, particularly in relation to the value placed on the environment and job satisfaction affected behaviour change interventions. Likewise, Morgenstern, Raslan, et al. (2016) found that energy managers believed participation in energy behaviour change interventions was strongly linked to the attitude of the individual employees.

However, as previously reported most studies in this area have concluded that whilst an individual's attitudes, beliefs and approach may be transferrable to the workplace (Mulville et al. 2017), a study by Menzes et al. (2012) found that attitude did not significantly impact energy use, which confirms studies in non-domestic settings that changes in habit my occur without a change in attitude (Siero et al. 1996, Tetlow et al. 2015, Bardsley et al. 2019).

Despite this, organisations can make use of individuals' personal pro-environmental values through the use of green or environmental champions to encourage their peers to adopt energy conservation (Carrico and Riemer 2011, Morgenstern, Raslan, et al. 2016, Ryan-Fogarty et al. 2016).

2.2.2 Energy behaviour change approaches

Energy behaviour change interventions comprise a variety of approaches including information, feedback, setting goals and rewards (Mulville et al. 2017). Information based energy behaviour change interventions are the most popular form of intervention (Mulville et al. 2017) and are more effective when the information is tailored to the specific audience, particularly when the behaviour change is relatively convenient and not costly in terms of money, time, effort (Steg 2008). However, these type of campaigns usually only result in modest behavioural change (Steg 2008) and modest savings (Carrico and Riemer 2011).

Feedback at both individual and group level is often used as an approach to encourage energy conservation behaviours in both domestic and non-domestic settings (Macarulla et al. 2015, Fisher and Irvine 2016, Mulville et al. 2017) and has the greatest success when delivered in a simple way as close to the behaviour change intervention as possible (Siero et al. 1996, Carrico and Riemer 2011). In non-domestic settings comparative feedback was found to encourage greater energy savings than individual feedback (Siero et al. 1996, Gulbinas and Taylor 2014, Ornaghi et al. 2018). Nolan et al. (2008) found that significant energy savings were achieved when staff were given information about energy conservation behaviour of others in the intervention group.

In both domestic and non-domestic settings energy behaviour change was found to diminish when feedback stopped, so continued engagement is required to maintain energy conservation (Dwyer et al. 1993, Darby et al. 2016). In non-domestic settings engagement in feedback was found to diminish over time (Gulbinas and Taylor 2014), although energy savings took longer to take hold (Murtagh et al. 2013, Mulville et al. 2017). Some studies found benefits from combining feedback with setting challenging, but still achievable goals in both domestic and non-domestic settings (Abrahamse et al. 2007, Macarulla et al. 2015).

The use of incentives or rewards is sometimes used as an approach to encourage behaviour change. Studies found that incentives usually fell into two categories, (1) financial rewards such as cash, bonuses, prizes or (2) social rewards such as goal-setting, points or public praise (Staddon et al. 2016). Handgraaf et al. (2013) found rewards that were given publically out performed rewards that were given privately and that social rewards out performed financial rewards. The studies concluded that incentives or rewards were successful at delivering energy savings but the savings were short lived (Staddon et al. 2016).

As discussed, Lally et al. (2010) found that it takes around sixty-six days for a behaviour to become a habit, which may explain why behaviour change interventions in both domestic and non-domestic settings have not been able to successfully deliver long term energy conservation (Fisher and Irvine 2016). Abrahamse et al. (2005) found that only five out of thirty-eight domestic energy behaviour change interventions maintained their reduction in energy use for more than two months.

Lots of behaviour change interventions have been run in both domestic and non-domestic settings but a lack of systematic evaluation and verifiable data make it difficult to quantify how much energy they actually saved and consequently assess how successful they were (Steg 2008, Morgenstern, Raslan, et al. 2016). Whilst the Carbon Trust (2013) publishes that a well implemented employee engagement scheme can lead to energy savings of between 5-10% of total energy use, studies have reported that some energy conservation interventions work better than others with non-healthcare energy conservation interventions, primarily domestic, universities and offices reporting potential energy savings of between 1-12% for heating and 1.5-20% for electricity (Abrahamse and Steg 2013, Mulville et al. 2014).

The best published domestic energy savings show a combined energy saving of between 17-27% come from four domestic small-group energy conservation interventions (Fisher and Irvine 2016) and the best published non-domestic energy savings reported up to 20% (with large variations) for electricity (Mulville et al. 2014) and 12% for heating (Schahn 2007 cited in Morgenstern 2016). The NHS SDU and GAP report potential energy savings of 3% from energy behaviour change interventions in healthcare (NHS Sustainable Development Unit 2010, Daly and Large 2016), based on findings from running Operation TLC at St Bartholomew's NHS Trust.

Despite these reported savings, some facilities and energy managers were not convinced that energy behaviour change interventions actually deliver energy savings and consequently thought building energy improvements were a better option (Bedwell et al. 2014, Morgenstern, Raslan, et al. 2016), which highlights the need for further academic study this area.

2.2.3 Energy behaviour change in healthcare

Whilst energy behaviour change in households has been considerably studied (Manika et al. 2016, Abrahamse et al. 2005), energy behaviour change in organisations has been studied to a lesser extent (Lo et al. 2012) and energy behaviour change in healthcare has been scarcely studied at all (McGain and Naylor 2014). Not only this but very little research has been done on the performance outcomes of behaviour change interventions (Young et al. 2015), particularly in healthcare organisations (Morgenstern, Raslan, et al. 2016) making it difficult to calculate the effectiveness of these interventions (Steg and Vlek 2009).

Healthcare is not like any other business (McCurdy and Weber 2002) it comprises of multi-functional complex buildings (Ziębik and Hoinka 2013) containing distinct features in terms of layout, lighting temperature and equipment (Leino-Kilpi et al. 2001), which are open 24 hours a day 7 days a week and 365 days a years (Harris et al. 2009). The buildings are occupied by a number of diverse stakeholders, including unwell and sometimes vulnerable patients with a variety of needs (Allen and Jones 2008, White 2013) who are sensitive to the local environment (Morgenstern, Li, et al. 2016). In addition the UK healthcare system is subject to constant restructures (Vinten 1992 cited in Tudor 2013), and unprecedented financial and operational pressure (Appleby 2013, The King's Fund 2015, Dunn et al. 2016).

A thorough literature review on 'energy in healthcare' found a number of academic publications on the topic (McGain and Naylor 2014, Morgenstern, Raslan, et al. 2016). These articles predominately focus on direct hospital energy usage from reported healthcare accounts (Williams et al. 1999, Saidur et al. 2010, Burpee and McDade 2014), identification of the most energy consuming activities and equipment the within the hospitals (Balaras et al. 2007, Lomas and Ji 2009, Soltani et al. 2015) and, retrofitting and designing sustainable healthcare buildings (Short et al. 2004, McGain and Naylor 2014, Department of Health 2015).

Whilst there are a number of academic publications that report on the topic of 'pro-environmental behaviour in hospitals' (Tudor 2013, McGain and Naylor 2014), some of the content of which may be utilised in an energy behaviour change intervention, a thorough review of relevant literature on 'employee energy behaviour change', 'energy employee engagement' and 'employee-centred energy conservation interventions in hospitals, healthcare and NHS' revealed only two direct academic publications on the topic. The first publication by Morgenstern, Raslan, et al. (2016) discusses the "applicability, potentials and limitations of employee-centred energy conservation interventions in English hospitals" and the second publication by Manika et al. 2016 discusses the "effects of an energy saving intervention in two hospitals".

Following a survey study of 70 NHS Trust energy managers in general acute-care hospitals Morgenstern, Raslan, et al. (2016) found that NHS employee-centred energy conservation interventions are of interest to these organisations and that a number of Trusts reported running successful campaigns. However, it also found that it was unclear how much energy and consequently money such campaigns deliver, how much the actions of clinical staff impacted on energy use and consequently the potential savings that could result from running an energy behaviour change intervention with clinical staff (Morgenstern, Raslan, et al. 2016).

The energy managers in the study by Morgenstern, Raslan, et al. (2016) also reported a number of barriers to running an energy behaviour change intervention in a hospital. A significant barrier lies in the professional focus and priority of the healthcare staff. To healthcare staff delivery of excellent patient care is the primary driver (NHS England 2014, Ryan-Fogarty et al. 2016) so by comparison energy conservation is a low priority, and is sometimes considered to be in conflict with delivery of the primary driver (Dunphy 2014, McGain and Naylor 2014). Consequently energy behaviour change interventions do not always receive support from healthcare staff (Dunphy 2014, McGain and Naylor 2014).

Like other studies into energy behaviour change Morgenstern, Raslan, et al. (2016) acknowledge that organisational, contextual and social factors affect the ability of hospital staff to engage and consequently participate in energy conservation interventions, to the extent that Topf (2005) reports that hospitals encourage ‘environmental numbness’, which is described by Gifford (1999) as societal indifference to environmental hazards and overconsumption. Primary factors creating environmental numbness include workplace culture, lack of resources, lack of knowledge, lack of control and feeling powerless (Harris et al. 2009, Dunphy 2014, McGain and Naylor 2014, Morgenstern, Raslan, et al. 2016, Ryan-Fogarty et al. 2016).

However, healthcare professionals make up the majority of staff in a hospital environment, with nurses representing the largest number of healthcare staff (NHS Digital 2017) so to achieve lasting behaviour change the energy managers reported that it is essential to involve healthcare staff (Morgenstern, Raslan, et al. 2016) and particularly nurses (Harris et al. 2009) in any energy conservation intervention. Engagement with healthcare staff is challenging but is possible if synergy can be found between patient care and energy conservation (Ryan-Fogarty et al. 2016).

Healthcare staff by the virtue of their profession have a strong propensity to care (Harris et al. 2009, Ryan-Fogarty et al. 2016) and duty to serve the public (Harris et al. 2009), therefore it may be possible to frame environmental and consequently energy conservation as an ethical responsibility (Harris et al. 2009), which aligns with the values of the profession. However, Topf (2005) also refers to the ‘moral-offset’; the supposition that healthcare professionals think they are already doing their bit (Gray 2011) resulting in ‘environmental numbness’.

2.2.4 Energy behaviour change in healthcare: Operation TLC

The second publication by Manika et al. 2016 explored the benefits and responses to staff, patients and the organisation from running Operation TLC in two Bart's hospitals. The paper uses secondary data gathered by GAP before and after running Operation TLC at the two general acute-care hospitals, including interviews with staff, observations of staff behaviour, examination of meter readings and patient experience surveys.

In 2012, Bart's developed a pilot energy behaviour change programme with their delivery partners GAP that was designed to solve the problem of poor staff practices, particularly leaving lights on in empty rooms, machines left on when not in use and heating on too high for too long, all of which resulted in wasted energy and detrimental environments for their patients from over lit, noisy and overheated wards (Daly and Large 2016).

The pilot programme evolved into Operation TLC, which is an energy reduction intervention focused on delivering an improved environment for patients and staff based around three primary actions:

- **T**urn off equipment,
- **L**ights out,
- **C**ontrol temperatures.

It is often highlighted that in healthcare no one set of actions will fit all (Ryan-Fogarty et al. 2015, Manika et al. 2016) consequently, behind these three primary actions lay up to twelve secondary actions that fit into the three primary categories, shown in Table 1.

Table 1. Operation TLC staff action list reproduced from GAP (2016)

Primary action	Secondary actions & additional information
Turn off equipment	Turn off any unwanted medical equipment where possible • Turning off equipment, and unplugging it once it's charged can help to preserve the battery
	Turn off computers, monitors and TVs that aren't being used • Equipment generates background noise, can contribute to light disturbances and can contribute to areas overheating.
Lights out	Switch off lights in unoccupied rooms
	Open blinds and make the most of natural light by switching main lights off • Increased exposure to natural light has been shown to improve patient recovery rates, reduce the need for pain relief and increase staff satisfaction.
	Introduce a quiet time for an hour or two after lunch • 'Quiet time' means turning lights off or dimming them in rooms and corridors to giving patients a peaceful time to rest & recover and time for you to catch up on other tasks.
	Switch lights off at night • Give patients a better night's sleep and improve their experience by switching off corridor and room lights as early as possible. Good sleep habits directly impact on mental and physical health. Staff at other Operation TLC hospitals tell us patients who get a better sleep are often easier to work with the following day.
Control temperature	Close the doors to patient rooms • This improves patient healing by allowing them to sleep better whilst also improving their privacy. Closing doors also keeps patients warmer and more comfortable.
	Close door when rooms aren't occupied • Closing doors to drugs and equipment stores keeps patients and staff safer. Closing toilet doors helps to improve hygiene on your ward.
	Close windows when the heating is on • This helps to improve temperature management on your ward. Having the windows, opens when the heating is on will make the system work harder for less benefit.
	Control heating gradually • Get to know how your wards heating controls work. In big buildings like hospitals it can take time for the temperature to adjust and over adjusting can make the ward too hot or too cold later in the day.
	Layer up if cold • Think about whether you can wear an extra layer; make sure your patients have access to extra blankets.
	Encourage patients or visitors remain active • Even wiggling your toes can help to improve circulation to keep you warm.

The healthcare staff participating in the intervention choose the secondary actions that will create a positive difference to their wards (Daly and Large 2016). The intervention reported using a mixed methods approach, including provision of information using messages, posters and stickers informing the staff about the benefits of natural light, reduced noise and improved sleep for patients (Daly and Large 2016). Other approaches used during the intervention included staff interviews and observations by GAP, patient surveys and energy meter readings (Manika et al. 2016).

Consequently, Operation TLC used an information based energy behaviour change approach that is tailored to the specific audience, which is the most popular form of intervention (Mulville et al. 2017) that is most effective when it is tailored to the specific audience (Steg 2008). The energy behaviour change actions in Operation TLC are based on a mix of curtailment activities, such as switching off lights and efficiency improvements, such as control heating gradually (Attari et al. 2010).

During development of the pilot, Daly and Large (2016) identified four key barriers that may prevent staff from completing the actions these included:

- **Lack of knowledge:** staff are unfamiliar with how the building and its systems work.
- **Lack of expectation:** staff did not know they were expected to or allowed to take actions to control their environment.
- **Habit and memory:** staff knew what to do but were too busy and simply forgot.
- **Facilities maintenance:** staff identified old and broken equipment that had not been fixed or replaced.

During the intervention, 70 patients took part in pre-intervention surveys and 88 took part in post-surveys. Some surveys were completed by the patients and some were completed by the patients with help from GAP. The surveys were completed anonymously and different patients completed the survey pre and post intervention (Manika et al. 2016). Observations by GAP were completed pre and post intervention on several days and nights at approximately the same time to monitor staff behaviours particularly in relation to doors left unnecessarily open and lights left unnecessarily on (Manika et al. 2016). Post-intervention four interviews were conducted by GAP with staff performing various roles (ward manager, healthcare support officer, nurse, discharge coordinator, housekeeper, education centre coordinator and office manager clinical lead) with ranging ages (23-60 years old) and length of service (2-23).

Daly and Large (2016) report the following benefits of running Operation TLC at the Bart's hospitals (270,000 m²):

- **Patients:** 38% fewer requests to change room temperature. Patients' hospital experience improved when sleep improved.
- **People:** Staff report a boost to team spirit and collaboration and feeling proud to improve patient care.
- **Planet:** 1,900 tonnes of carbon dioxide (CO_2e) saved per annum.
- **Pocket:** £428,000 saved per annum.

Following study of the secondary data gathered by GAP during Operation TLC at the Bart's hospitals, Manika et al. (2016) tested the following hypotheses:

- H1: Patients' perceptions of quality of sleep will improve after the energy saving intervention.
- H2: Patients' perceptions of privacy will improve after the energy saving intervention.
- H3: Patients' perceptions of thermal comfort will improve after the energy saving intervention.
- H4: Patients' overall satisfaction with hospital experience will increase after the energy saving intervention.
- H5: Patients' perceptions of quality of sleep will be positively and significantly related to overall satisfaction with hospital experience.
- H6: Patients' perceptions of privacy will be positively and significantly related to overall satisfaction with hospital experience.
- H7: Patients' perceptions of thermal comfort will be positively and significantly related to overall satisfaction with hospital experience.
- H8: Patients' perceptions of privacy will be positively and significantly related to perceptions of quality of sleep.
- H9: Patients' perceptions of thermal comfort will be positively and significantly related to perceptions of quality of sleep.
- H10: H5 to H9 will be moderated by the energy saving intervention.

Manika et al. (2016) used patient questionnaire data to examine H1 to H4 and structural equation modelling (SEM) (Mplus 7 software) was used to examine H5 to H10.

From the analysis Manika et al. (2016) concluded that H1 was supported and the intervention was proven to improve sleep quality for patients. H2, H3 and H4 were rejected, as the intervention was not found to change perceptions of thermal comfort, privacy and satisfaction with hospital experience. H5 and H6 were supported as quality of sleep and privacy were shown to positively affect satisfaction with hospital experience, although H7 was rejected, as thermal comfort was not shown to positively affect satisfaction with hospital experience. H8 was supported as privacy was shown to positively relate to quality of sleep but H9 was rejected, as thermal comfort was not shown to positively relate to quality of sleep. H10 was also rejected, as the intervention does not moderate H5 to H9.

The article concluded that the intervention was perceived to benefit patients and the organisation although the relatively low sampling size meant the results may not have reflected the differences in treatments, patients, environments and medical equipment that are found in the two hospitals (Manika et al. 2016).

Increasing demand and constrained financial resources are currently putting the NHS under unprecedented financial and operational pressure, with the Kings Fund (2015) reporting an aggregate deficit of £1.85 billion (unaudited) in 2015/16, a threefold increase on the previous year and the largest aggregate deficit in NHS history (Dunn et al. 2016). Additionally there is a crisis being felt by mental health and community hospitals (the Kings Fund 2015) and a requirement for the NHS to deliver £22 billion of improvements by 2020/21 (Dunn et al. 2016).

The behaviour of staff is reported to waste about 30% of energy in their buildings (Brown et al. 2012) and it is widely recognised that user behaviour can achieve energy savings in non-domestic buildings (Banks and Redgrove 2012, The Carbon Trust 2013, Mulville et al. 2014). The NHS SDU reports that energy behaviour change interventions could be more cost-effective than traditional building energy efficiency and technology solutions (NHS Sustainable Development Unit 2009). Therefore, a successful energy behaviour change intervention could diminish energy waste and delivery some much-needed financial savings.

2.3 Engaging healthcare professionals

Operation TLC is an energy behaviour change programme that has been specifically developed for healthcare professionals working in NHS Trusts (Daly and Large 2016). As nurses make up the largest number of professionals in the healthcare system (NHS Digital 2017), running Operation TLC with nursing staff provides an opportunity to make a significant impact on energy conservation within hospitals.

In order to run a successful behaviour change intervention with nursing staff it is important to understand the skills that underpin the role of a nurse so that we may tap into these abilities when running the intervention, together with the decision making process that nurses adopt in order to gain an understanding of what will motivate the nursing staff to participate in the behaviour change activities.

Critical thinking, critical analysis, clinical reasoning, clinical judgement and decision-making skills are considered essential for qualified nurses and underpinned the clinical and managerial leadership role of a nurse (Holland and Roberts 2013). Tappen (1989) describes critical thinking as a question-based approach to find different solutions to a problem and critical analysis as tool used by nurses to evaluate the alternative solutions for the best possible outcome.

Clinical reasoning is a linear process used by nurses to make clinical judgements by coming to a full understanding of the patient problem, plan and implement the chosen interventions, evaluate their outcomes and learn from the process. For patients to receive the best possible care nurses need to develop clinical reasoning skills (Levett-Jones et al. 2010).

Aston et al. (2010) identify three main decision-making theories:

- the information-processing model,
- the intuition model, and
- the cognitive continuum theory.

The information-processing theory of decision-making is based on how we obtain and store information gathered from a number of sources and experiences in the short and long term. When information is gathered for the first time, it is stored in the short-term memory. As more information is gathered, the previous information retained is moved from a short-term memory and stored as a long-term memory. Over time more skills, experience and knowledge are acquired and the long-term memory retains more and more information. Then as new information is gathered it may ‘trigger’ a person to remember material that has been stored in the long term memory, which is useful for understanding or undertaking the task in hand or decision to be made (Aston et al. 2010).

However, how we use information is not the only explanation of how we make decisions. Use of intuition in decision-making is based on making intuitive judgements without rational grounds for the decision. This may be as a result of stored information and previous experience but it differs from an information-processing model in that no conscious processing of information occurs when decision making (Benner et al. 1996). This is described by Vaughan (1979, p.46) as “knowing without being able to explain how we know”.

Cognitive continuum theory of decision making is based on judgement and cognition ranging from ill-structured intuition decisions to well-structured analysis (Cader et al. 2005). It represents a spectrum from making an intuitive decision to a decision based on conscious information processing and analysis (Thompson and Dowdin 2002).

From the main decision-making theories, it can be concluded that decision-making comprises a combination of interpersonal, cognitive and technical skills (Holland and Roberts 2013) and critical thinking, critical analysis, clinical reasoning, clinical judgement and decision-making are very similar and often used interchangeably (Thompson and Dowdin 2002).

Thompson et al. (2004) states that decision-making in nursing is dependent on five interrelated factors:

1. the clinical environment,
2. the patient that can be found within that environment,
3. the nurse's perception of their clinical role,
4. operational autonomy, and
5. the degree to which they see themselves as an active and influential decision-maker.

The Nursing and Midwifery Council (NMC) Standards require student nurses to acquire the skills to be able to make decisions determined by an evidence base and clear decision-making pathway. The NMC Standards comprise of four 'domains' each with a set of generic and field-specific set of competencies that student nurses are required to achieve in order to qualify as a nurse and gain entry to the NMC professional register. Competence 1 in Domain 3: Nursing practice and decision making states "They (nurses) must make person-centred, evidence based judgements and decisions in partnership with others involved in the care process, to ensure high quality care" (Nursing and Midwifery Council 2010, p.2).

Cleary-Holdforth and Leufer (2009) describe evidence based practice as a holistic approach to delivering care that puts the patient at the core of nursing and is based on three key influential factors that contribute to decision making by nurses:

- patient preference or opinion,
- the nurse's experience and expertise, and
- relevant evidence from research, expert reports, or significant organisations.

Evidence based practice is popular amongst healthcare professionals and actively encourages critical assessment and questioning as part of the decision making process in the pursuit of patient improvement and better practice (Jolley 2009).

Nurses often have to make complex decisions and the expertise of the nurse impacts directly on their decision making ability (Thompson et al. 2004). Consequently, a less experienced nurse may take more time to collect information on which to base their decisions, whereas a highly experienced nurse spends less time seeking information when making a decision (Thompson et al. 2004).

The fundamental priority in NHS England's business plan 'Five Year Forward Plan' (2014-2019) is to improve patient care (NHS England 2014), which is aligned with the decision making processes above that nurses undertake in their role. Each industry has its own unique motivators for a successful employee behavioural intervention (Manika et al. 2013) and for nurses this is clearly improving the health and wellbeing of its patients. Consequently, to run a successful behavioural change programme with nurses it is essential that patient care is at the heart of the intervention (Morgenstern, Raslan, et al. 2016).

In line with NMC Standards and evidence based practice in nursing (Jolley 2009), the behaviour change intervention will need to be based on trustworthy evidence based research that the intervention will improve the health and wellbeing of the patients. Although it is hard to define, it is also important that the nursing staff perceive intuitively that the behavioural change intervention is the right thing to do for their patients (Cleary-Holdforth and Leufer 2009).

In the case of Operation TLC changing the energy behaviours of healthcare staff should create a better environment for their patients and consequently has the potential to provide the following health and wellbeing benefits not only for patients but for staff also (Daly and Large 2016):

- **Turn equipment off:** noise from equipment, including televisions has the potential to create both psychologically and physiologically detrimental impacts to health of patients and healthcare professionals (Mazer, 2012), therefore turning equipment off when it is not in use and introducing quiet times should improve patient and staff wellbeing.
- **Lights out:** increasing natural daylight has the potential to:
    - alleviate sleep disturbances by 38% (Bartick et al. 2010),
    - for mental health patients, sunlit rooms allowed an average of 3.67 days shorter hospital stays (Agency for Healthcare Research and Quality 2005),
    - increase intensity of sunlight creates less perceived stress and marginally less pain; patients also took 22% less analgesic medication per hour and had 21% less pain medication (Walch et al. 2005), and
    - increase in natural light is associated with reductions in various factors including 25% less staff sick leave, 32% less tiredness, 45% fewer headaches, 31% fewer sore throats and a tangible decrease in stress (Bartick et al. 2010).

- **Control temperature:** 90% of wards are at risk of overheating as a result of poor insulation and ventilation; and the severity of the risk will increase as average global temperatures continue to rise (Committee on Climate Change, 2014), increasing the severity and frequency of storms, flooding and heatwave events, which negatively impact on both mental and physical health (St. Louis and Hess 2008, The Lancet 2018).

Taking two of the five interrelated factors of decision making in nursing, the intervention must be tailored to the type of patient and the particular clinical environment that it will be run in (Thompson et al. 2004). The behaviour change intervention will have to take into account the level of experience of the nursing staff participating in the programme and ensure that those participating in the intervention believe themselves to be active and influential within the programme to ensure success (Thompson et al. 2004).

As success of the intervention will depend on the ability of the nursing staff to embed the behaviours into their daily routine long after the behaviour change intervention has been run, it is essential that the nursing staff are empowered to take operational autonomy of the project from the start (Ryan-Fogarty et al. 2016).

Over recent years changes in health policy has meant the role of a nurse has grown significantly and they are expected to take on greater levels of responsibility (Holland and Roberts 2013). Therefore, to gain acceptance of the behaviour change intervention, nursing staff must believe that the programme is reasonable to do as part of their daily duties and not an additional burden.

However, greater levels of responsibility also mean nurses have greater independence over their clinical practice (Holland and Roberts 2013). Consequently, if the nursing staff believe the behaviour change intervention is the correct thing to do for their patients then they have the autonomy to make it happen in their wards.

In a study examining the impact of gender on energy saving attitude and behaviour, Paco et al. (2015) found that female students were significantly more likely to adopt energy saving behaviours. In 2017, 89% of nursing staff in NHS England were female (NHS Digital 2018), consequently this demography may have a positive effect on the introduction of a nurse-led energy behaviour change intervention in a NHS hospital.

2.4 Health research methodology

From the previous chapter it has been established that nurses make decisions determined by an evidence base and clear decision-making pathway (Nursing and Midwifery Council 2010). Evidence in healthcare is produced by conducting research based on evidence based methodology and must include quantitative and qualitative methods (Holloway and Wheeler 2002, Polgar and Thomas 2013).

Qualitative research in nursing is the building and testing of theories using a group of non-statistical approaches to gain an understanding of patient or health professionals' experiences and behaviour (Holloway 2008, Borbasi and Jackson 2015). Quantitative research in nursing is the building and testing of theories using a group of statistical or numerical approaches (White and Millar 2014 cited in Ingham-Broomfield 2014).

There are a number of forms of data collection in qualitative and quantitative research that may be used to gather data, including but not limited to surveys, questionnaires, interviews, focus groups, observation and measurement (Holloway 2008, Polgar and Thomas 2013, Davies and Hughes 2014).

Interviewing is a common form of qualitative data collection with nurses and is used as the main form of data collection when assessing a patient (Holloway and Wheeler 2002). Atkinson and Silverman (1997) suggest that interviewing is the most favoured form of research in society. Interviewing differs from general forms of conversation as it has a clearly defined format of questions and responses (Saks and Allsop 2007). Interviewing happens on a one-to-one basis or as part of a focus group (Holloway and Wheeler 2002).

A focus group comprises of a collection of people, often with common background or characteristics that are interviewed by a researcher for the purposes of gaining information on a specific topic or set of questions (Holloway and Wheeler 2002). Unlike one-to-one interviews, a focus group facilitates discussion within the group of interviewees based on shared perceptions, which stimulates ideas and facilitates a broader exploration into a topic (Saks and Allsop 2007).

A survey is a method for collecting information from people on their attitudes and behaviours (Fink 2003a, Mathers et al. 2010). Fink (2003) states a good survey should have:

- a specific objective or objectives,
- appropriate research design,
- straightforward questions,
- appropriate sample, and
- a valid survey instrument or instruments.

Surveys can take many forms from questionnaires to reviewing data collections, such as a population census (Fink 2003a, Mathers et al. 2010). Questionnaires can be face-to-face, telephone, on-line or paper based (Mathers et al. 2010), and are a practical and cost effective method of surveying a group of people (Fink 2003a).

Observation and measurement are the most common methods for data collection in both health research and clinical practice (Polgar and Thomas 2013). Observation is direct monitoring by perception of someone or something under study (Holloway 2008, Polgar and Thomas 2013).

The advantage of observation over other forms of data collection such as surveys, questionnaires and interviews in health research is that the researcher is able to directly hear and see what the patient actually says and how they act, rather than rely on the patient's interpretations and perceptions of their actions (Holloway 2008, Polgar and Thomas 2013). Observation data collection takes place in the context of qualitative field research and provides an authentic picture of patient behaviour in their natural environment (Holloway 2008, Polgar and Thomas 2013).

Measurement is the procedure of quantifying an object, person or event under study into specific units. The validity of the measurement process or tool being used is paramount to the credibility of the findings and subsequent hypothesis (Creswell 1994, Polgar and Thomas 2013). Measurement as a form of data collection takes place in the context of quantitative field research and provides an authentic picture of the subject under study (Creswell 1994, Polgar and Thomas 2013).

Whether quantitative or qualitative research methods are used to collect data, Jirojwong et al. (2014, p. 131) discusses that data collected may go through some or all of the following stages of analysis "familiarisation with the data, transcription of recorded material, organisation of data, coding, de-identifying, re-coding, categorising and exploration of relationships between categories".

The data collected will lead to a set of empirically verifiable hypothesis or statements based on scientific evidence (Creswell 1994, Polgar and Thomas 2013). Hypotheses should be tested under controlled conditions in order to discount other competing hypotheses (Davies and Hughes 2014, Polgar and Thomas 2013, Holland 2008).

Hypotheses may be integrated to form a theory, which is an exploratory assertion that specifies the relationship between two or more sets of variables (Polgar and Thomas 2013, Burns and Grove 2011), often indicating a claimed pattern of cause and effect (Davies and Hughes 2014) that is ideally narrowed down to a specific statement of the problem (Nieswiadomy 2012). Lippke and Ziegelmann (2008) discuss that good theories can be used to explain and predict health behaviour, and likewise are needed in order to understand what drives behavioural change in order to design and evaluate interventions.

Operation TLC hypothesises that turning lights out, turning off equipment and controlling temperatures will reduce energy consumption, improve patient wellness and staff satisfaction. Leading to the theory that Operation TLC saves energy whilst creating healthy environments for staff and patients (Daly and Large 2016).

2.5 Healing environments

Environmental control was one of Florence Nightingale's main pillars of health, so recognition that the healthcare environment is a key element of patient healing has been understood throughout the history of nursing (Harris et al. 2009, Huisman et al. 2012).

A research project commissioned by NHS Estates concluded the hospital environment has a direct impact on patient treatment and significant impact on health outcomes (Lawson, B., Phiri, M. and Wells-Thorpe 2003). A review of over 600 academic studies found that for staff a healthy hospital environment reduces stress and fatigue whilst improving effectiveness, and for patients a healthy hospital environment reduces stress and increases patient safety whilst improving overall health outcomes (Ulrich et al. 2004). Therefore, Ulrich et al. (2008) concluded there is little doubt that the healthcare environment has an impact on the outcomes of its users.

Consequently, implementing an initiative to improve the healthcare environment has positive impacts on both the physical health of the staff, patients and the environment, and the psychological health of staff and patients (Harris et al. 2009). As Operation TLC claims to improve the patient environment whilst reducing energy (Daly and Large 2016) it is important to identify credible evidence based research of the potential environmental benefits associated with the actions in the staff behaviour change intervention to ensure buy-in from the nursing staff.

2.5.1 Impacts of light on staff and patients

It is widely acknowledged that natural light provides significant health benefits over synthetic light, including reducing depression, decreasing fatigue, improving alertness, modulating circadian rhythms, and treating conditions such as hyperbilirubinemia among infants (Ulrich et al. 2008). Studies have found that access to windows and increased daylight levels are linked to shortened hospital stays (Agency for Healthcare Research and Quality 2005, Joseph 2006, Mathews 2013), a reduction in sleep disturbances (Bartick et al. 2010), reduced levels of depression, reduced pain and reduced requests for medication (Walch et al. 2005). Natural light also decreases medical error rates (Ovitt 1996 cited in Harris et al. 2009).

In addition, studies also reported increased patient (Mathews 2013) and staff satisfaction (Edwards and Torcellini 2002, Boyce et al. 2003) with access to natural light in the environment. In contrast, increased levels of bright synthetic light creates disruption to the circadian rhythm (Bartick et al. 2010, Amundadottir et al. 2016).

National Institute of General Medical Sciences describes circadian rhythms as "physical, mental and behavioural changes that follow a roughly 24-hour cycle, responding primarily to light and darkness in an organism's environment. Circadian rhythms can change sleep-wake cycles, hormone release, body temperature and other important bodily functions" (National Institute of General Medical Sciences cited in Acosta et al. 2015), so impacts to the circadian rhythm can significantly affect human health (Amundadottir et al. 2016).

Therefore, there is strong evidence that synthetic light negatively influences human health and natural light positively influences human health (Bartick et al. 2010). An article by Wynn-Jones (2002) reported that research studies by Hollwich and Dieckhues (1980) and others had led to a ban of fluorescent lighting in German healthcare facilities in an attempt to encourage natural light. And the use of natural light is also directly influencing the design of new hospital buildings (Ming et al. 2011), for example the Ng Teng Fong General Hospital in Singapore was designed so that every patient has direct access to a window and consequently natural light (Ng Teng Fong General Hospital 2018), shown in Figures 6 and 7.

Figure 6. An image of Ng Teng Fong hospital, Singapore

Figure 7. An image of a Ng Teng Fong hospital ward

The community hospital used during this case study is relatively new and there is excellent use of daylight in the common areas, most notably the entrance and cafeteria.

Consequently, one the primary actions for Operation TLC behaviour change initiative is "Lights out" to make use of natural light and includes a number of practical secondary actions in this category for nursing staff to do, including:

- switching off lights in unoccupied rooms,
- opening blinds and make the most of natural light by switching main lights off,
- introducing quiet time for an hour or two after lunch, which involves turning lights off or dimming them in rooms and corridors to giving patients a peaceful time to rest and recover and time for nursing staff to catch up on other tasks, and
- Switch lights off at night to enable patients to get a better night's sleep (Daly and Large 2016).

2.5.2 Impacts of noise on staff and patients

It is widely acknowledged that a quiet and calm hospital environment has benefits on the wellbeing of staff and patients (Department of Health 2007, Li et al. 2011, Konkani and Oakley 2012, 2014, Stafford et al. 2014), including reduced use of sedation and shorter hospital recovery rates (Buxton et al. 2013). When noise exceeds comfortable levels it has detrimental psychological and physiological effects on the health of staff and patients alike (Mazer 2012, Basner et al. 2014).

Noise is also the most reported cause of stress (Mazer 2012, Basner et al. 2014) and sleep disturbances (Royal College of Nursing 2012, Park et al. 2014) in hospitals. It was reported by Royal College of Nursing (2012) that noise at night was the primary concern for patients about the hospital environment and a study by Park et al. (2014) found that 86% of patients surveyed reported having “bad sleep” as a direct consequence of noise on the ward.

In the UK, the Chartered Institution of Building Services Engineers (CIBSE) (Chartered Institute of Building Services Engineers 2015) and DoH (Department of Health 2007) have published standards for acceptable noise levels in hospitals; for general wards and single occupancy wards both standards advise a noise rate of 30 decibels (dB). Hilton (1985) reported that noise levels exceeding 60dB negatively affect sleep in hospitals.

Noise levels above 85dB are considered to be harmful to health (Schneider 2005) and consequently the UK Control of Noise at Work Regulations 2005 sets the upper exposure action value at 85dB, above which an employer is required to take reasonably practicable measures to reduce noise exposure (HSE 2011). To put this in perspective conversational speech is reported to be around 60dB, a vacuum cleaner around 80dB, a pneumatic hammer around 100dB and a jet aircraft around 120dB (Hsu et al. 2012, Ryherd et al. 2012).

A number of studies found that background noise in hospitals frequently exceeded the recommended levels, with background noise levels typically measuring 45-68dB and peak noise levels typically measuring above 85dB (Ulrich et al. 2004). Some of the main sources of noise in the hospital environment were found to be staff and visitors (23%) followed by noise from other patients (Buxton et al. 2013). Table 2 shows a summary of the noise levels of a variety of activities and equipment in an intensive care ward (Pugh et al. 2007).

Table 2. A summary of the causes of noise in an intensive care ward (Pugh 2007)

Activity	Noise level (dB)
Noise cause directly by behaviour	
Items falling onto floor	Up to 92
Equipment movement (e.g. bed)	90
Talking	75 – 85
Door closure	85
Pager	84
Telephone	70 – 80
Television	79
Noise due to equipment	
Connection of gas supply	88
Ventilator alarm	70 – 85
Monitor alarm	79
infusion alarm	65 – 77

Whether noise originates from equipment or behavioural activities, hospital wards can be unhealthy environments when decibel levels remain unchecked (Ulrich et al. 2008). Consequently, one the primary actions for Operation TLC behaviour change initiative is to "Turn off equipment" and includes a number of practical secondary actions for nursing staff to do in order to reduce noise on hospital wards, including:

- Turn off any unwanted medical equipment where possible,
- Turn off computers, monitors and TVs that aren't being used, and
- Introduce quiet time (Daly and Large 2016).

2.5.3 Impacts of temperature on staff and patients

It is widely acknowledged that extreme temperatures have a negative impact on human health through heat strokes and hypothermia, which may be fatal when the body's core temperature is pushed beyond its tolerance (Angus 1968, Basu and Samet 2002, McMichael et al. 2006, Nicol et al. 2012).

The impact of temperature on staff and patients in healthcare environments is highly complex, as it is influenced by both specific health-related requirements and thermal comfort (Abrudan et al. 2016). Consequently, Cannistraro and Bernardo (2017) report that controlling indoor environments is a significant issue for hospitals.

Health-related temperature requirements range significantly, for example patients with multiple sclerosis require cool temperatures (Davis and Jacobson 1971) whereas patients with Raynaud's Syndrome require warmer temperatures (Porter et al. 1981). Warmer temperatures can also help to ease physical ailments that affect older people, such as rheumatism and arthritis (Angus 1968). Drug use associated with illness also reduces the ability of people to thermo-regulate (Havenith 2001). Consequently, inappropriate temperatures in hospitals can have significant effects on the health of patients (Abrudan et al. 2016).

In addition to health-related requirements, generally hospitals have to accommodate two very different groups of people (Del Ferraro et al. 2015). Firstly, patients who tend to have a low metabolic rate because of their immobility from lying in bed and consequently feel colder (Skoog et al. 2005). Secondly, the healthcare staff who tend to have a higher metabolic rate from the physical activities associated with caring for the patients and consequently feel warmer (Del Ferraro et al. 2015).

Another factor that may contribute to the differences between patients and healthcare staff is clothing (Del Ferraro et al. 2015). For example, patients tend to wear bed wear that have lower insulation levels than healthcare staff who tend to wear uniforms made of dense hardwearing material that have high insulation levels (Skoog et al. 2005).

Additionally age may contribute to the differences between patients and healthcare staff (Del Ferraro et al. 2015). One of the most significant challenges for the NHS an ageing population (Appleby 2013) and whilst some wards are currently populated with elderly patients this is predicted to increase (Thompson 2015).

It is commonly agreed that age reduces the ability to thermo-regulate (Havenith 2001), so coupled with lower activity levels and lower clothing insulation it is reasonable to assume that older patients will require higher temperatures to achieve thermal comfort than the healthcare staff (van Hoof and Hensen 2006). A reduced ability to thermo-regulate can lead to a number of health issues including heat strokes, hypothermia and an increased number of falls (Havenith 2001).

Thermal comfort is an indicator that the body is healthy in its environment and thermal discomfort is a warning that the environment might present a danger to this health (Fanger 1970, Nicol et al. 2012). Thermal comfort is defined as "...that condition of mind that expresses satisfaction with the thermal environment" (British Standards Institute 2005). Inappropriate thermal comfort conditions lead to decreased work efficiency and an increased likelihood of the personnel errors (Pourshaghaghy and Omidvari 2012). Consequently, thermal comfort is a key factor of a "healthy and productive" workplace (Djongyang et al. 2010).

Following a statistical examination of observations on the requirements for a comfortable environment Bedford and Warner (1939) developed the following list:

- Average temperature of the internal surfaces, including walls should not be significantly lower than air temperature, preferably warmer,
- Air temperature at head height should not be distinctly warmer than at floor level; occupant's head should not be exposed to excessive radiant heat,
- Indoor environment should be as cool as is compatible with comfort,
- There should be adequate air movement, for UK this should be a minimum of 1.5 meters per second; with rates increasing in higher temperatures,
- Air movement should be variable not monotonous, and
- Relative humidity should never exceed 70%, preferably much lower.

People adapt to their surroundings unconsciously using physiological adaption (Angus 1968, Fanger 1970, Nicol and Humphreys 2002, Nicol et al. 2012) and consciously using a range of adaptive behaviours (Nicol et al. 2012, Humphreys et al. 2016) from everyday short-term actions such as choosing appropriate clothing to long-term actions such as choosing the design and construction of a building according to the local climate (Humphreys et al. 2016).

Air temperature, relative humidity, radiant heat and air movement all influence the regulation of body temperature through physiological processes by affecting the balance between heat produced inside the body through activity and the heat loss to the environment (Brown 1959 cited in Angus 1968).

For cooler climates like the UK, it is broadly accepted that air temperature is the most important factor affecting thermal comfort and for hotter climates like Australia relative humidity is of greater importance (Angus 1968). This is confirmed by Griffiths (1990) who reported having the 'right temperature' was found to be the most important consideration by people in a user satisfaction survey of UK buildings, closely followed by 'air freshness'.

CIBSE recommend winter operative temperatures of 22-24^{o}C and summer operative temperatures of 23-25^{o}C for general hospital wards (Chartered Institute of Building Services Engineers 2015) and the UK DoH recommend temperatures of 18-28^{o}C for general hospital wards (Department of Health 2007) to cover all eventualities.

Consequently, one the primary actions for Operation TLC behaviour change initiative is to "Control temperatures" and includes a number of practical secondary actions for nursing staff to do in order to control to temperatures on hospital wards, including:

- close the doors to patient rooms,
- close door when rooms aren't occupied,
- close window when heating is on,
- control heating gradually,
- layer up if cold, and
- encourage patients or visitors remain active (Daly and Large 2016).

2.5.4 Human factors and thermal comfort

A human body requires a constant internal temperature, otherwise known as its core temperature of around 37.5°C (Nicol et al. 2012, Abrudan et al. 2016). The body primarily manages its core temperature by physiological processes that divert blood to and from the periphery of the body to control heat loss (Djongyang et al. 2010, Nicol et al. 2012).

Heat loss occurs primarily from the skin to the environment through several processes, including radiation, convection and evaporation (Djongyang et al. 2010, Nicol et al. 2012). Cooling by convection occurs when heat is lost from the body to the surrounding air (Djongyang et al. 2010, Nicol et al. 2012). Cooling by radiation occurs when heat is lost from the body to surrounding surfaces and cooling by evaporating occurs when heat is lost from the body through evaporating moisture from the skin (Djongyang et al. 2010, Nicol et al. 2012). Cooling by evaporating moisture from the skin, otherwise known as sweating is a human's natural cooling mechanism and the amount of sweat produced is a measure of heat strain (Angus 1968).

Heat loss from the body occurs when the external temperature is lower than the mean skin temperature; and vice versa, heat from the air flows into the body when the external temperature is higher than the mean skin temperature (Djongyang et al. 2010, Nicol et al. 2012). In the short-term, the body uses these physiological processes collectively working together to thermo-regulate the body's core temperature (Djongyang et al. 2010, Nicol et al. 2012).

People vary in physical characteristics, temperaments and adaptability, so there is a wide variation in individuals' subjective perceptions of thermal comfort (Angus 1968, Abrudan et al. 2016). Consequently, a person's age, gender, culture, personality and expectation of conditions based on previous experience may all influence their thermal comfort (Djongyang et al. 2010, Nicol et al. 2012).

For example, as older people become less active they feel the cold more and need a warmer environment to feel comfortable (Angus 1968, Del Ferraro et al. 2015). However, the link between gender and thermal comfort shows mixed results (Karjalainen 2012) with some field studies finding little difference in the thermal comfort range between men and women (Ballantyne et al. 1977, Humphreys 1978) whilst others report that females are more sensitive to deviation from thermal comfort and consequently more likely to express thermal dissatisfaction than males (Schellen et al. 2012).

A factor that effects the body's thermal-regulatory process is a person's metabolism, which is a series of energy consuming chemical processes that are required for the body to function, such as breathing, digesting food and repairing cells (NHS 2017). Genes, age, gender and body size, particularly the level of fat and muscle, all effect a person's metabolism or metabolic rate; for example, as people become older they tend to loose muscle mass and consequently have a lower metabolic rate (NHS 2017).

The thermo-regulatory system is controlled by the autonomic nervous system (Peiper and Pitzer 2004), which appreciates moderate change, so there is an advantage to variable stimuli within the acceptable perimeter changes for humans (Angus 1968). Humphreys et al. (2016) concluded that people could be comfortable in variable conditions if they have the facility to physically adapt.

For example, in the short-term, research found that it took about ten days for soldiers living and training in one thermal environment to achieve full performance in a significantly different thermal environment (Prosser 1958). Roberts (1978) concluded that in the long-term adaption might even become irreversible, for example, people raised in hot dry climates had a different distribution and use of sweat glands compared to people raised in temperate climates.

In addition to physiological and physical factors, people have the ability to adapt to their surroundings using a range of adaptive behaviours (Nicol et al. 2012, Humphreys et al. 2016) from everyday activities. Some of these activities are chosen and controlled directly by the individual, such as putting on additional clothing when indoor temperatures cool or opening a window when indoor temperatures increase. These personal adaptive activities are immediate not gradual (Brager and de Dear 1998).

Other activities are chosen or controlled by others such as adjusting the set temperature on a building management system in hospital. In reality, thermal comfort is usually achieved by using a number of small adaption activities that are multiplicative in their effect, so collectively create a greater change (Nicol et al. 2012).

Whilst there isn't an ideal comfortable temperature, ranges of temperature can be established within which the majority of occupants in the same environment are comfortable in; these are called 'comfort zones' (Angus 1968, Fishman and Pimbert 1982). Fishman and Pimbert (1982) found that temperature varied by 4.9^{o}C in the comfortable range, and between 2.0-1.5^{o}C in the warm/too warm range and 2.5^{o}C in the cool range. Fishman and Pimbert (1982) concluded that people rapidly felt thermal dissatisfaction when the environment was no longer in the comfort zone, although Fanger (1970) predicted a minimum of 5% of people will be dissatisfied with any one indoor environment.

However, field studies also found that when a person does not have the ability to change their clothing, the activity they are doing or increase the air flow in the environment then the comfort zone can be as narrow as a ±2^{o}C (Nicol et al. 2012). Therefore, the range of the comfort zone is wider (±4.9^{o}C) when there is more access to adaptive mechanisms and narrows (±2^{o}C) when there is no access to adaptive mechanisms (Fishman and Pimbert 1982, Nicol et al. 2012).

Field studies in offices and schools have also found that as people rarely adjusted their clothing during the working day a small proportion of the people experienced mild discomfort from a temperature drift of ±2^{o}C in the day (Humphreys 1979). As other adaptive mechanisms, such as changes to the heating system, occur gradually in relation to changes in the local environment, some field studies have found that changes to the daily mean indoor temperature should not exceed ±1^{o}C and weekly mean indoor temperature should not exceed ±3^{o}C (Humphreys 1978, Nicol and Raja 1996, Morgan and DeDear 2002 cited in Nicol et al. 2012).

Halawa and Van Hoof (2012) also concluded that people experienced a wider range of temperatures that they were comfortable in when they adjusted their expectations. The concept of adaptive thermal control has wide academic support (Halawa and Van Hoof 2012) and has been incorporated into the main international standards for evaluating thermal comfort, including the North American Standards Institute ASHRAE Standard 55: 2017, International Standards Organisation (ISO) 7730: 2005 and British Standards Institute (BS EN) 16798-1:2019.

BS EN 16798-1: 2019 sets a recommended temperature drift limit of ±3^{o}C for mean indoor temperature to achieve a medium level of expected thermal comfort, ±2^{o}C for a high level of expected thermal comfort and ±4^{o}C for a moderate level of expected thermal comfort (British Standards Institute 2019).

2.5.5 Environmental factors and thermal comfort

Outdoor climate is an important factor in indoor climate and thermal comfort (de Carvalho et al. 2013), particularly in 'passive' buildings; that is buildings that are not mechanically cooled or heated (Humphreys 1978). Field studies have shown that in pleasant climates thermal comfort can be achieved by minimising the difference between outdoor and indoor temperatures (Humphreys 1978). When the outdoor climate becomes unpleasantly hot or cold, then thermal comfort may only be achieved by inverting the relationship between the outdoor temperature and indoor temperature (Humphreys 1978).

Humphreys (1978) found that preferred indoor temperature correlated to average external temperature; in that as external temperatures increased, preferred indoor temperatures also increase and vice versa. Humphreys (1978) field studies in a variety of building types revealed that in the UK people found indoor temperatures as low as 19^{o}C acceptable in the winter and as high as 24^{o}C acceptable in the summer.

In the UK, the mean outdoor temperature rarely exceeds 20^{o}C, therefore indoor temperature should not exceed 27.4^{o}C in a passive or naturally ventilated building using the equation:

$$\theta com = 0.33\,\theta rm + 20.8$$

where θcom is the comfort temperature and θrm is the daily mean outdoor air temperature (Chartered Institute of Building Services Engineers 2015). CIBSE define an overheating building as one that exceeds 28^{o}C for a set period of 1% of the annual occupied hours (Chartered Institute of Building Services Engineers 2015), although Nicol et al. (2012) suggests this set period of time should be 1% of the working day.

Increasing temperatures and heatwaves are acknowledged consequences of climate change (St. Louis and Hess 2008, Watts et al. 2015). As heat loss or gain from buildings depends on indoor-outdoor temperature difference it is anticipated that climate change will exacerbate issues of overheating in buildings and create a challenge to keep indoor temperature within a safe range (Nicol et al. 2012).

Healthcare environments have to accommodate a number of specific health-related requirements (Abrudan et al. 2016) and environments, such as operating rooms (Balaras et al. 2007). Therefore, hospitals require efficient heating, ventilation and air conditioning systems (HVAC) to facilitate the variety of indoor environmental conditions for patients and staff (Balaras et al. 2007).

HVAC are used to control indoor temperatures and airflow, which have a direct effect on the thermal comfort of the occupants (Friedman 2004, Balaras et al. 2007). Human body temperature is higher at the head than at the feet, therefore to avoid thermal discomfort from cold feet (Angus 1968), which restricts blood circulation and causes chill-blains (Goette 1990) the distribution of heat within the environment is as important as the indoor temperature. Traditional central heating systems use heated pipes or radiators to warm up the enclosed air in a room through convection, so effects such as stratification need to be considered and avoided (Friedman 2004).

Using air-conditioning to cool buildings creates a negative climate change feedback loop; with wide scale use of air-conditioning in hotter countries such as USA adding to global warming which creates higher global temperatures, which creates an increased demand for air conditioning and so on (Nicol et al. 2012).

If walls are insulated, much of the radiant heat from a heating panel is re-radiated back into the room (Baker 2009, Karadağ 2009) and inner surfaces gain heat which warms them (Karadağ 2009). Rates of heat loss through materials is measured using the thermal transmittance coefficients or U-values. U-values are measured in W/m^2K, which is the rate of heat flow in Watts (W) through one square meter (m^2) of a structure when there is a temperature difference across the structure of one degree kelvin (K) (Baker 2009, Harris 2012).

Heat from the sun can be excessive in highly glazed buildings (Nicol et al. 2012). When heat from the sun enters a glazed building, the solar radiation is absorbed by solid surfaces that it encounters, heating them. Heat passes from these solid surfaces into the air by convection and partially re-radiates at a much longer wavelength (Hodder and Parsons 2008), some of which stays in the building and is taken up by the occupants, their clothing and other internal objects and the rest absorbed by window glass which is opaque to it (Hodder and Parsons 2008).

A problem with constant overheating of an indoor environment is that the occupants become acclimatised to the conditions as physiologically the sensitivity of nervous receptors lessen with continuous exposure (Angus 1968). In an experiment conducted by Leithead and Lind (1964) a group of men became acclimatised to artificially heated conditions over nine days; they also noticed a considerable reduction in thermal discomfort, sweating, pulse rates, rectal temperatures and physical effort after three days.

Circulated air can relieve heat stagnation and opening windows is the most common adaptive behaviour used by people for circulating air and cooling indoor temperatures (Rijal et al. 2007). The rate of ventilation is calculated by the number of complete air changes per hour in a room assuming that for each air change an equal amount of air has entered and lost equal to the total volume of the air in the room (Gratia and De Herde 2003, Frank 2005, Eicker et al. 2006).

In a room at an ordinary temperature, there is an ascending current of air above every person that has been warmed by the body (Angus 1968), therefore excessive ventilation can create substantial heat loss (Angus 1968).

Field studies by Nicol and Humphreys (2004) found that in hot environments comfort temperatures increased by 2^{o}C when fans were used to circulate air. People perceive that high humidity makes an environment feel hotter, but the effect of using fans in environments with high humidity did not provide consistent results (Nicol and Humphreys 2004).

Ventilation also removes vitiated air and replaces it with fresh air (Bedford and Warner 1939). The assumption is that ventilation is required to remove the build-up of carbon dioxide (CO_2), which is dangerous to human health (Bedford and Warner 1939, Angus 1968). However, experiments have proven that concentrations of carbon dioxide (CO_2) in normal building conditions are harmless and it is the build-up of disagreeable heat moisture and odours that cause occupants to take action (Bedford and Warner 1939, Angus 1968).

Indoor air quality includes a measure of CO_2 and fresh air levels being introduced per person in an indoor environment (Dwyer 2011). Therefore, high levels CO_2 are an indicator that an indoor environment may not be adequately ventilated (Dwyer 2011). Table 3 shows the British Standards (BS) EN 16798-1: 2019 indoor environmental quality (IEQ) categories of CO_2 concentrations (ppm) above outdoor CO_2 concentrations for occupied bedrooms.

Table 3. Indoor environmental quality (IEQ) categories in BS EN 16798-1: 2019 (British Standards Institute 2019) of CO_2 concentrations (ppm) above outdoor CO_2 concentrations for occupied bedrooms

Category	Description	CO_2 level (ppm) above outdoor CO_2 level
IEQ_I	High indoor environmental quality	380
IEQ_{II}	Medium indoor environmental quality	550
IEQ_{III}	Moderate indoor environmental quality	950
IEQ_{IV}	Low indoor environmental quality	950

The Earth Systems Research Laboratory Global Minotoring Division reported an average global atmospheric carbon dioxide concentrations of 405 ppm in 2017 and 408 ppm in 2018, therefore a figure of 406.5 ppm was used during this study for the average atmospheric carbon dioxide concentrations.

2.5.5.1 Modelling and measuring thermal comfort

From the literature review, a number of mechanisms were identified as influencing adaptive thermal comfort, including:

- Physical environmental stimuli, such as outdoor climate and indoor climate, and
- Human physiology, psychological, cultural and social stimuli.

These mechanisms were modelled by Djongyang et al. (2010), shown in Figure 8.

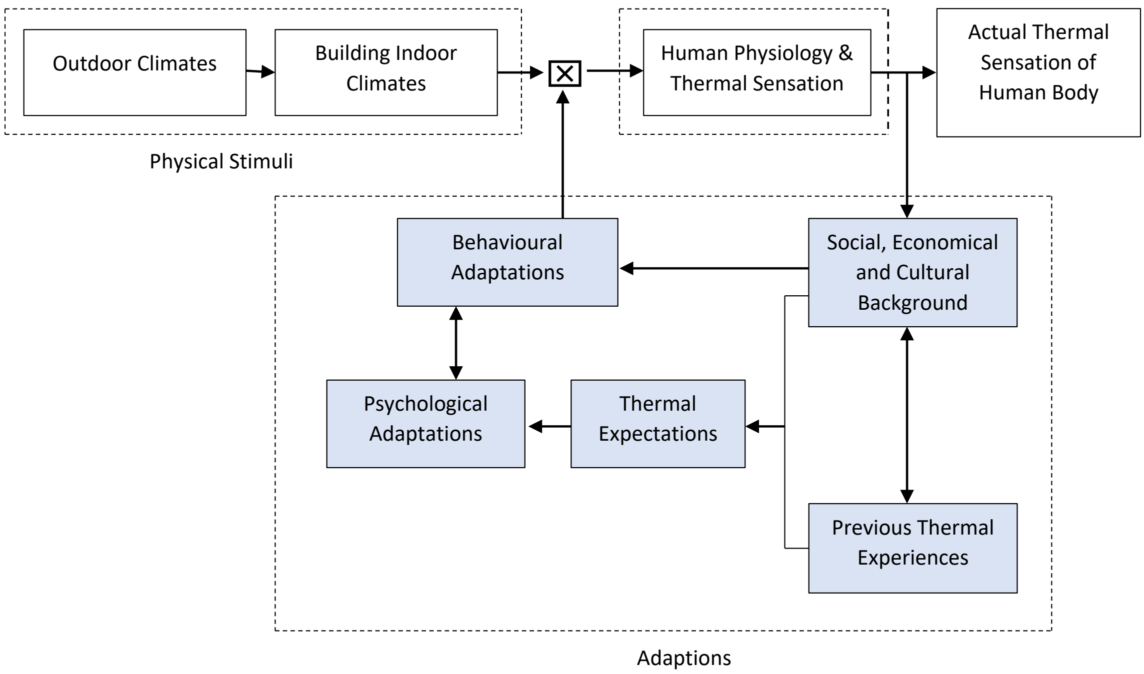

Figure 8. Thermal comfort adaptive model mechanisms reproduced from Djongyang et al. 2010

Fanger's (1970) predicted mean vote (PMV) model is used in international standards, such as ASHRAE 55: 2017, ISO 7730: 2005 and BS EN 16798-1: 2019 by building designers to calculate indoor thermal comfort (Nicol and Humphreys 2002, Abrudan et al. 2016). The PMV equation includes six parameters to predict the thermal comfort of a building's occupants and shows the results on ASHRAE 7-point thermal sensation scale (Beizaee and Firth 2011), shown in Figure 9.

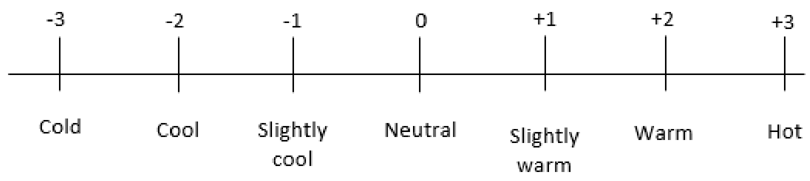

Figure 9. ASHRAE 7-point thermal sensation scale reproduced from ASHRAE 55 2017

Four of the PMV parameters comprise of environmental variables, including:

- Air temperature, which is the temperature of the air in the indoor space,
- Mean radiant temperature (MRT), which is weighted average of all the temperatures from surfaces in the indoor space,
- Air velocity, which is the rate of air movement in the indoor space over a given period, and
- Relative humidity (RH), which is the percentage of water vapour in the air within the indoor space.

Whilst two of the PMV parameters comprise of human variables, including:

- Clothing insulation (Clo), which is the amount of thermal insulation worn by the occupant(s), and
- Metabolic rate (Met), which energy generated by the occupant(s).

Standards ASHRAE 55: 2017and ISO 7730: 2005 state the recommended acceptable normal PMV range for indoor thermal comfort is between -0.5 and +0.5 for a building**.** A function of PMV is the Predicted Percentage of Dissatisfied (PPD), which predicts the percentage of occupants that will be dissatisfied with the indoor thermal comfort of an environment (Cannistraro and Bernardo 2017). ASHRAE 55: 2017 and ISO 7730: 2005 states the recommended acceptable PPD range for indoor thermal comfort is less than 20% dissatisfaction.

Underlying all the standards and consequently the PMV model is the assumption that mechanical ventilation is the normal standard and that natural ventilation is not (Nicol and Wilson 2010). Therefore, whilst the PMV-PPD model has been proven effective for air-conditioned buildings it is based on studies undertaken in an artificial clinical setting (Oseland 1995) and has proven not to be a good fit for non-air conditioned buildings, such as naturally ventilated ones (Beizaee and Firth 2011). Reviews of a number of field studies in various climates and environments show the PMV model underestimated thermal comfort (Humphreys 1976, Auliciems 1981).

A number of field studies have also shown that thermal comfort varies between different environments in the same climate, which the PMV model does not distinguish if the environmental variables are the same (Beizaee and Firth 2011). For example, Fishman and Pimbert (1982) found the thermal neutral temperature was 2^{o}C lower in homes at than in offices in the same climate. Thermal comfort also varies between different people in the same environment with the same clothing and metabolic rate, which the PMV model does not distinguish (Djongyang et al. 2010).

Humphreys et al. (2016) discusses that a thorough examination of an indoor environment can be simply achieved using an occupancy enquiry about the comfort of the environment in conjunction with concurrent measurement of the thermal environment (Humphreys et al. 2016).

2.6 Summary the key findings from the literature review

2.6.1 Energy behaviour change

Factors	In non-domestic settings, key factors influencing energy conservation include: • **Organisational factors**, including culture, policies, practices, resources and workload (Siero et al. 1996, De Groot and Steg 2009, Carrico and Riemer 2011, Lo et al. 2012, Morgenstern, Raslan, et al. 2016, Mulville et al. 2017). • **Contextual factors**, including control over workspace and equipment, accountability and stakeholder collaboration (Menzes et al. 2012, Bull et al. 2014, Dunphy 2014, Goulden and Spence 2015, Staddon et al. 2016, Ornaghi et al. 2018). • **Social factors**, including group or social norms, knowledge and values (Rothenberg 2003, Topf 2005, McDiarmid 2006, Harris et al. 2009, Chatterton 2011, Bedwell et al. 2014, Cotton et al. 2015).
Approaches	Energy behaviour change interventions comprise a variety of approaches including: • **Information based:** most effective when tailored to specific audience and is not costly in terms of money, time and effort. Delivers modest change (Steg 2008, Carrico and Riemer 2011, Mulville et al. 2017). • **Feedback:** comparative more effective than individual. Diminishes when feedback stops or overtime if feedback continues (Siero et al. 1996, Nolan et al. 2008, Gulbinas and Taylor 2014, Macarulla et al. 2015, Fisher and Irvine 2016, Mulville et al. 2017, Ornaghi et al. 2018). • **Goal setting:** most effective when used with feedback and when goals are challenging but achievable (Abrahamse et al. 2007, Macarulla et al. 2015). • **Incentives and rewards:** social rewards outperform financial rewards. Rewards given publically outperform those give privately (Handgraaf et al. 2013, Staddon et al. 2016).
Duration	It takes around sixty-six days for a behaviour to become a habit (Lally et al. 2010).
Savings	• Well implemented behaviour change produces savings of 5-10% (The Carbon Trust 2013). • In non-domestic settings, best published energy savings are up to 20% for electricity (with large variations) (Mulville et al. 2014) and 12% for heating (Schahn 2007 cited in Morgenstern 2016). • In healthcare, Operation TLC ran in two Bart's hospitals produced energy savings of 3% (NHS Sustainable Development Unit 2010, Daly and Large 2016).

2.6.2 Healthy environment

Healthcare environments	Healthcare is not like any other business (McCurdy and Weber 2002) as it comprises of: • Multi-functional complex buildings (Ziębik and Hoinka 2013). • Distinct in terms of layout, lighting temperature and equipment (Leino-Kilpi et al. 2001). • Open 24 hours a day 7 days a week and 365 days a years (Harris et al. 2009). • Occupied by a number of diverse stakeholders, including unwell and sometimes vulnerable patients with a variety of needs (Allen and Jones 2008, White 2013) who are sensitive to the local environment (Morgenstern, Li, et al. 2016).
Light	The literature review showed that increased natural light provides significant health benefits (Ulrich et al. 2008), including: • Reduced stay in hospital (Agency for Healthcare Research and Quality 2005, Joseph 2006, Mathews 2013). • Reduction in sleep disturbances (Bartick et al. 2010). • Reduced pain and requests for medication (Walch et al. 2005). • Reduced depression (Mathews 2013). • Decreased medical error rates (Ovitt 1996 cited in Harris et al. 2009). • Increased patient (Mathews 2013) and staff satisfaction (Edwards and Torcellini 2002, Boyce et al. 2003).
Noise	The literature review showed that: • When noise exceeds comfortable levels it has detrimental psychological and physiological effects on the health of staff and patients, increasing stress levels and disturbing sleep patterns (Mazer 2012, Basner et al. 2014). • A quiet hospital environment reduced use of sedation and hospital recovery rates (Buxton et al. 2013).
Temperature	The literature review showed that the impact of temperature on staff and patients in healthcare environments is highly complex, as it is influenced by both specific health-related requirements and thermal comfort (Abrudan et al. 2016). It is widely acknowledged that: • Extreme temperatures have a negative impact on human health including heat strokes and hypothermia, which may be fatal (Angus 1968, Basu and Samet 2002, McMichael et al. 2006). • Inappropriate thermal comfort conditions lead to decreased work efficiency and an increased likelihood of errors by staff (Pourshaghaghy and Omidvari 2012).

2.6.3 Energy behaviour change in healthcare

Operation TLC	Operation TLC comprises 3 primary actions: 1. **T**urn off equipment, 2. **L**ights out, and 3. **C**ontrol temperatures. With 12 secondary actions supporting the primary actions (NHS Sustainable Development Unit 2010, Daly and Large 2016).
Barriers	Daly and Large (2016) identified four key barriers that may prevent healthcare staff from implementing Operation TLC energy behaviour change intervention, including: • **Lack of knowledge:** staff are unfamiliar with how the building and its systems work. • **Lack of expectation:** staff did not know they were expected to or allowed to take actions to control their environment. • **Habit and memory:** staff knew what to do but were too busy and simply forgot. • **Facilities maintenance:** staff identified old and broken equipment that had not been fixed or replaced.
Benefits	When Operation TLC was ran in two Bart's hospitals it produced the following benefits (NHS Sustainable Development Unit 2010, Daly and Large 2016): • **Patients:** 38% fewer requests to change room temperature and patient's hospital experience improved when sleep improved, • **People:** staff reported a boost to team spirit & collaboration, and staff felt proud to improve patient care, • **Planet:** annual savings of 1900 tonnes of CO_2e, and • **Pocket:** annual savings of £428,000 (3% energy saving).

The design of the energy behaviour change intervention and methods used in this study are discussed in the next chapter.

Chapter 3 Research Design

This chapter presents the methodology used in this study linking the chosen approach back to the behaviour change approaches and factors identified in the literature review. Section 3.1 provides a description of the case study, including the sampling strategy, location of the research hospital and regional climatic information. Section 3.2 presents a detailed description of the behaviour change intervention used in this study, including the design, stakeholder involvement, launch events, training and feedback.

Section 3.3 provides details of the approach and equipment used for measuring and monitoring energy during the study. Section 3.4 provides details of the approaches and equipment used for measuring and monitoring the ward environment (light, sound, air temperature, relative humidity, thermal comfort, carbon dioxide and window movements). Section 3.5 provides details of the approaches used for measuring and monitoring the staff and patients' experience (staff comfort surveys n = 30 participants and 463 surveys, staff focus groups n = 30 participants and 6 focus groups, Trust management information and patient bed movements) during the study.

Section 3.6 provides summary details of the monitoring equipment used. Section 3.7 provides details, including schematics and equipment location, of the single and multi-occupied rooms participating in the study. Section 3.8 provides a summary linking the primary Operation TLC actions with the monitoring equipment and section 3.9 provides a summary linking the monitoring equipment and data collection measures with the associated research hypotheses. Section 3.10 provides details of the inferential statistical analysis that will be carried out on the variables in subsequent chapters. Section 3.11 provides details of a study pilot over a 24-hour period on one of the research wards. A summary of the key findings from this chapter is presented in section 3.12.

3.1 The case study

Steg (2008) advises that it is essential to measure energy use before and after an intervention and compare the effects of the intervention to those in a control group in order to make it possible to conclude whether the behaviour and the factors influencing it changed in the expected way and evaluate to what extent these changes are due to the intervention, and not to some naturally occurring event (Steg 2008).

Consequently, this study comprised of a before and after study carried out in three identical wards in the same hospital. One ward acting as the control and the other two wards actively participating in the behaviour change intervention in order to provide an appropriate number of comparators for a valid academic study (Steg 2008).

A purposive sampling strategy was adopted for this study comprising (1) identification of a generalizable NHS mental health or community hospital in the Trust participating in this study (2) with at least three similar in-patient wards in terms of size, layout, orientation and location, which is the minimum appropriate number of comparators for a valid academic study (Steg 2008), and (3) practical for one researcher to undertake in terms of resources and workload.

Following an analysis of the Trust's estate, a community hospital in the south of England was found to contain three identical in-patient wards in terms of size, layout and orientation. Please see Appendix B for a copy of the ward layouts. Each of the three study wards comprise of two four-bed multi-occupancy rooms and four single occupancy rooms. Please see section 3.7 for schematics of the room types. The intervention was run in two wards, "Intervention A" and "Intervention B" with the third, "Control" acting as a control ward.

The wards accommodate thirty-six (twelve on each ward) older persons' in-patients requiring acute care, containing both male and female patients aged over 65[2], some of which (on average 27.5%[2]) have mental health conditions such as dementia and Alzheimer's. Two of the most current challenges for the NHS are the growth of mental health illness in society (The King's Fund 2015) and an ageing population (Appleby 2013), so these wards are significant in terms of NHS patient demographics. Please see Chapter 4, section 4.3.1.2 for a summary of basic demographics for the patients in the study wards.

Staffing levels were identical on the three wards, comprising of ten nursing staff (one ward manager, one ward supervisor, four nurses and four healthcare support workers) on each ward; a total of 30 nursing staff involved in the research project. Daily shift patterns on the ward were also identical with each ward comprising of four shifts (1) 07:30:00 - 15:30:00 (2) 07:30:00 - 21:00:00 (3) 13:00:00 - 21:00:00 (4) 20:30:00 - 08:00:00 and each shift comprised of one nurse and one healthcare support worker. The ward managers and supervisors primarily worked a day shift (08:30:00 - 16:30:00) depending on operational requirements. Please see Chapter 4, section 4.3.1.1 for a summary of basic demographics for the staff participating in this study.

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[2] Figures obtained from Trust's Tableau management information reporting system (Tableau 2003), accessed on 01/08/2018

The community hospital, which opened in 2007 was procured using a Private Finance Initiative (PFI) model. A PFI is a public-private partnership contractual arrangement, whereby a private organisation funds the design, build and maintenance of a building on behalf of a public sector organisation (Akintoye et al. 2003). The public sector organisation repays these costs back over a number of years with significant interest (Gaffney et al. 1999).

The community hospital provides acute-care clinical services including, walk-in surgeries (minor injuries, general practice surgery, blood tests), elective day and short stay surgery, CT and MRI scanners, long term conditions, stroke rehabilitation and four in-patient wards (NHS England 2018). NHS England has 771 hospital sites, comprising of 217 general acute-care hospitals, 54 specialist acute-care hospitals, 100 mixed service hospitals, 113 other in-patient sites and 287 community hospitals (HSCIC 2016b).

3.1.1 Location of the research hospital and local climate

The hospital participating in this study is located in the south of England, which has a temperate climate of type Cfb in the Köppen classification (Kottek et al. 2006), standing for: warm temperate (C), fully humid (f) with warm summers (b).

From the literature review, it was established that outdoor climate is an important factor in indoor climate and thermal comfort (de Carvalho et al. 2013), particularly in passive buildings. Whilst the hospital has mechanical ventilation and heating systems operating throughout the hospital, it does not have air conditioning, so outdoor climate is a particularly relevant factor in indoor climate and thermal comfort during the non-heating period.

Figure 10 shows the monthly averages of the daily minimum and maximum ambient temperatures for southern England between 1981-2010 (The Met Office 2018a) and Figure 11 shows the monthly averages of the daily minimum and maximum ambient temperatures for southern England for the twelve months that included the study period (1st August 2017 - 30th April 2018) (The Met Office 2018b).

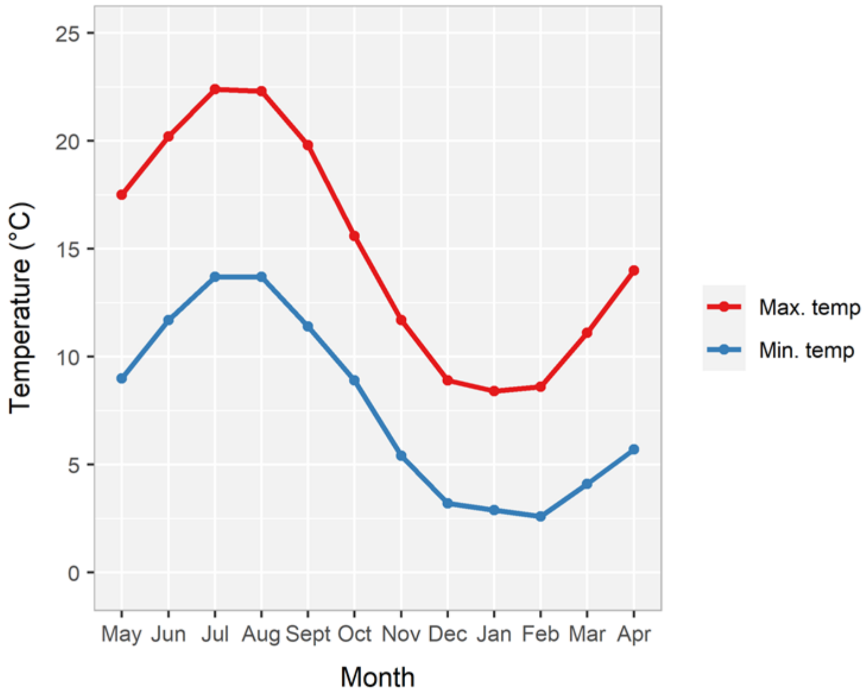

Figure 10. Monthly averages of the daily minimum and maximum ambient temperatures for southern England between 1981-2010

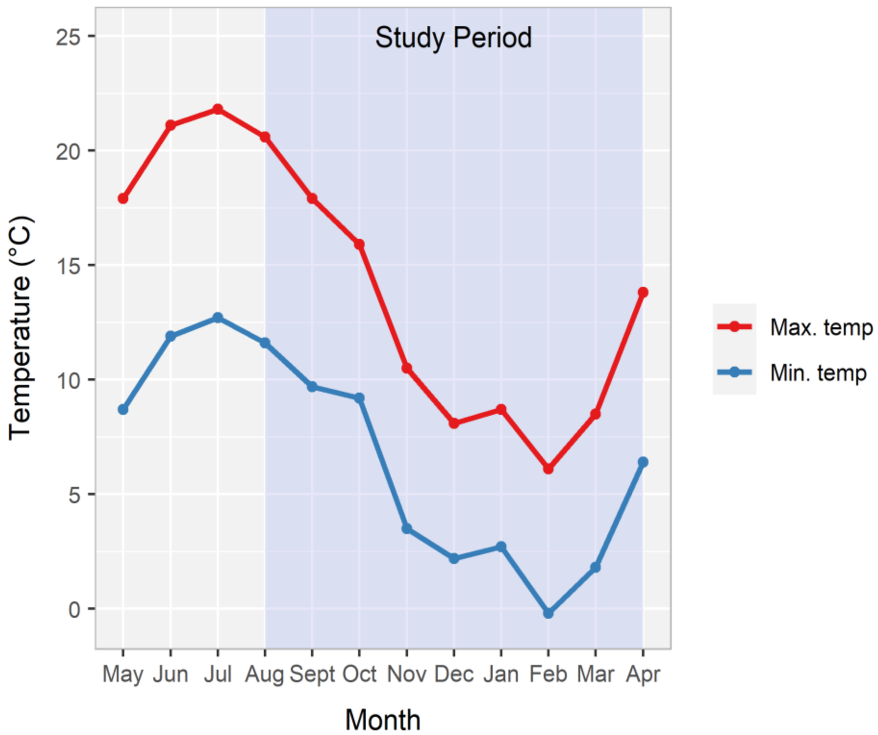

Figure 11. Monthly averages of the daily minimum and maximum ambient temperatures for southern England for the twelve months that includes the study period (1st August 2017 - 30th April 2018)

Figure 12 shows the average of the monthly hours of sunshine for southern England between 1981-2010 (The Met Office 2018a) and the average of the monthly hours of sunshine for southern England for the twelve months that included the study period (1st August 2017 - 30th April 2018) (The Met Office 2018b).

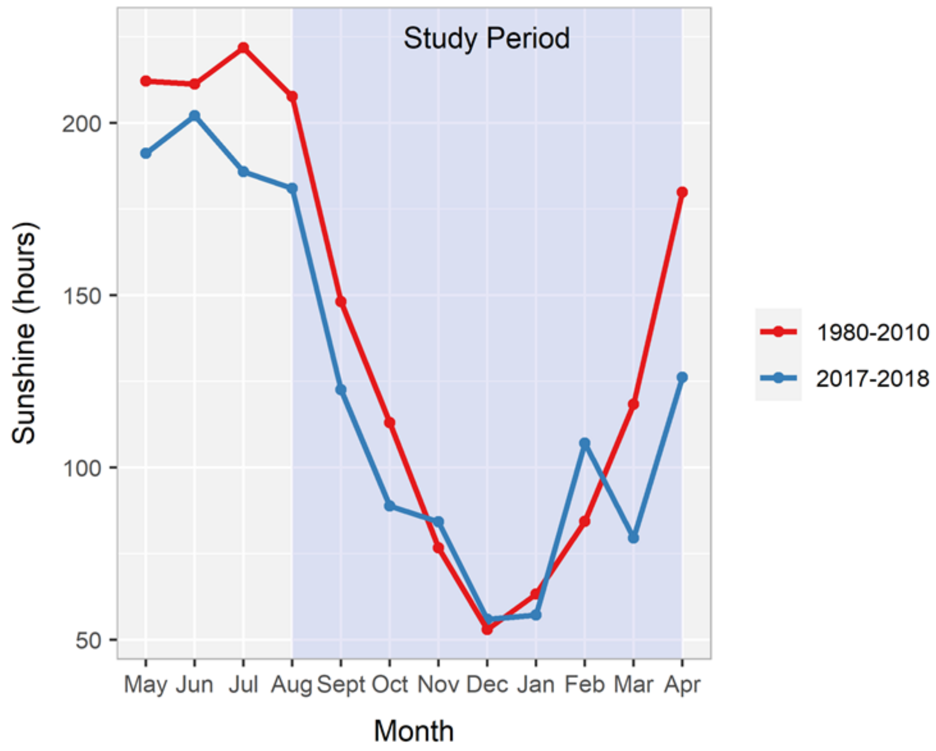

Figure 12. Average of the monthly hours of sunshine for southern England for 1981-2010 and for the twelve months that includes the study period (1st August 2017 - 30th April 2018)

3.2 The intervention

3.2.1 Designing the intervention

Following an examination of nineteen frameworks of behavioural change interventions Michie et al. (2011) concluded that a behavioural change intervention typically starts with deciding what approach to take and then designing the specifics of the intervention itself (Michie et al. 2011). This study used an information based behaviour change approach, shown in Figure 13 modelled from an adapted version of Triandis' Theory of Interpersonal Behaviour incorporating the key organisational, contextual and social factors identified during the literature review.

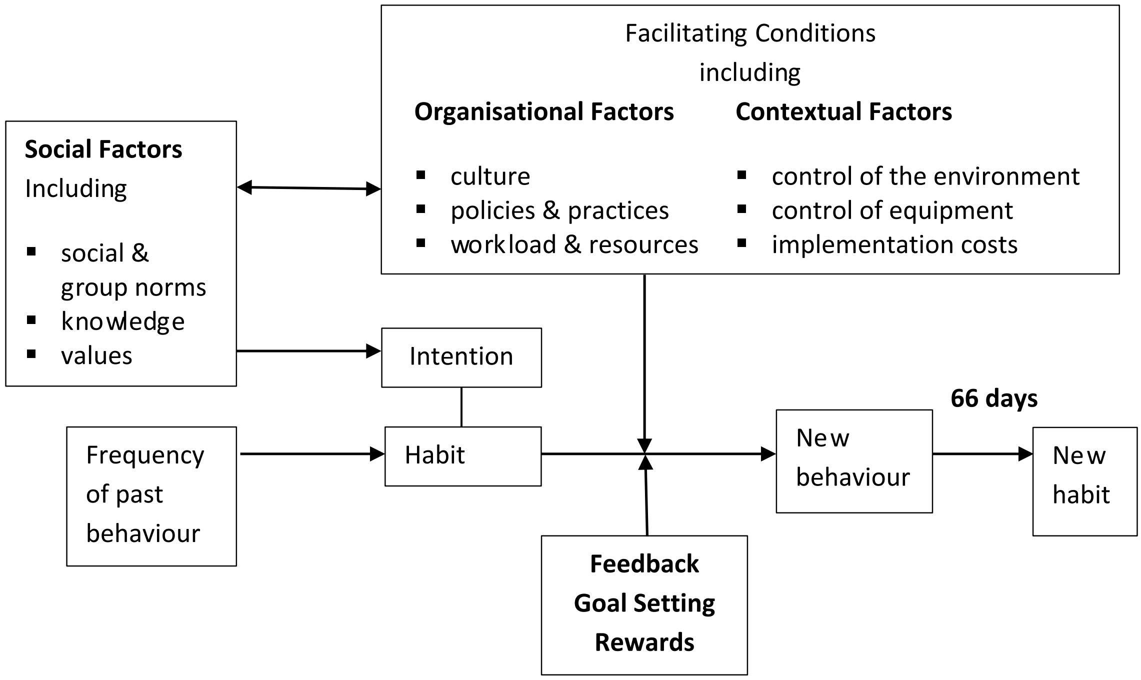

Figure 13. Model of the behaviour change approach used in a NHS community hospital adapted from the revised version of Triandis' Theory of Interpersonal Behaviour reproduced in Chatterton (2011)

The specifics of the intervention itself were based on an adapted version of GAP's Operation TLC behaviour change intervention. Manika et al. (2016) identified there is currently a research gap of linking an energy behaviour intervention to the respective hospital building, processes and interfaces with the occupants. Consequently, GAP's Operation TLC behaviour change approach was adapted to take into consideration the processes and interfaces of the occupants in the older-persons' acute-care in-patient wards involved in this study.

To run a successful energy behavioural change intervention with nursing staff it is essential that patient care is at the heart of the intervention (Morgenstern, Raslan, et al. 2016) and energy saving is a low-priority as it is sometimes perceived by the clinical staff as being in conflict with their main priority of delivering excellent patient care (McGain and Naylor 2014). Therefore, improving patient care was promoted as the main outcome of the intervention and energy saving was referred to as a secondary outcome.

Also, the primary action 'Turn off equipment' was changed to 'Turn off equipment and unwanted noise', as noise was reported by Royal College of Nursing (2012) as the primary concern for patients about the hospital environment and a study by Park et al. (2014) found that 86% of patients surveyed reported having "bad sleep" as a direct consequence of noise on the ward.

It takes around sixty-six days for a behaviour to become a habit (Lally et al. 2010), therefore the behaviour change intervention was actively run for three months (1st November 2017 - 31st January 2018) and then monitored for further three months post-intervention (1st February - 30th April 2018) to assess whether the behaviour changes remained consistent or tailed off after the intervention period. Please see Appendix C for a timeline of key activities in the behaviour change intervention.

3.2.2 Stakeholder engagement

Siero et al. (1996) and Mulville et al. (2016) found it was more effective to focus on workplace culture and practices than the attitude of the staff involved in the intervention, therefore an Energy Policy was developed by the Trust and communicated to all staff in the hospital before the intervention to enforce the organisation's culture towards energy conservation. Please see Appendix D for a copy of the contents of the Energy Policy.

Morgenstern, Raslan, et al. (2016) and Cox et al. (2012) identified that senior and middle management commitment is an essential part of organisational culture when implementing a successful pro-environmental intervention. Consequently, the intervention had a Trust Board sponsor and visible support from the senior and middle management team on site.

The literature review revealed that staff are more likely to adopt pro-environmental behaviour when encouraged by peers (Bedwell et al. 2014, Staddon et al. 2016), particularly when the behaviour is visible to peers (Bedwell et al. 2014). And as Carrico and Riemer (2011), Morgenstern, Raslan, et al. (2016), Ryan-Fogarty et al. (2016) advocate the use of champions to encourage their peers to adopt energy conservation, the healthcare support workers on the intervention wards were actively encouraged to be Operation TLC champions by the Ward Manager.

3.2.3 Intervention actions and tools

It is often highlighted that in healthcare no one set of actions will fit all (Ryan-Fogarty et al. 2015, Manika et al. 2016), therefore the Trust's Operation TLC champions tailored the generic list of primary and secondary Operation TLC actions and developed a bespoke action list shown in Table 4, to include the actions they believed would improve the health and wellbeing of the patients on their wards.

Table 4. Operation TLC staff actions adapted for use in the Trust intervention wards during the behaviour change study at the NHS community hospital participating in the study

Primary action	Secondary actions & additional information
Turn off equipment and unwanted noise	Turn off any unwanted medical equipment where possible • Turning off equipment, and unplugging it once it's charged can help to preserve the battery
	Turn off computers, monitors and TVs that aren't being used • Equipment generates background noise, can contribute to light disturbances and can contribute to areas overheating.
	Close doors, cupboards and bins quietly • Noise can be both psychologically and physiologically detrimental to the health of patients and staff so preventing unnecessary noise is good for you and your patients.
Lights out	Switch off lights in unoccupied rooms
	Open blinds and make the most of natural light by switching main lights off • Increased exposure to natural light has been shown to improve patient recovery rates, reduce the need for pain relief and increase staff satisfaction.
	Introduce a quiet time for an hour after lunch • 'Quiet time' means turning lights off or dimming them in rooms and corridors to giving patients a peaceful time to rest & recover and time for you to catch up on other tasks.
	Introduce night time switch off • Give patients a better night's sleep and improve their experience by switching off corridor and room lights as early as possible. Good sleep habits directly impact on mental and physical health. Staff at other Operation TLC hospitals tell us patients who get a better sleep are often easier to work with the following day.
Control temperature	Close door when rooms aren't occupied • Closing doors to drugs and equipment stores keeps patients and staff safer. Closing toilet doors helps to improve hygiene on your ward.
	Close windows when the heating is on • This helps to improve temperature management on your ward. Having the windows open when the heating is on will make the system work harder for less benefit.
	Layer up if cold • Think about whether you can wear an extra layer; make sure your patients have access to extra blankets.
	Encourage patients or visitors remain active • Even wiggling your toes can help to improve circulation to keep you warm.

Research gaps identified by Manika et al. (2016) included linking the energy behaviours in hospitals explicitly to the respective building, processes and interfaces with the occupants (Manika et al. 2016). Therefore, as a community hospital with elderly and often vulnerable patients, the Operation TLC champions took the decision to remove the following action that was on the generic Operation TLC action list for safety reasons:

- Close the doors to patient rooms
    - This improves patient healing by allowing them to sleep better whilst also improving their privacy. Closing doors also keeps patients warmer and more comfortable.

Following a discussion between the Operation TLC champions and the Ward Manager, ‘quiet time’ was designated as 13:30:00 - 14:30:00 to enable a quiet period directly after lunch but before visiting hours, and ‘night time switch off’ was set at 23:00:00 to enable sufficient time to complete the last medicine round of the day.

The literature review highlighted the issue that staff have little, if no control over their environment in organisations and consequently feel detached from their work space (Bull et al. 2014, Dunphy 2014) and disconnected with energy conservation at work (Mulville et al. 2017). As staff on the intervention wards have no direct control over the heating systems in their wards, the Operation TLC champions took the decision to remove the following secondary action from the generic Operation TLC action list:

- Control heating gradually
    - Get to know how your wards heating controls work. In big buildings like hospitals it can take time for the temperature to adjust and over adjusting can make the ward too hot or too cold later in the day.

To prevent environmental numbness from a lack of knowledge and resources (Harris et al. 2009, Dunphy 2014, McGain and Naylor 2014, Morgenstern, Raslan, et al. 2016, Ryan-Fogarty et al. 2016) staff on the intervention wards were provided with a collection of informative tools including cards, posters, stickers and thermometers, some examples are shown in Figure 14.

Figure 14. Examples of some of the tools used during the behaviour change intervention

As it is essential that the nursing staff are empowered to take operational autonomy of the programme from the start (Ryan-Fogarty et al. 2016), the Operation TLC champions on the intervention wards were given the responsibility of distributing and promoting these tools.

3.2.4 Launch events, training and feedback

To demonstrate the commitment of the senior and middle management team (Cox et al. 2012, Morgenstern, Li, et al. 2016) to the behaviour change intervention and to enthuse the ward staff to participate in it, a launch event was organised for the staff away from the ward environment. To ensure everyone in the intervention wards had an opportunity to attend, two sessions were held and the staff were provided with refreshments and food. The launch event was combined with an initial training workshop, which was run by the researcher and a representative from Global Action Plan (GAP) with support from the Trust Board sponsor.

The event was attended by the on-site senior and middle management team, together with representatives from the hard facilities provider, representatives from the soft facilities provider, nurses, healthcare support workers and housekeeping staff from the two intervention wards to show both peer (Bedwell et al. 2014) and management involvement, and collaborative working across stakeholder groups (Tudor 2013, McGain and Naylor 2014).

Operation TLC is an information based energy behaviour change intervention, which is one of the most popular forms of behaviour change interventions (Mulville et al. 2017). As evidence based practice is popular amongst healthcare professionals (Jolley 2009), the information provided during the intervention was based on evidence based academic research, which demonstrated the intervention actions will improve the wellbeing and experience of the patients and the experience of the staff on the intervention wards. Please see Appendix E for a copy of the presentation for the launch and training Workshop 1.

In an attempt to overcome issues around workload and resources (Ryan-Fogarty et al. 2016), the actions associated with the intervention were introduced in phased approach. Consequently, the initial training workshop only covered half of the bespoke Operation TLC action list with a second training workshop scheduled two weeks after the first. Like the first training workshop, the second training workshop was held in two sessions away from the ward environment with food and refreshments provided. The second workshop comprised of a refresher on the actions launched during the first training workshop and training on the second half of the action list. Please see Appendix F for a copy of the presentation for training Workshop 2.

The literature review revealed that group feedback had the greatest success (Macarulla et al. 2015, Fisher and Irvine 2016, Mulville et al. 2017), particularly when delivered in a simple way as close to the behaviour change intervention as possible (Siero et al. 1996, Carrico and Riemer 2011) and that continued engagement is required to maintain energy conservation (Dwyer et al. 1993, Darby et al. 2016). Therefore, refresher training and feedback sessions were held regularly during the 3-month intervention period. Wherever possible, refresher training and feedback sessions were incorporated into scheduled team briefs in order to overcome issues around workload and resources (Ryan-Fogarty et al. 2016).

Studies also concluded that incentives or rewards were successful at delivering energy savings (Staddon et al. 2016). Handgraaf et al. (2013) found that social rewards out performed financial rewards and awards that were given publically out performed rewards that were given privately. Therefore, during the feedback sessions staff were given social rewards, including public praise as well as incentives, including promotional pens and 'thank-you' heart chocolates.

3.2.5 Model of the behaviour change intervention

From the literature review and discussion in this chapter, a model was developed summarising the sustainability (economic, environmental and social) factors that affect the ward environment and were consequently measured and monitored during this study. Together with the anticipated sustainability benefits from running the behaviour change intervention used in the study. The model is shown in Figure 15.

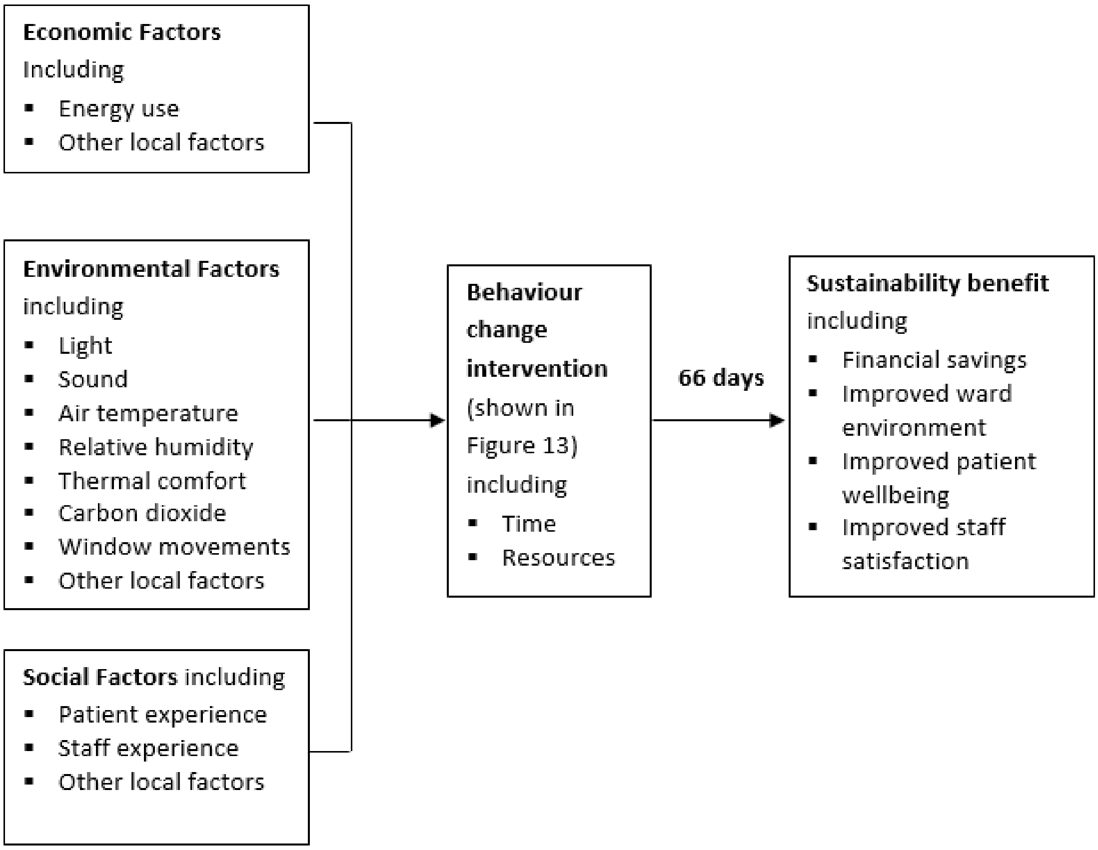

Figure 15. Model of the sustainability (economic, environmental and social) factors affected by the energy behaviour change intervention used in a NHS community hospital and the anticipated sustainability (economic, environmental and social) benefits

3.3 Energy monitoring

In order to analyse the anticipated benefits of implementing an energy behaviour change intervention a mixed methods approach was adopted using quantitative and qualitative data collection methods to measure the ward environment and the experience of the staff and patients.

From the literature review, it was identified that the potential benefits of implementing an energy behaviour change intervention, adapted from Operation TLC was reduced energy consumption and lower carbon emissions (Daly and Large 2016). Consequently, one of the primary actions for the Trust Operation TLC behaviour change initiative was 'Turn off equipment', which included secondary actions such as turn off any unwanted medical equipment, where possible and turn off computers, monitors and TVs that aren't being used.

The study measured electricity use via a set of three LEM split core current clamps (0-150A, 0-10V DC output) (LEM 2018) attached to a MadgeTech Volt101A data logger, shown in Figure 16. A set of current clamps and logger was fixed to the 3-phase electricity supply on the lighting distribution board and the small power distribution board for each of the three wards. The loggers were set to single measurement with a sampling frequency of every minute to provide the maximum amount of data for a quarterly (3-monthly) download, which was the download frequency agreed with the hard facilities provider.

Figure 16. LEM AC split core current clamps and data logger used to measure small power and lighting on the electrical distribution boards for the control and intervention study wards during the study period (1st September 2017 - 30th April 2018)

Morgenstern, Li, et al. (2016) reported that the electrical and heating layout in hospitals does not always correspond with the ward layout, making it extremely challenging to measure the impact of the running the intervention on energy usage at ward level. Whilst the research wards have independent electricity supplies for lighting and small power they share a heating system, therefore the project was unable to quantitatively measure the impact of the behaviour change intervention on gas consumption.

3.4 Environmental monitoring

From the literature review, it was established that a thorough examination of an indoor environment can be simply achieved using an occupancy enquiry about the comfort of the environment in conjunction with concurrent measurement of the thermal environment (Humphreys et al. 2016). Humphreys et al. (2016) went on to state that it is because of this simplicity, field study work is a feasible and successful method for measuring thermal comfort. Therefore, the indoor environment was monitored using quantitative data measurement and qualitative occupancy enquiries.

3.4.1 Light

The literature review showed that increased natural light provides significant health benefits (Ulrich et al. 2008), reduced stay in hospital (Agency for Healthcare Research and Quality 2005, Joseph 2006, Mathews 2013), a reduction in sleep disturbances (Bartick et al. 2010), reduced pain, reduced requests for medication (Walch et al. 2005), reduced depression (Mathews 2013) and decreased medical error rates (Ovitt 1996 cited in Harris et al. 2009). As well as increased patient (Mathews 2013) and staff satisfaction (Edwards and Torcellini 2002, Boyce et al. 2003). Consequently, one of the primary actions for the Trust Operation TLC behaviour change intervention was 'Lights out'.

Light was measured using both qualitative and quantitative methods. The literature review concluded that observation and measurement are the most common methods for data collection in both health research and clinical practice (Polgar and Thomas 2013). Consequently, light was qualitatively measured throughout the study period using staff observations recorded in staff comfort surveys, discussed in section 3.5.2 together with pre-intervention and post-intervention focus groups, discussed in section 3.5.3.

Concurrently, nine unbranded silicon photodiodes, calibrated against a class 1 LICOR cosine corrected silicon photodiode (LI-COR 2007), each attached to a MadgeTech Volt101A data logger, were used to quantitatively measure if the lights were on, dimmed or off in the four-bed rooms on the three study wards, shown in Figure 17.

Figure 17. Unbranded silicon photodiodes and data logger used to measure light in the control and intervention study wards during the study (1st August 2017 - 30th April 2018)

A light sensor and logger was located on top of a wall-mounted cupboard on the wall furthest from the windows in each of the four-bed rooms, shown in section 3.7. The loggers were set to single measurements with a sampling frequency of one minute to provide the maximum amount of data for a monthly download, which was the download frequency agreed with the Ward Manager to minimise patient disturbance.

Due to the vulnerable nature of the patients on the research wards, all doors on the research wards are kept open and are only closed as the result of an infection outbreak, so the patients were also affected by the lights in the corridor. Consequently, a light sensor and logger was also located on top of a wall-mounted cupboard at the nurses' station, which is in the corridor of each ward. The light sensor and sampling frequency (minutely) was the same as those used in the patient rooms, show in Figure 17.

3.4.2 Sound

The literature review showed that when noise exceeds comfortable levels it has detrimental psychological and physiological effects on the health of staff and patients increasing stress levels and disturbing sleep patterns (Mazer 2012, Basner et al. 2014), whilst a quiet hospital environment reduced use of sedation and hospital recovery rates (Buxton et al. 2013).

Consequently, one of the primary actions for the Trust Operation TLC behaviour change initiative was 'Turn off…. unwanted noise', which in addition to turning off noisy equipment included secondary actions such as introducing quiet time and night time switch off.

Sound was monitored using both qualitative and quantitative methods. As the literature review concluded that observation and measurement are the most common methods for data collection in both health research and clinical practice (Polgar and Thomas 2013), sound was qualitatively measured throughout the study period using staff observations recorded in staff comfort surveys, discussed in section 3.5.2 together with pre-intervention and post-intervention focus groups, discussed in section 3.5.3.

Concurrently, noise levels (dB) were quantitatively measured using six Reed SD4023 sound monitors (REED Instruments 2017) in the four-bed rooms on the three research wards, shown in Figure 18.

Figure 18. Reed SD4023 sound monitor used to measure noise levels (dB) in the control and intervention study wards during the study (1st August 2017 - 30th April 2018)

A sound monitor was located on top of a wall-mounted cupboard on the wall furthest from the windows in each of the four-bed rooms, shown in section 3.7. The sensors were set to single measurements with a sampling frequency of every one second to provide the maximum amount of data for a monthly download, which was the download frequency agreed with the Ward Manager to minimise patient disturbance.

3.4.3 Temperature and thermal comfort

It is widely acknowledged that extreme temperatures have a negative impact on human health including heat strokes and hypothermia, which may be fatal (Angus 1968, Basu and Samet 2002, McMichael et al. 2006). Consequently inappropriate temperature in hospitals can have significant effects on the health of patients (Abrudan et al. 2016). Pourshaghaghy and Omidvari (2012) also report that inappropriate thermal comfort conditions lead to decreased work efficiency and an increased likelihood of errors by staff.

The literature review showed that the impact of temperature on staff and patients in healthcare environments is highly complex, as it is influenced by both specific health-related requirements and thermal comfort (Abrudan et al. 2016). Consequently, one of the primary actions for the Trust Operation TLC behaviour change intervention was ‘Control temperature’ (Daly and Large 2016).

The literature review identified air temperature, mean radiant temperature, airflow and relative humidity as the environmental variables for measuring thermal comfort (Fanger 1970, Cannistraro and Bernardo 2017). In addition, clothing insulation and metabolic rate are the human variables associated with thermal comfort (Fanger 1970, Nicol et al. 2012).

The literature review also identified that a thorough examination of an indoor environment can be simply achieved using an occupancy enquiry about the comfort of the environment in conjunction with concurrent measurement of the thermal environment (Humphreys et al. 2016).

Therefore, thermal comfort was measured using both qualitative and quantitative methods. As the literature review concluded that observation and measurement are the most common methods for data collection in both health research and clinical practice (Polgar and Thomas 2013), thermal comfort was qualitatively measured throughout the study period using staff observations recorded in staff comfort surveys, discussed in section 3.5.2 together with pre-intervention and post-intervention focus groups, discussed in section 3.5.3.

3.4.3.1 Air temperature and relative humidity

Concurrently, air temperature (^{o}C) and relative humidity (%) levels were quantitatively measured using thirty-nine match-box sized MadgeTech RHTemp101 loggers (MadgeTech 2017), shown in Figure 19 and detailed further in Amin et al. (2016).

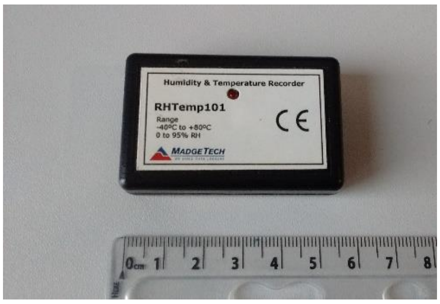

Figure 19. MadgeTech RHTemp101 logger used to measure air temperature and relative humidity in the control and intervention study wards during the study (1st August 2017 - 30th April 2018)

A logger was located directly above each patient between the bed and their chair in each of the four-bed and the single occupancy rooms, shown in section 3.7. The loggers were set to single measurements with a sampling frequency of every five minutes to provide the maximum amount of data for a monthly download, which was the download frequency agreed with the Ward Manager to minimise patient disturbance.

3.4.3.2 Thermal comfort

In addition, airflow and mean radiant temperature were quantitatively measured using a Delta OHM MD32.3 WBGT (Wet Bulb Globe Temperature) monitor (Delta-OHM 2017), shown in Figure 20 and detailed further in Amin et al. (2016). As the intervention wards are occupied by older persons in-patients, a standard clothing insulation level (Clo = 1) was used, which corresponds to the insulating value of clothing needed to maintain a person in comfort sitting at rest in a room with an average temperature of 21^{o}C (British Standards Institute 2009). Similarly, a metabolic rate (met) setting of 1 was used, which represented seated and relaxed in accordance with BS EN ISO 7730: 2005 (British Standards Institute 2005). The monitors were set to single measurement with a sampling frequency of fifteen seconds as used in Amin et al. (2016).

Figure 20. Delta OHM WBGT monitor used to measure thermal comfort in the control and intervention study wards over a pre-intervention (22nd August 2017) and a post intervention (2nd April 2018) period during the study

Monitoring occurred pre-intervention (22nd August 2017) and post intervention (2nd April 2018) in a four-bed multi-occupancy room in both the control ward and an intervention ward to enable a comparison of airflow and mean radiant temperature in both warm and cool outside (ambient) climatic conditions. Monitoring was conducted in consistent places in the test areas, shown in Figure 21, including the back of the room and by the windows, and in various conditions, including windows open, windows closed, fans on and fans off. The monitoring equipment was left in each place for a minimum of one hour to enable stabilisation of the globe thermometer.

Figure 21. Location of Delta OHM WBGT monitor used to measure thermal comfort in the study wards over a pre-intervention (22nd August 2017) and a post intervention (2nd April 2018) period during the study

3.4.3.3 Indoor air quality

The literature review identified that a thorough examination of an indoor environment can be simply achieved using an occupancy enquiry about the comfort of the environment in conjunction with concurrent measurement of the indoor air quality (Humphreys et al. 2016). Therefore, indoor air quality was measured using both qualitative and quantitative methods.

As the literature review concluded that observation and measurement are the most common methods for data collection in both health research and clinical practice (Polgar and Thomas 2013), air quality was qualitatively measured throughout the study period using staff observations recorded in staff comfort surveys, discussed in section 3.5.2 together with pre-intervention and post-intervention focus groups, discussed in section 3.5.3.

3.4.3.3.1 Carbon dioxide

NHS England hospitals providing acute care, including the Trust hospital participating in the study, have a high ventilation rate of six air changes per hour for general and single wards, which is achieved predominately by mechanical ventilation supplemented by opening windows (Department of Health 2007). With the specified six air changes per hour it would be expected that the CO_2 level would remain fairly constant for a normally functioning ventilation system. As a consequence this study only quantitatively measured carbon dioxide, which was identified during the literature review as an important indicator for indoor air quality (Dwyer 2011) affecting the ward environment.

Therefore, concurrently to the observed qualitative occupancy enquiry, indoor air quality was quantitatively measured by recording carbon dioxide (CO_2 ppm) levels using six Extech SD800 CO_2 monitors (EXTECH Instruments 2013), shown in Figure 22 and detailed further in Bourikas et al. (2018).

Figure 22. Extech SD800 CO_2 monitor used to measure carbon dioxide (CO_2) in the study wards during the study (1st August 2017 - 30th April 2018)

Each monitor was located on top of a wall-mounted cupboard on the wall furthest from the windows in each of the four-bed rooms, shown in section 3.7. The monitors were set to single measurements with a sampling frequency of every one minute to provide the maximum amount of data for a monthly download, which was the download frequency agreed with the Ward Manager to minimise patient disturbance.

3.4.3.3.2 Window movements

Griffiths (1990) reported having the 'right temperature' was found to be the most important consideration by people in a user satisfaction survey of UK buildings, closely followed by 'air freshness'. Circulated air can relieve heat stagnation and opening windows is the most common adaptive behaviour used by people for circulating air and cooling indoor temperatures (Rijal et al. 2007). In addition, one of the secondary actions for the Trust Operation TLC behaviour change intervention, associated with the primary action 'Control temperature', was 'Close windows when the heating is on'.

Therefore, concurrently to the observed qualitative occupancy enquiry, window movement was quantitatively measured using fifty-four Micro-Electro-Mechanical Systems (MEMS) FXLS8471Q 3-axis accelerometers, shown in Figure 23 and as detailed further in Bourikas et al. (2018).

Figure 23. 3-axis accelerometer used to measure window movement in the control and intervention study wards during the study (1st August 2017 - 30th April 2018)

An accelerometer was located on the bottom left side of every window in each of the four-bed and single occupancy rooms, shown in section 3.7. The accelerometers were set to single measurements with a range of ±2g, sample rate of 12.5 samples per second (SPS) and a trigger of 1.5 metres per second per second (m/s^2), to enable the most sensitive setting that facilitated fortnightly downloading, which was the frequency agreed with the Ward Manager to minimise patient disturbance.

3.5 Staff and patient experience monitoring

Primary staff data was gathered from one quantitative method in the form of Trust management information discussed in section 3.5.1, and two qualitative methods in the form of staff comfort surveys discussed in section 3.5.2 and staff focus group interviews discussed in section 3.5.3.

As a community and mental health hospital, the Trust's in-patients primarily comprise of vulnerable often elderly patients, making it incredibly challenging and in most cases impossible to directly measure patient experience. Consequently, it was concluded by Health Research Authority that the patients occupying the study wards would not be able to give informed consent to complete a comfort survey.

However, just because the patients are not able to speak for themselves this does not mean that they should not be heard. Two of the most current challenges for the NHS is the growth of mental health illness in society (The King's Fund 2015) and an ageing population (Appleby 2013), so it's incredibly important to try to improve the experience of being in hospital for these patients.

Consequently, the study used two quantitative methods to gather primary data and two qualitative methods to gather secondary data on the patients' experience of the environment during the study.

Primary patient and staff data was gathered from Trust management information discussed in section 3.5.1 and primary patient data was gathered from movement sensors on the patients' beds discussed in section 3.5.4. Secondary data on the patients' experience of the environment was gathered by the nursing staff through observations and interviews with patients. The observations and comments were recorded using a free-text box at the end of the staff comfort survey, discussed in section 3.5.2 and during the staff focus groups, discussed in section 3.5.3.

3.5.1 Trust primary management information

From the literature review, it was identified that the potential benefits of implementing an energy behaviour change intervention was improved staff satisfaction in such categories as improved staff sickness and retention together with improved patient wellbeing and experience in the category of reduced hospital stay (Daly and Large 2016).

Consequently, the following quantitative primary data sets relating to staff and patients' on the study wards were gathered directly from the Trust's Tableau management information reporting system (Tableau 2003), including:

I. levels of staff sickness and staff turnover, and
II. length of patient hospital stays.

From the literature review, it was established that a person's age, gender, culture, personality and expectation of conditions based on previous experience may all influence their thermal comfort (Nicol et al. 2012) and that females are more likely to adopt energy saving behaviours (Paco et al. 2015). Consequently, basic anonymised demographic information was also gathered from the Trust's Tableau management information system (Tableau 2003) for the staff and patients participating in the study, including age, gender and ethnicity.

3.5.2 Staff comfort surveys

The literature review revealed that a survey is an effective method for collecting information from people on their attitudes and behaviours (Fink 2003a, Mathers et al. 2010) and questionnaires are practical and cost effective method of surveying a group of people (Fink 2003a). Therefore, a staff comfort survey was used in the study to assess how the nursing staff perceived the lighting, noise, temperature, humidity, airflow, air quality and overall comfort on the wards.

The staff comfort survey comprised a paper questionnaire (Mathers et al. 2010) based on Stoop (2001) to ensure straightforward and appropriate research design (Fink 2003a), using an ASHRAE 7-point thermal sensation scale (Beizaee and Firth 2011) to ensure valid survey instruments (Fink 2003a) and facilitate easy comparison (Fink 2003b).

A purposive sampling strategy (Etikan 2016) was adopted for the staff comfort surveys in consultation with the Ward Manager comprising (1) completion of a weekly comfort survey, and (2) ad hoc completion of additional surveys if the staff were experiencing particular thermal comfort or discomfort, to ensure appropriate sampling of the ward environment and minimise disturbance to the ward routines.

The questionnaire was voluntary, anonymous and answers were confidential in order to encourage participation (Fink 2003a, Mathers et al. 2010). Staff were encouraged to discuss thermal comfort with their patients and complete the free text box with feedback from the patients in order to gather secondary information on the patients' experience of the environment.

Please see Appendix G for a copy of the staff comfort survey.

3.5.3 Staff focus groups

The literature review revealed that a focus group facilitates discussion within a group of interviewees based on shared perceptions, which stimulates ideas and facilitates a broader exploration into a topic (Saks and Allsop 2007, Cyr 2014). Therefore, to supplement the findings from the staff comfort surveys and gather additional primary information from the staff and secondary information about the patients' experience of the environment, qualitative data was gathered using pre-intervention and post-intervention focus groups with the staff in each of the three study wards.

The qualitative data covered the staff's views on the ward environment at the time of the focus group in relation to lighting, noise, temperature and humidity. Together with the staff's views on the impact that the physical environment of the wards was having on their patients in relation to patient wellbeing, recovery and their experience of being in hospital. The staff were also asked what they would like to change about their environment to improve it.

A purposive sampling strategy (Etikan 2016) was adopted for the staff focus groups in consultation with the Ward Manager comprising (1) one pre-intervention (held during August 2017) and one post-intervention (held during May 2018) focus group for each ward participating in the study (2) small groups of four to five attendees per session as recommended by Morse (1994) to enable participants a greater opportunity to talk and (3) held in a meeting room to minimise interruptions (Morse 1994) with refreshments (hot drinks and biscuits) to create a relaxed and friendly environment to encourage openness (Morse 1994). Each session was recorded with permission of the participants.

Please see Appendix H for a copy of the staff focus group questions and transcripts.

3.5.4 Patient bed movements

From the literature review, it was identified that the potential benefits of implementing a behaviour change intervention, adapted from Operation TLC, was improved patient experience in the category as improved sleep and rest (Daly and Large 2016). Therefore, patients' rest was monitored by gathering primary data on patient bed movements.

Patient bed movements were quantitatively measured using thirty-six MEMS FXLS8471Q 3-axis accelerometers, shown in Figure 24. An accelerometer was located on the back left-hand or right-hand side of each of the patient's headboard in the four-bed and single occupancy rooms. The location was chosen in consultation with the Ward Manager to create the least disturbance to the patients, shown in section 3.7.

Figure 24. 3-axis accelerometer shown on (1) a standard bed (left) and (2) a falls bed (right) used to measure patient bed movements in the control and intervention study wards during the study (1st August 2017 - 30th April 2018)

The accelerometers were set to single measurements with a range of ±2g, sample rate of 12.5 SPS and a trigger of 1.5 m/s^2, to enable the most sensitive setting that facilitated fortnightly downloading, which was the frequency agreed with the Ward Manager to minimise patient disturbance.

3.6 Summary of the monitoring equipment used during the study

Table 5 shows summary details of the ISO 7726 compliant monitoring equipment used in this study.

Table 5. Summary of the monitoring equipment used during the study, including sampling frequency, accuracy and sensitivity

Variable	Monitoring equipment / type	Sampling frequency	Download frequency	Accuracy	Sensitivity
Electricity (small power & lighting)	LEM AC current AT-B10 attached to a MadgeTech Volt101A data logger	Minutely	3 monthly	±1.5%	± 0.5%
Light	Unbranded silicon photodiodes attached to a MadgeTech Volt101A data logger	Minutely	Monthly	±5%	Typically 30 µA per 100 klux
Sound	Reed SD4023 sound monitors	Secondly	Monthly	±1.4dB	0.1dB
Air temperature & relative humidity	MadgeTech RHTemp logger	5 minutely	Monthly	±0.5°C ±3%RH	0.01°C 0.1%RH
Thermal comfort	Delta OHM MD32.3 WBGT	15 secondly	1 day before and after	±1.5%	0.01 m/s 0.1°C
CO_2	Extech SD800 CO_2 monitor	Minutely	Monthly	±40ppm	1ppm
Window movements	MEMS FXLS8471Q 3-axis accelerometers	12.5 samples per second	Fortnightly		
Bed movements	MEMS FXLS8471Q 3-axis accelerometers	12.5 samples per second	Fortnightly		
Staff sickness	Trust management information	Monthly	Monthly		
Staff turnover	Trust management information	Monthly	Monthly		
Patient length of stay	Trust management information	Monthly	Monthly		
Staff comfort survey	Paper questionnaire	Weekly	Weekly		
Staff focus groups	Facilitated group interview	Hourly	3 interviews before and after		

3.7 Summary of the ward layout and location of the monitoring equipment

In summary, each of the single occupancy rooms in the study wards contained the following monitoring equipment:

- One MadgeTech RHTemp logger measuring air temperature and relative humidity located between the patient bed and chair at head height.
- Two 3-axis accelerometers measuring window movements located in the bottom left corner of each window.
- One 3-axis accelerometers measuring patient bed movements located in the bottom right or left corner of each bed headboard.

Figure 25 provides a schematic of the layout for a single occupancy room in the study wards, including the location of the monitoring equipment.

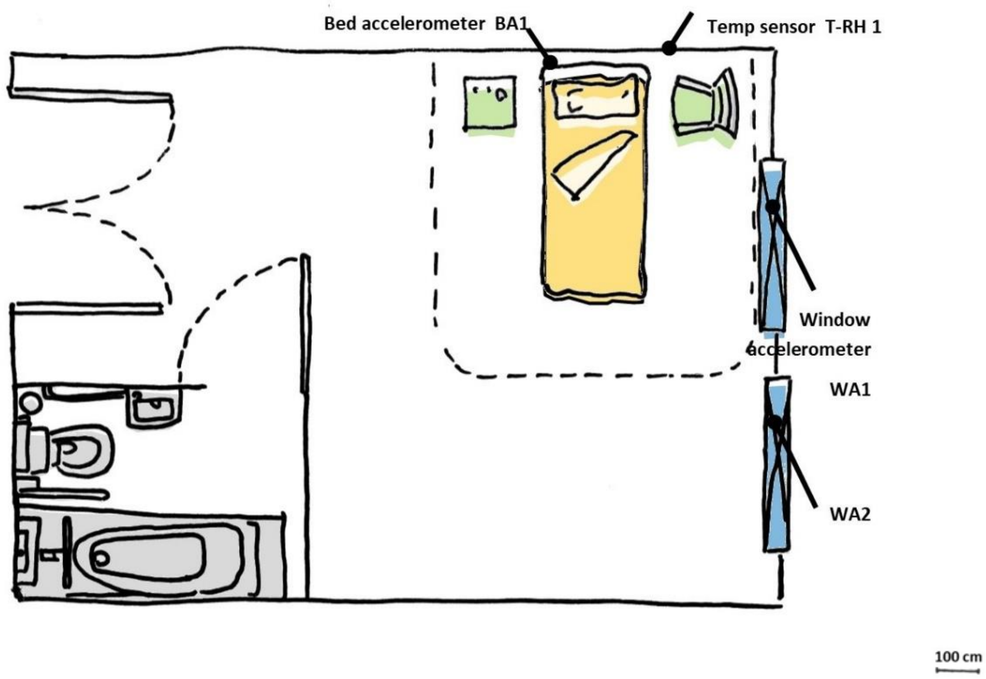

Figure 25. Single room layout and location of the monitoring equipment used during the study

In summary, each of the four-bed multi-occupancy rooms in the study wards contained the following monitoring equipment:

- Four MadgeTech RHTemp loggers measuring air temperature and relative humidity located between each patients' bed and their chair at head height.
- Five 3-axis accelerometers measuring window movements located in the bottom left corner of each window.
- Four 3-axis accelerometers measuring patient bed movements located in the bottom right or left corner of each bed headboard.
- One Extech SD800 CO_2 monitor measuring carbon dioxide located on top of a wall mounted cupboard on the wall furthest from the windows.
- One Reed SD4023 sound monitor measuring noise levels (dB) located on top of a wall-mounted cupboard on the wall furthest from the windows.
- One unbranded silicon photodiodes light sensor and data logger measuring light levels located on top of a wall mounted cupboard on the wall furthest from the windows.

Figure 26 provides a schematic of the layout for a four-bed multi-occupancy room in the study wards, including the location of the monitoring equipment.

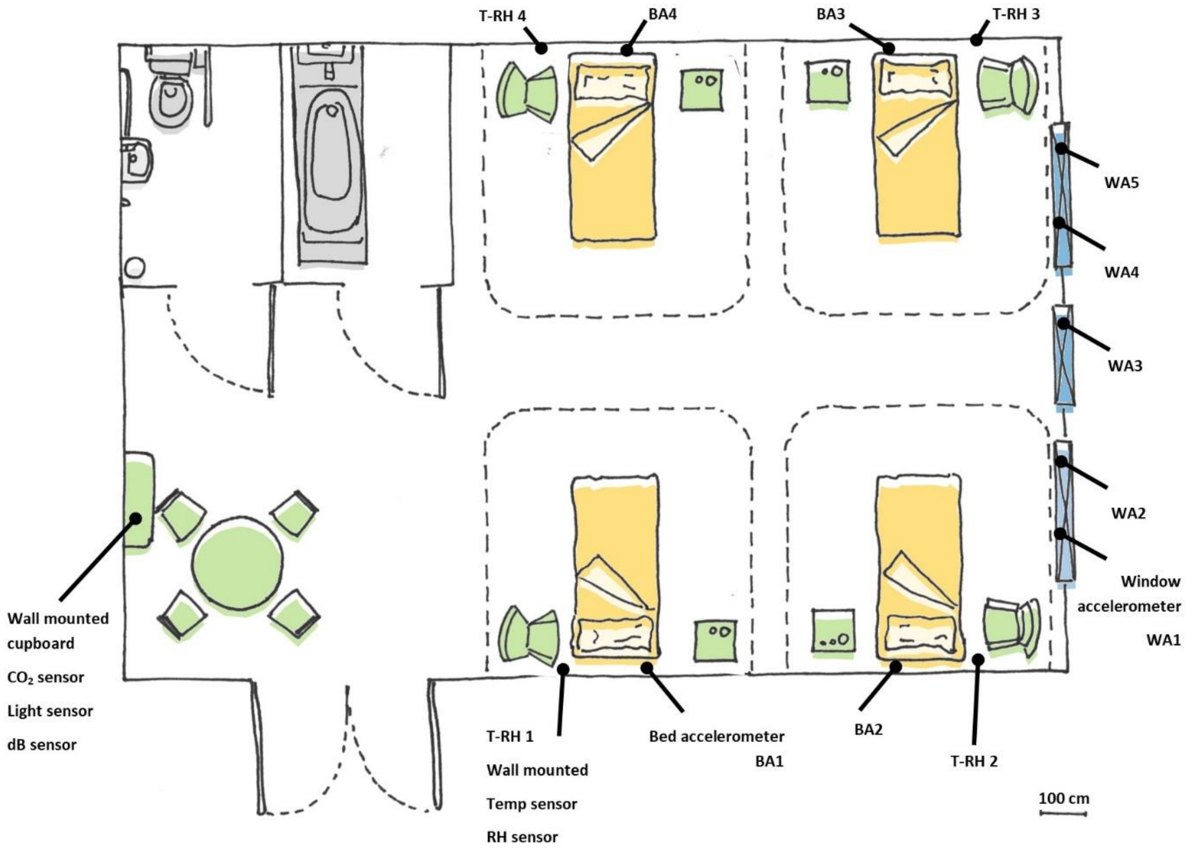

Figure 26. Four-bed multi-occupancy room layout and location of the monitoring equipment used during the study

3.8 Summary linking the Operation TLC primary actions to the data variable and monitoring equipment

Table 6 shows the summary details linking the monitoring equipment and the data variables to the associated Operation TLC primary actions designed to create a healthy environment.

Table 6. Summary linking the monitoring equipment and the data variables to the associated Operation TLC primary actions designed to create a healthy environment

Operation TLC primary actions	Variable	Monitoring equipment / type	Sampling frequency
Turn off equipment & unwanted noise (to reduce noise levels)	Electricity (small power)	LEM AC current AT-B10 attached to a MadgeTech Volt101A data logger	Minutely
	Sound	Reed SD4023 sound monitors	Secondly
	Staff comfort survey (noise question)	Paper questionnaire	Weekly
	Staff focus groups (noise question)	Facilitated group interview	3 interviews before and after
Lights out (to reduce artificial lighting and increase natural light)	Light	Unbranded silicon photodiodes attached to a MadgeTech Volt101A data logger	Minutely
	Electricity (lighting)	LEM AC current AT-B10 attached to a MadgeTech Volt101A data logger	Minutely
	Staff comfort survey (lighting question)	Paper questionnaire	Weekly
	Staff focus groups (lighting question)	Facilitated group interview	3 interviews before and after
Control temperatures (to improve temperature and thermal comfort)	Air temperature & relative humidity	MadgeTech RHTemp logger	5 minutely
	Window movements	MEMS FXLS8471Q 3-axis accelerometers	12.5 samples per second
	Thermal comfort	Delta OHM MD32.3 WBGT	15 secondly
	Carbon dioxide (CO_2)	Extech SD800 CO_2 monitor	Minutely
	Staff comfort survey (temperature & overall comfort questions)	Paper questionnaire	Weekly
	Staff focus groups (temperature & environment questions)	Facilitated group interview	3 interviews before and after

3.9 Summary linking the monitoring equipment and data collection measures to the associated research hypotheses

Table 7 shows the summary details linking the monitoring equipment and data collection measures to the associated research hypotheses.

Table 7. Summary linking the monitoring equipment and data collection measures to the associated research hypotheses

Monitoring equipment	Data collection measure(s)	Associated hypothesis
LEM AC current AT-B10	Electricity from small power (kWh)	H1: The intervention group did not switch off equipment more than the control group
LEM AC current AT-B10	Electricity from lighting (kWh)	H2: The intervention group did not switch off lights more than the control group
Unbranded silicon photodiodes	Light on/off events	
Unbranded silicon photodiodes	Light on/off events	H3: The intervention group did not implement night time switch off
LEM AC current AT-B10	Electricity from small power (kWh) and lighting (kWh)	H4: The intervention group did not save more energy than the control group
Reed SD4023 sound monitors	Noise levels (dB)	H5: The intervention group did not reduce noise levels more than the control group
MadgeTech RHTemp logger	Air temperature (°C)	H6: The intervention group did not control temperature more than the control group
MEMS FXLS8471Q 3-axis accelerometers	Window movement events (count)	
Unbranded silicon photodiodes	Light on/off events	H7: The intervention group did not implement quiet time
Reed SD4023 sound monitors	Noise levels (dB)	
MEMS FXLS8471Q 3-axis accelerometers	Patient bed movement events (count)	
MEMS FXLS8471Q 3-axis accelerometers	Patient bed movement events (count)	H8: The intervention group did not have more patient rest than the control group
Trust management information	Patient length of stay (days)	H9: The intervention group did not have lower patient length of stay than the control group
Trust management information	Staff sickness levels (%)	H10: The intervention group did not have lower staff sickness than the control group
Trust management information	Staff turnover (%)	H11: The intervention group did not have lower staff turnover than the control group

3.10 Inferential statistical analyses

A series of inferential statistical tests, shown in Figure 27 were completed on the numerical (energy for lighting, energy for small power, sound, air temperature, relative humidity, carbon dioxide) and categorical variables (light, window movements, patient bed movements) in Chapter 4, including:

- I_1 = comparing the control and intervention study groups before the intervention,
- I_2 = comparing the control and intervention study groups during the intervention,
- I_3 = comparing the control and intervention study groups after the intervention,
- I_4 = comparing the intervention group between the study periods before and during, and
- I_5 = comparing the intervention group between the study periods during and after.

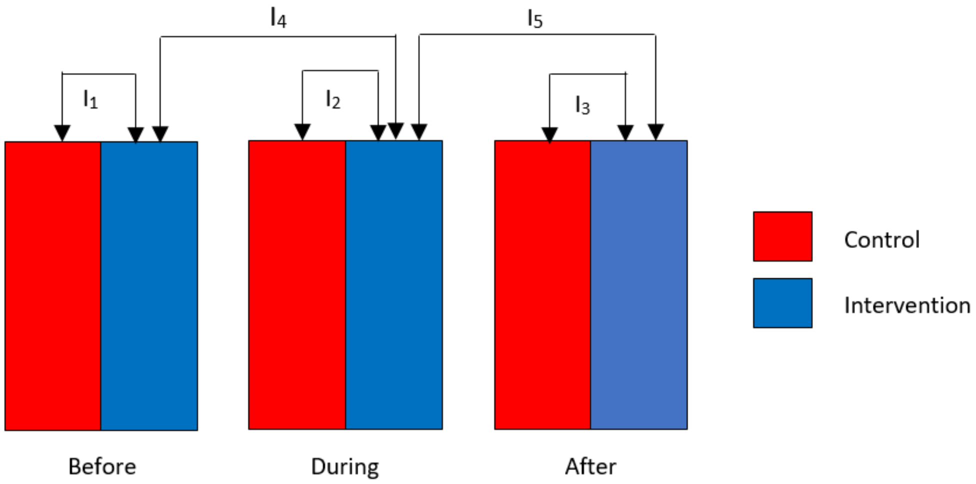

Figure 27. Model showing the inferential statistical tests (I_1, I_2, I_3) completed on the numerical and categorical variables comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the numerical and categorical variables for the intervention group comparing between the study periods before: during and during: after

In order to complete the inferential statistical tests, the quantitative data was aggregated to average minutely values and then merged into a single dataset. All inferential statistical analyses were completed on the merged dataset using R Studio software programme (CRAN 2018).

For the numerical data that show a significant difference post hoc tests were also undertaken to limit the effect of the error rate on multiple analyses and show which groups are significantly different from other groups (Field et al. 2012). For the categorical data odds ratio tests were also undertaken to quantify the strength of the association between the variables being tested (Everitt and Hothorn 2006).

Details of the individual inferential statistical methods used and the results of the inferential statistical tests completed on each of the quantitative variables are found in the relevant sections in Chapter 4.

3.11 Study pilot: 24 hours on a study ward

In order to familiarise with the quantitative data used in the study and test the accuracy of the monitoring equipment, a pilot was undertaken before the start of the behaviour change intervention. The pilot occurred in Intervention B ward over a 24-hour period starting at 14:30:00 on 12th October 2017 ending at 14:30:00 on 13th October 2017.

For the pilot, qualitative data gathered from observations noted by the study researcher was gathered, organised and analysed against the quantitative data gathered from air temperature, relative humidity, light, sound and CO_2 monitors together with movement sensors on the windows and patient beds concurrently in time order.

The starting was post lunch and so represented a relatively quiet period of the day to start the observations. There were no unusual or critical events at either hospital or ward level during the pilot period and the quantitative data gathered during the pilot was found to be comparable with data gathered on Intervention B ward for the month of October 2017.

The quantitative data was analysed using R Studio programming software (CRAN 2018) and is presented below. In order to analysis the relationships between the variables; the quantitative and qualitative datasets were aggregated to average minutely values and then merged into a single dataset in R to enable statistical testing.

3.11.1 Qualitative data criteria

The observations noted by the researcher on the ward included a timestamp and a description of the observation. The observations were then categorised into observed events using the criteria shown in Table 8.

Table 8. Criteria for the observed events noted by the researcher in Intervention B ward over a 24-hour period (14:30:00 12th October 2017 - 14:30:00 13th October 2017) during the study pilot

Event category	Criteria	Measurement
Light	Observations of the artificial lighting in the following states: ON, OFF, DIMMED. All interventions are manual.	Description and count
Sound	Observations of events that created an audible noise above that considered background noise from the following: alarms, doorbells, people (staff, patients, visitors), doors & cupboards, activities (ablutions, housekeeping, meals & refreshments) and equipment (medical equipment, televisions, radios, metal waste bins)	Description and count
Window movement	Observations of the changes of windows in the following states: OPEN, CLOSED, AJAR. All interventions are manual.	Description and count
Bed movement	Observations of events that created a visible patient movement from the following: patient examinations, sitting up / laying down in the bed, getting on / off the bed, turning in the bed.	Description and count
Occupancy	Observations of people in the room and those leaving / coming into the room.	Description and count

3.11.2 Findings from the pilot

3.11.2.1 Light

The data from the light sensor showed a clear pattern of the artificial lighting being fully switched on between the hours of 08:50:00 to 20:30:00, dimmed between the hours of 06:00:00 to 08:50:00 and 20:30:00 to 22:20:00, and fully switched off between the hours of 22:20:00 to 06:00:00. The UK Met Office reported 2.7 daily average hours of sunlight in UK for October 2017 (The Met Office 2018b), which may explain the reason for the lighting being fully on in the patient bay during the day time.

Whilst all the occupants have full access to the controls for the artificial lights in the patient bay, the six lights in the patient bay are controlled simultaneously by one switch that can be switched to off, dimmed or on, consequently the occupants are unable to control individual lights in the patient bay. Whilst the patients had access to a reading lamp above each bed, none of these were used during the 24-hour period and the nursing staff used small torches when checking the patients during the night.

When the observed light events were mapped to the light data, shown in Figure 28, the light data did not always show changes in local light levels when the staff entered the ward with a flashlight at night to check or assist patients. However, it showed a clear correlation between the observed light events categorised by the researcher as switched ON, switched OFF and levels changed to DIMMED and the quantitative data from the light sensor.

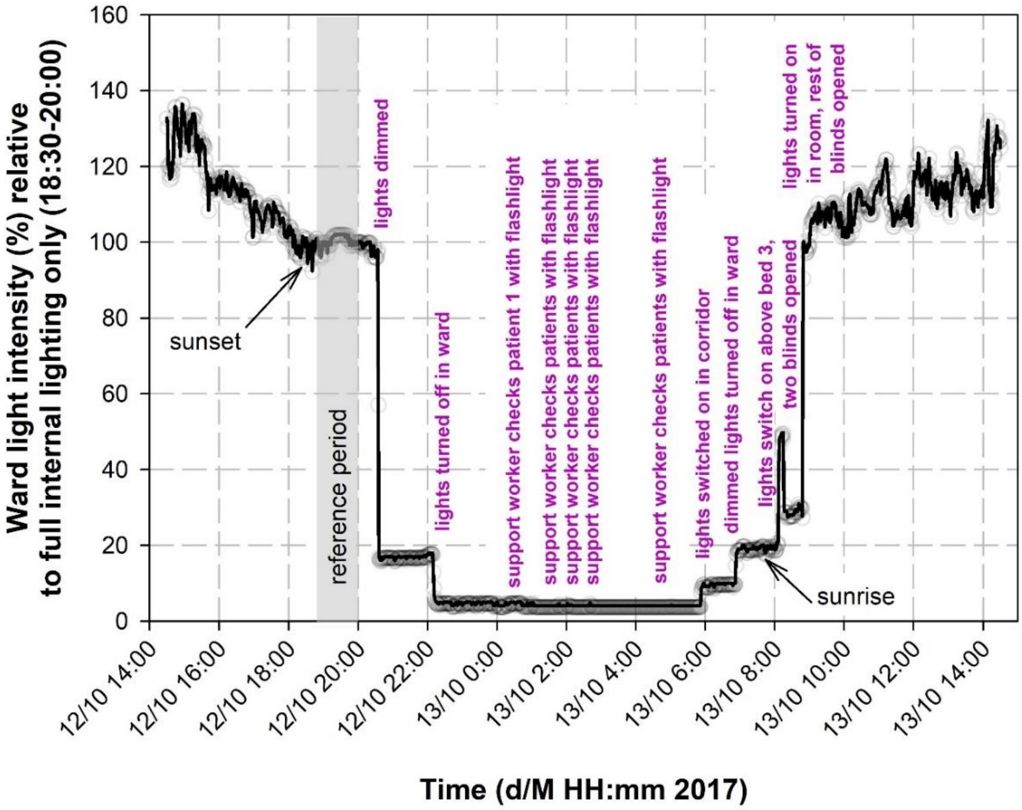

Figure 28. Quantitative light data shown against qualitative observed light events in an older-persons' community hospital ward during the 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

3.11.2.2 Sound

Quantitative data gathered from the sound monitor showed that noise levels on the ward ranged between 35dB and 104dB and the median noise level was 48dB over the 24-hour period. As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003).

A noise level of 30dB is the target for general wards and single occupancy wards (Chartered Institute of Building Services Engineers 2015, Department of Health 2015), noise levels above 85 decibels (dB) are considered to be harmful to health (Schneider 2005), noise levels exceeding 60dB negatively affect sleep in hospitals (Hilton 1985) and background noise levels during the day have typically measured up to 68dB in hospitals (Ulrich et al. 2004).

The study pilot showed that over the 24-hour period noise levels on the ward were above the recommended 30dB noise level for general wards 100% of the time, above the 85dB level considered harmful to health for 0.04% of the time and above the 60dB level that may negatively affect sleep in hospitals for 0.65% of the time. Although, percentage of time is perhaps a somewhat misleading metric as the number of events above a threshold is a better indicator.

When the observed noise events were mapped to the sound data exceeding 60dB at night, shown in Figure 29, the findings identified the events that have the potential to wake patients on the ward during the night time. This showed 44% of peak noise events (maximum dB level in a one-minute period) exceeding 60dB at night were caused by patients, 25% by medical equipment mainly alarms, 24% by staff and 4% occurred from incidents elsewhere on the ward (noise from outside of the patient bay). Thirteen of the fifty-five noise events above 60dB at night were associated with the staff.

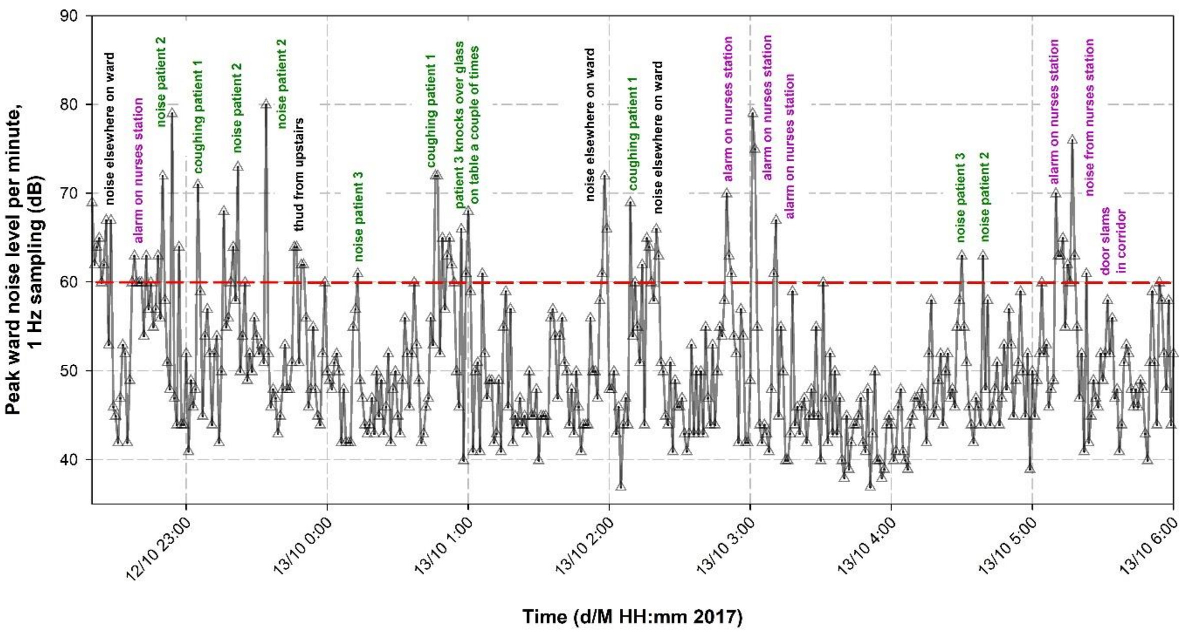

Figure 29. Quantitative sound data at night (22:20:00 - 06:00:00) that exceeded the 60dB sleep disturbance level shown against qualitative observed noise events in an older-persons' community hospital ward during the 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

When the association between sound data above 60dB at night and patient bed movement events was statistically analysed using a Pearson's Chi-squared test of Independence (95% confidence level), the results showed there was a significant relationship ($X^2(1) = 140.42$, $p < 2.2e\text{-}16$) between these variables during the night time. As increased noise levels were seen to correlate with increased movements of patients in their beds a general reduction of noise in the wards during the night is recommended to enhance patient wellbeing and experience.

A Pearson's Chi-squared test of Independence was chosen as the variables were categorical (count of binary variables) and non-paired with a large sample size (>20). The staff accounted for 35% (n=72) of the observed noise events (n=207) at night (as noted by the researcher, not considering a dB threshold) and 46% of these correlated with a patient bed movement event, suggesting there is scope for the nursing staff to reduce noise on the ward to increase patient rest at night.

When the daytime events that created peak noise above 85dB (Ulrich et al. 2004) in the patient bay, shown in Figure 30 a quarter (25%) of the peak noise events above 85dB were caused by staff and 75% by patients. When the association between the sound data above 85dB and patient bed movement events was statistically analysed using a Pearson's Chi-squared test of Independence with a 95% confidence level, the results showed there was a significant relationship ($X^2(1) = 955.99$, $p = < 2.2e\text{-}16$) between these variables across the 24-hour period.

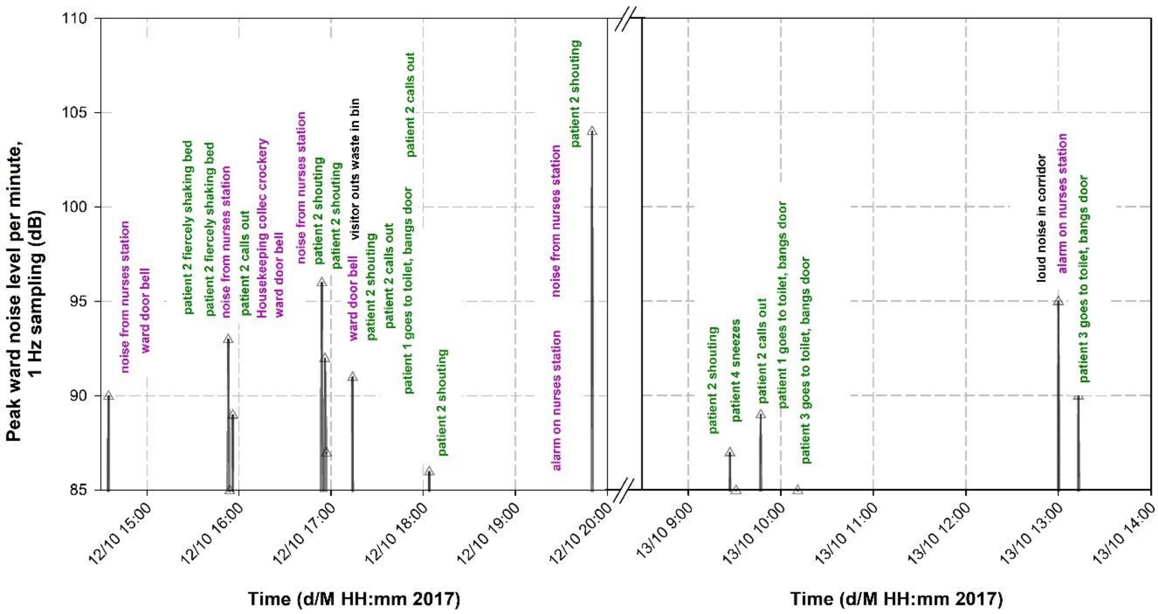

Figure 30. Quantitative sound data that exceeded the 85dB peak noise level shown against qualitative observed noise events in an older-persons' community hospital ward during the 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

When the association between the sound data above 68dB during the day and patient bed movement events was statistically analysed using a Pearson's Chi-squared test of Independence with a 95% confidence level, the results showed there was a significant relationship ($X^2(1) = 301.49$, p = < 2.2e-16) between these variables during the daytime. As increased noise levels were seen to correlate with increased movements of patients in their beds, the introduction of 'quiet-time' rest periods during the day is recommended to increase patient rest during the day and allow time for nursing staff to catch up on other duties, such as updating patient notes.

The staff accounted for 32% (n=131) of the observed noise events (n=412) during the day (as noted by the researcher, not considering a dB threshold) and 32% of these exceeded the 68dB threshold, 49% correlated with a patient bed movement event, suggesting there is scope for the nursing staff to reduce noise on the ward to increase patient rest during the day.

When the association the association between day time sound data and observed occupancy levels in the patient bay was statistically analysed using a Spearman's rho test (95% confidence level), the results showed there was a significant relationship (p = 1.9e-7) between these variables during the day time, although the correlation was weak (r_s = 0.14). A Spearman's rho test was chosen as the data is numerical with a non-normal distribution and a large sample size.

When the association between night time sound data and observed occupancy levels in the patient bay was statistically analysed using a Spearman's rho test (95% confidence level), the results showed there was not a significant relationship (r_s = - 0.03, p = 0.48) between these variables during the night time. This is because the major source of high sound level events are the patients at night and the patient occupancy level does not change.

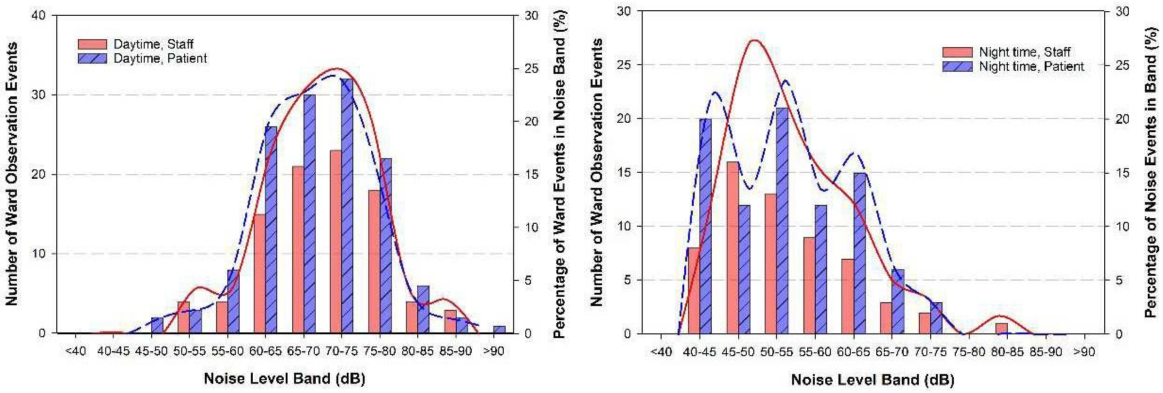

Figure 31. Binned distribution of the number and percentage of patient bay observed noise events and sound level (dB) for (1) LEFT daytime and (2) RIGHT night time periods relating to staff and patients as a source

Figure 31 compares the contribution of staff and patients to noise events in both the day and night periods. Whilst patients are the major source of noise events in both cases, the distribution of noise events for staff and patients is remarkably similar. At night only 20% of the observed bay noise events are associated with direct interaction with patients. 44% of night time events were directly associated with the activity at the nurses' station located outside of the patient bay (talking, coughs, printer, telephone calls) further suggesting there is scope to reduce night time noise through behaviour change training of staff.

3.11.2.3 Air temperature

As outdoor climate is an important factor affecting indoor climate and thermal comfort (de Carvalho et al. 2013) the ambient (outside) air temperature data from the local weather station (The Met Office 2018b) was compared to indoor air temperature across the 24-hour period, shown in Figure 32.

Ambient air temperature was found to be consistently lower than the internal air temperature. The maximum difference was 11.5°C at 20:46:00 on 12th October 2017 and the minimum difference was 7.1°C at 12:16:00 on 13th October 2017. The building has a high thermal mass alongside high ventilation rate, which creates a fairly unified temperature across the 24-hour period.

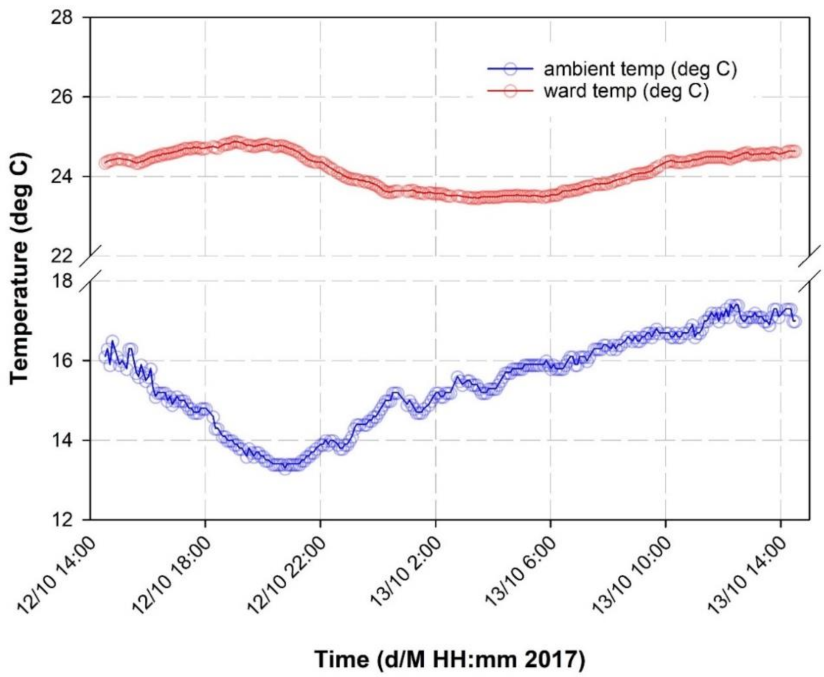

Figure 32. A comparison between local ambient air temperature (The Met Office 2018b) and internal ward air temperature in an older-persons' community hospital ward during the 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

Quantitative data gathered from the temperature loggers showed that air temperatures on the ward ranged between 23.1⁰C and 25.1⁰C and median air temperature was 24.0⁰C during the study pilot. As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003). In accordance with BS EN 16798-1: 2019 temperature drift limits, the study ward achieved a high level (±2⁰C) of expected thermal comfort (British Standards Institute 2019).

CIBSE recommend air temperatures of between 23⁰C and 25⁰C for a general ward in the UK summer (non-heating) period (Chartered Institute of Building Services Engineers 2015). The study pilot showed air temperatures on the ward were within the recommended level 99% of the time over the 24-hour period, shown in Figure 33.

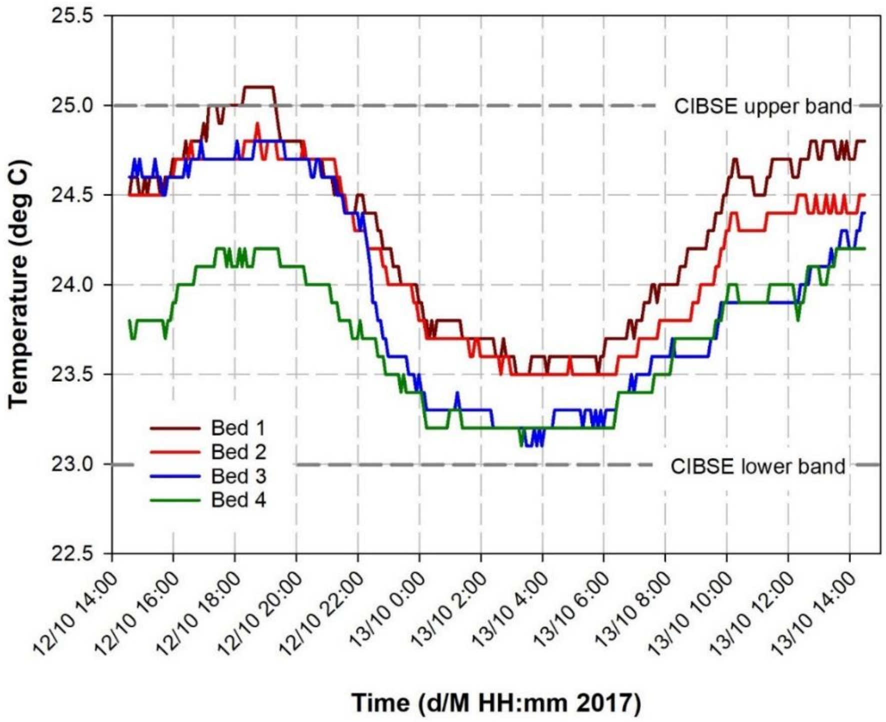

Figure 33. Air temperature (°C) data findings in an older-persons' community hospital ward during the 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017. For bed location see Figure 26.

When the association between air temperature data and observed occupancy levels on the ward was statistically analysed using a Spearman's rho test (95% confidence level), the results showed there was not a significant relationship ($r_s = 0.02$, $p = 0.49$) between these variables across the 24-hour period, as a result of high thermal mass alongside high air change rate in the building. A Spearman's rho test was chosen as the data is numerical with a non-normal distribution and a large sample size.

3.11.2.4 Relative humidity

As outdoor climate is an important factor affecting indoor climate and thermal comfort (de Carvalho et al. 2013) the ambient (outside) humidity from the local weather station (The Met Office 2018b) was compared to indoor relative humidity data across the 24-hour period, shown in Figure 34.

Ambient humidity was found to be consistently higher than internal relative humidity. The difference ranging between 20% and 46% was due to the internal relative humidity remaining constantly around 55% as a result of the high ventilation rate in the ward.

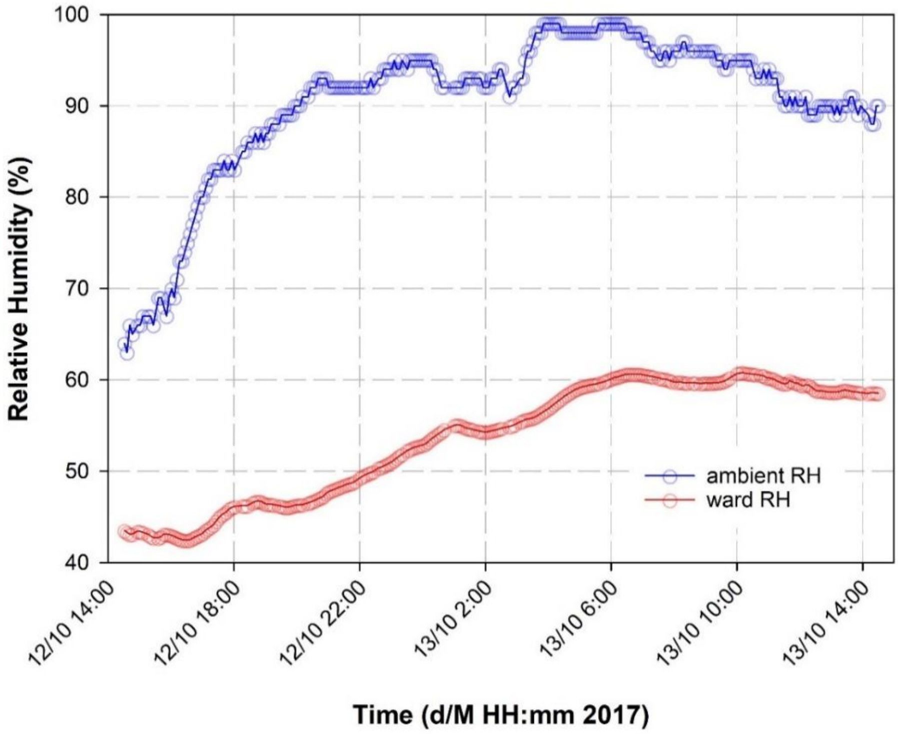

Figure 34. A comparison between local ambient relative humidity (The Met Office 2018b) and internal ward relative humidity in an older-persons' community hospital ward during the 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

Quantitative data gathered from the humidity logger showed that relative humidity levels on the ward ranged between 42% and 62% and median relative humidity was 56% during the pilot study. As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003).

CIBSE recommend internal relative humidity levels between 40% and 70% in the UK (Chartered Institute of Building Services Engineers 2015). The study pilot showed that relative humidity levels on the ward were within the recommended levels 100% of the time across the 24-hour period, shown in Figure 35.

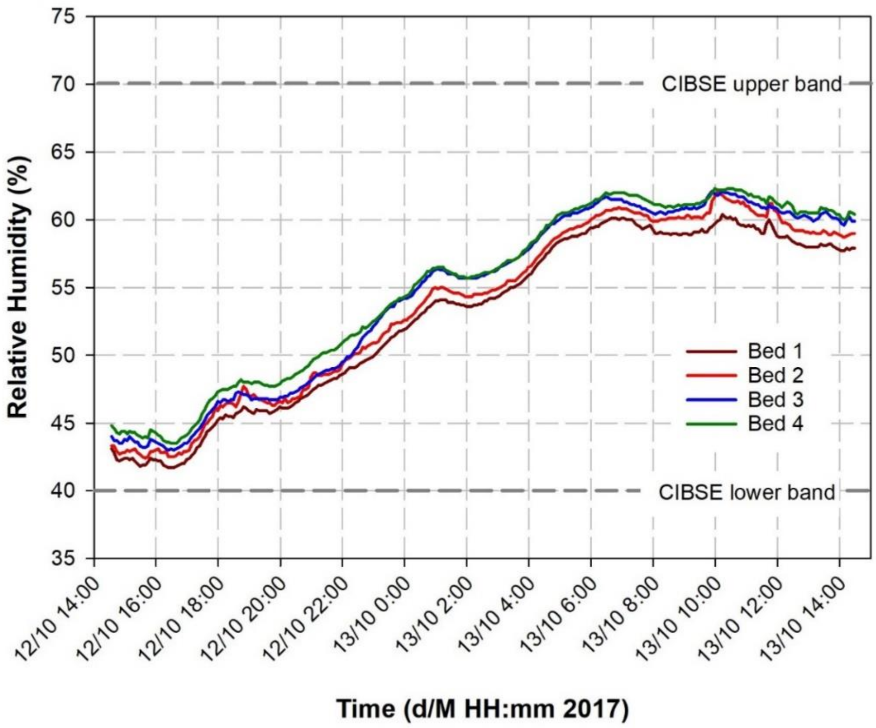

Figure 35. Relative humidity (%) data findings in an older-persons' community hospital ward during the 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017. For bed location see Figure 27.

When the association between the relative humidity data and observed occupancy levels on the ward was statistically analysed using a Spearman's rho test (95% confidence level), the results showed a significant relationship ($p = 0.001$) between these variables across the 24-hour period, although the positive correlation was weak ($r_s = 0.07$) as a result of the high air change rate in the building masking the occupancy effect. A Spearman's rho test was chosen as the data is numerical with a non-normal distribution and a large sample size.

3.11.2.5 Carbon dioxide

Quantitative data gathered from the CO_2 monitor showed that CO_2 levels on the ward ranged between 486 ppm and 679 ppm and median CO_2 was 580 ppm during the study pilot. As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003).

When benchmarked against BS EN 16798-1: 2019 (British Standards Institute 2019) CO_2 concentrations (ppm) and using the average global atmospheric carbon dioxide concentrations during 2017 of 405 ppm (National Oceanic & Atmospheric Administration 2019) as the outdoor CO_2 concentration figure, the CO_2 data was found to be in the high indoor environmental quality range (IEQ_I) for 100% of the time.

When the association between the CO_2 data and observed occupancy levels on the ward was statistically analysed using a Spearman's rho test (95% confidence level), as expected the results show there was a significant relationship (p = 6.9e-10) between these variables across the 24-hour period, although the positive correlation was weak (r_s = 0.14) as the result of the high air change rate in the building masking the occupancy effect. A Spearman's rho test was chosen as the data is numerical with a non-normal distribution and a large sample size.

3.11.2.6 Window movements

Quantitative data gathered from the 3-axis accelerometers on the windows in the ward showed that only one window was open and then closed twice during the 24-hour period. This low level of window engagement was typical of that observed throughout the month.

3.11.2.7 Patient bed movements

The quantitative data from the 3-axis accelerometers on the four patient beds showed 179 patient bed movements and qualitative observations categorised as bed movement events showed 261 observations across the 24-hour period in the ward. The difference is associated with (1) the thresholding level set on the accelerometer and (2) false positive observations due to beds with pressure mattresses which re-pressurise and can be falsely interpreted as a patient movement by observation.

When the observed bed movement events were mapped to the patient bed movement data (3 axis accelerometer sensors), shown in Figures 36-39, the findings identified the events in the patient bay that have the potential to disturb patient rest. These figures show that 49% of bed movement events were caused by patient examinations and assistance by nurses, 48% by patients mainly getting in and out of bed and 3% by staff talking to patients. The high noise events (above 85dB) shown in Figure 30 are overlaid across Figures 36-39 as green and red arrows. A red arrow corresponds to observed patient movement at the same time as the noise event (the patient them self could be the source), a green arrow shows the noise event did not result in patient movement. Of the 10 patient source above 85dB noise events, 8 were from patient 2, with 1 from patient 3 and 4.

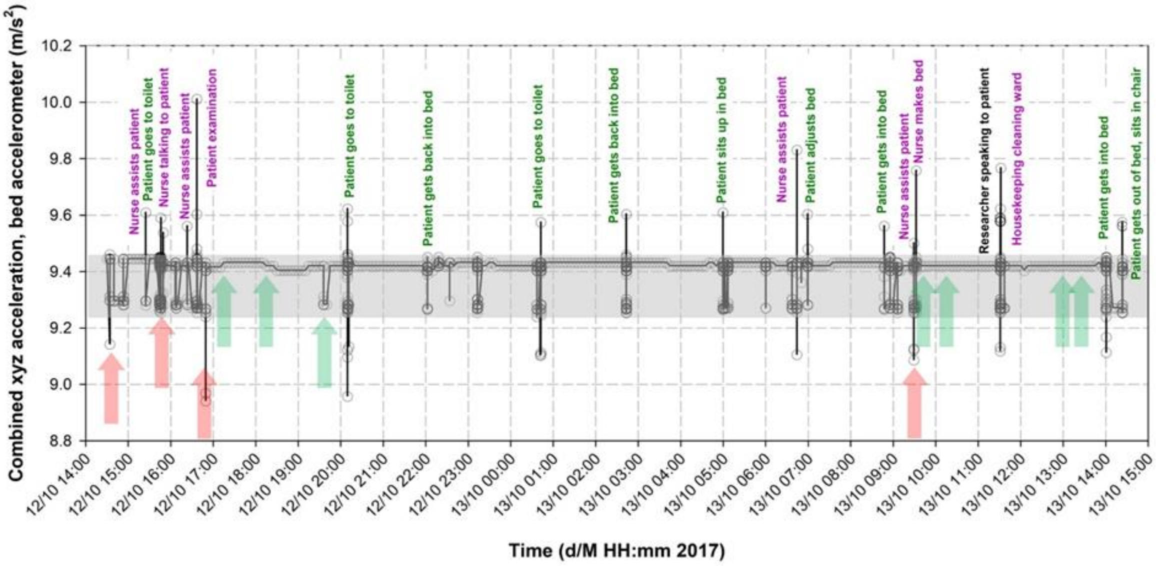

Figure 36. Quantitative bed movement data on Bed 1 with combined acceleration (xyz) forces (m/s^2) shown against qualitative observed bed events for Bed 1 in an older-persons' community hospital ward during a 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

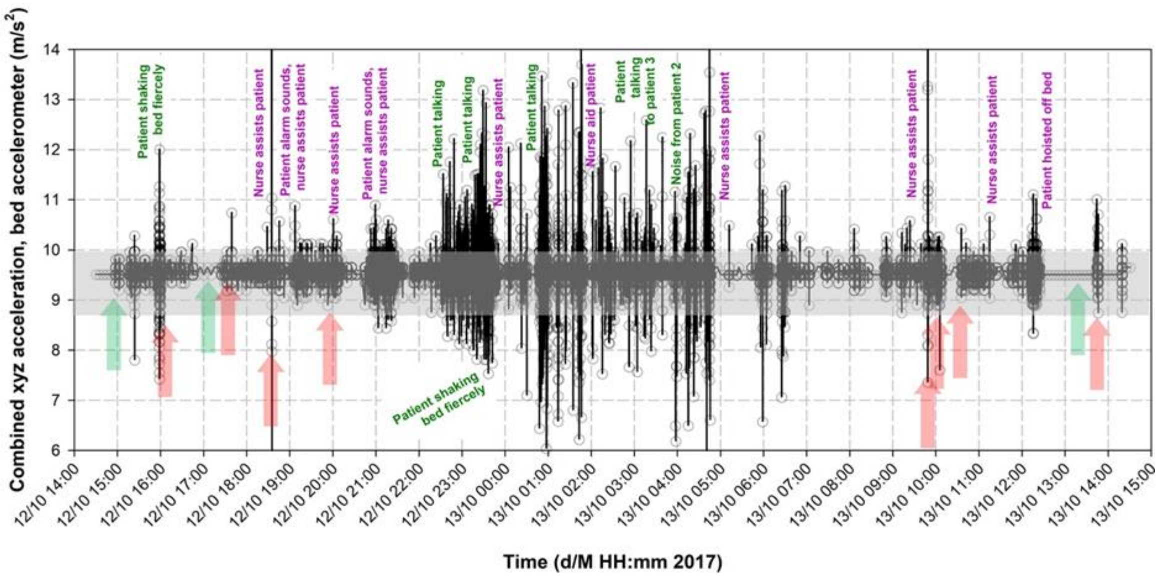

Figure 37. Quantitative bed movement data on Bed 2 with combined acceleration (xyz) forces (m/s^2) shown against qualitative observed bed events for Bed 2 in an older-persons' community hospital ward during a 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

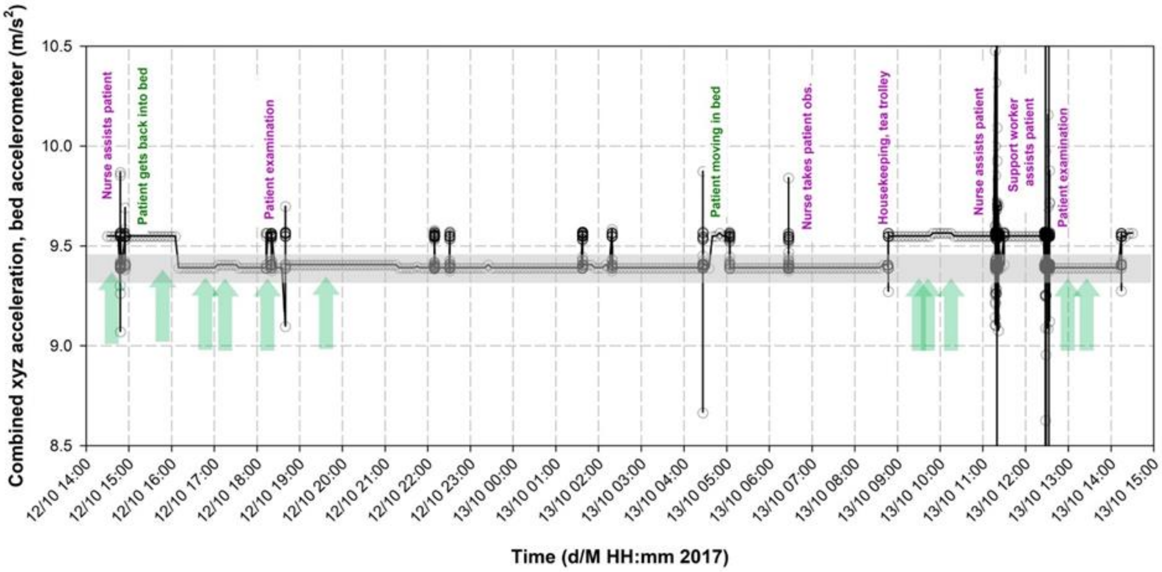

Figure 38. Quantitative bed movement data on Bed 3 with combined acceleration (xyz) forces (m/s^2) shown against qualitative observed bed events for Bed 3 in an older-persons' community hospital ward during a 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

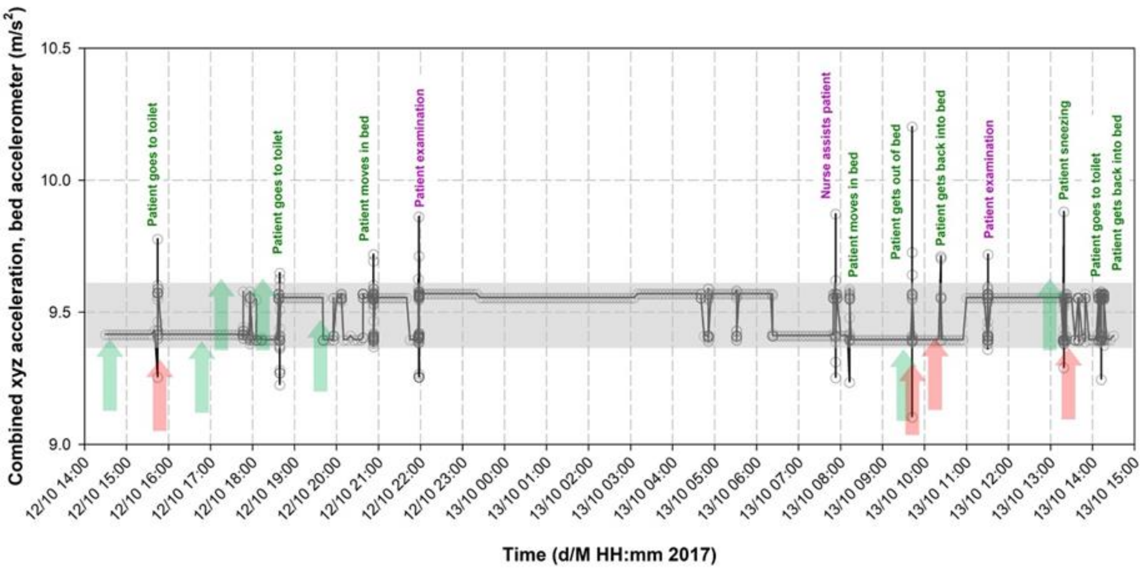

Figure 39. Quantitative bed movement data on Bed 4 with combined acceleration (xyz) forces (m/s^2) shown against qualitative observed bed events for Bed 4 in an older-persons' community hospital ward during a 24-hour study pilot from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

Figure 37 shows that for patient 2, bed movement is observed to occur with above 85dB noise events only in the case where patient 2 is the source of the noise. In effect this patient is not observed to be disturbed by other noise events, the patient acts as the primary source of disturbance. For the case of patient 1, only 1 sound event bed movement (14:30:00, 12/10/17) cannot be associated with another activity in the patient bay, such as the patient talking to a nurse.

Figure 38 shows that none of the noise events are observed to impact on Patient 3 in terms of bed movement. Similarly, in the case of Figure 39, other patient activities (such as getting out of bed) are observed to coincide with the >85dB noise events. There is the possibility that the patient may have chosen, in part, to initiate this activity as a result of the noise disturbance

Whilst the quantitative bed data on the whole reflected the qualitative observed bed events for beds 1, 3 and 4, bed 2 was more problematic to match. The patient in bed 2 was reportedly suffering from dementia and was observed talking loudly, calling out and moving in the bed for a significant amount of the 24-hour period, which made it difficult to match the appropriate observations to the quantitative bed data. This highlights that an accelerator based approach does have limitations amongst particular patient groups.

3.11.3 Summary of Study Pilot

During the case study air temperature, relative humidity and carbon dioxide remained within the recommended levels for the majority of the 24-hour period (Chartered Institute of Building Services Engineers 2015). Whilst noise levels in the patient bay were always above the recommended level (30dB) they generally fell in line with previous studies in UK hospitals that reported background noise levels typical measuring 45-68dB and peak noise levels typically measuring above 85dB (Ulrich et al. 2004). Lights were fully switched on between 08:50:00 and 20:30:00, and fully switched off between 22:20:00 and 06:00:00. Only one window was opened and then closed during the 24-hour period.

The inferential statistical analysis showed there was a relationship between movements of the patients in their beds and noise levels in the patient bay (1) above 68dB during the day, (2) above 60dB at night and (3) above 85dB across the 24-hour period. As increased noise levels were seen to correlate with increased movements of patients in their beds, the introduction of ‘quiet-time’ rest periods during the day and a general reduction of noise in the wards during the night is recommended to enhance patient wellbeing and experience.

There was an observed correlation between occupancy levels in the patient bay and (1) noise levels during the day and (2) movement of the patients in their beds at night. Staff accounted for 10% of the observed noise events that exceeded 68dB during the day and 24% of the observed noise events that exceeded 60dB at night. There was an observed correlation between observed noise events created by staff and the movement of the patients in their beds (1) 49% during the day and (2) 46% during the night, suggesting there is scope for the nursing staff to examine elements of their practice which can reduce noise on the bay to increase patient rest.

The pilot study also showed that the occupants in the patient bay, particularly the nursing staff had very little control over air temperature, relative humidity, carbon dioxide and lighting on the ward for which the controls were too limited. The results from this case study have subsequently led to the introduction of a lighter summer uniform for nurses alongside the trailing of 'quiet time' periods (daytime and night time) to enhance the patient environment and their experience.

3.12 Summary of the research design

3.12.1 Case study

Hospital	• NHS community hospital with a PFI contractual arrangement. • Located in south of England with a temperate climate.
Study wards	• 3 identical (size, layout, orientation, location) in-patient acute care wards (one control ward = 'Control', and two intervention wards = 'Intervention A' and 'Intervention B'). • Each ward comprises two 4-bed occupancy rooms and four single occupancy rooms. • Each ward accommodates a total of twelve older-persons' in-patients (above 65 years, average 27% with mental health conditions). • Each ward accommodates 10 staff work four shifts across 24-hour period.

3.12.2 The Intervention

Approach and factors	• An information based behaviour change approach was used modelled from an adapted version of Triandis' Theory of Interpersonal Behaviour. • The approach included consideration of social (group norms, knowledge and values), organisational (culture, policies, practices, workload and resources) and contextual (control of the environment, equipment and implementation costs) factors.
Details	• The intervention was based on an adapted version of GAP's Operation TLC. • Operation TLC comprises 3 primary actions (1) **T**urn off equipment & unwanted noise (2) **L**ights out (3) **C**ontrol temperatures and eleven secondary actions to support the primary actions tailored to the specific patients and environment. • Two secondary actions (1) quiet time and (2) night time switch off would occur daily at (1) 13:30:00 - 14:30:00 and (2) 23:00:00 respectively • Consequently, for this study (1) day time was defined as 06:00:00 - 22:39:00 and (2) night time was defined as 23:00:00 - 05:59:00. • The staff participating received two training workshops together with regular refresher training and feedback sessions held in conjunction with scheduled team meetings. • Use of social rewards (public praise) was used during the feedback sessions as well as incentives (promotional pens, 'thank-you' heart chocolates). • Evidence based information and education tools (cards, posters, stickers, thermometers) were utilised by Operation TLC Champions.
Duration	• Intervention was run for 3 months as it takes around sixty-six days for a behaviour to become a habit (Lally et al. 2010). • The wards were monitored 3 months prior to the intervention to provide adequate benchmark data and 3 months after the intervention to monitor tail-off.

3.12.3 Linking the data collection methods with the research questions

3.12.3.1 RQ1: In what ways and to what extent does running a behaviour change intervention in a hospital reduce energy consumption?

Variable	Monitoring equipment / type	Sampling frequency	Research hypothesis
Electricity (small power & lighting)	LEM AC current AT-B10 attached to a MadgeTech Volt101A data logger	Minutely	H1: The intervention group did not switch off equipment more than the control group H2: The intervention group did not switch off lights more than the control group H4: The intervention group did not save more energy than the control group
Light	Unbranded silicon photodiodes attached to a MadgeTech Volt101A data logger	Minutely	H2: The intervention group did not switch off lights more than the control group

3.12.3.2 RQ2: In what ways and to what extent does running a behaviour change intervention in a hospital improve patient well-being?

Variable	Monitoring equipment / type	Sampling frequency	Research hypotheses
Light	Unbranded silicon photodiodes attached to a MadgeTech Volt101A data logger	Minutely	H3: The intervention group did not implement night time switch off H7: The intervention group did not implement quiet time
Sound	Reed SD4023 sound monitors	Secondly	H5: The intervention group did not reduce noise levels more than the control group H7: The intervention group did not implement quiet time
Air temperature	MadgeTech RHTemp logger	5 minutely	H6: The intervention group did not control temperature more than the control group
Window movements	MEMS FXLS8471Q 3-axis accelerometers	12.5 samples per second	
Patient bed movements	MEMS FXLS8471Q 3-axis accelerometers	12.5 samples per second	H8: The intervention group did not have more patient rest than the control group
Patient length of stay	Trust management information	Monthly	H9: The intervention group did not have lower patient length of stay than the control group

3.12.3.3 RQ3: In what ways and to what extent does running a behaviour change intervention in a hospital improve staff satisfaction?

Variable	Monitoring equipment / type	Sampling frequency	Research hypothesis
Staff sickness	Trust management information	Monthly	H10: The intervention group did not have lower staff sickness than the control group
Staff turnover	Trust management information	Monthly	H11: The intervention group did not have lower staff turnover than the control group

A full analysis of the quantitative data gathering from the sustainability (economic, environmental and social) factors during the study (1st August 2017 - 30th April 2018) is presented in the next chapter.

Chapter 4 Findings: Quantitative Data

This chapter outlines the analysis carried out on the quantitative data collected from the monitoring equipment during this study, which aims to test the theory that *"running a behaviour change intervention in a hospital saves energy whilst creating a healthy environment that improves patient wellbeing and staff satisfaction"*.

The quantitative data was analysed in line with the stages of analysis identified by Jirojwong et al. (2014), namely familiarisation, organisation, categorisation and exploration of the relationships between the categories. This chapter presents the results from these stages of the data analysis.

The details of the processing carried out on the individual data variables prior to analysis, are discussed in the appropriate sections below. The quantitative data was analysed using R Studio programming software (CRAN 2018). The inferential statistical analyses were completed using the merged dataset discussed in Chapter 3, section 3.10.

Section 4.1 presents the findings from the energy data (electricity for lighting and small power) collected during the study. Section 4.2 presents the findings on the environmental data (light, sound, air temperature, relative humidity, thermal comfort, carbon dioxide and window movements) collected during the study. Section 4.3 presents findings from the staff and patient experience data (Trust management information and patient bed movements) collected during the study. A summary of the findings from the quantitative data is presented in section 4.4.

4.1 Energy data

Due to a logistical issue with gaining access to the distribution boards, the AC current clamps and data loggers were not installed onto the electrical distribution boards for lighting and small power until 1st September 2017, consequently the study period 'before' the intervention comprises two months (1st September - 31st October 2017) in the energy data sections only.

In order to analyse the energy data for lighting and small power, the values (volts) from the AC split core current clamps (3 x 0-150A, 10DC output) and data loggers were initially processed into power demand values (kW) using the following equation:

$$kW = V_{out} \times ((MaxI \times V_{main})/1000)/LPV$$

where,

V_{out} = measured combine current clamp voltage

MaxI = combined peak current of the 3 x current clamps, 450V

V_{main} = mains voltage, 240V

LPV = logger peak value, 30V

4.1.1 Lighting

To familiarise with the energy data from lighting, first the frequency distribution of the full dataset was displayed graphically using a histogram and quantile-quantile (Q-Q) plot, shown in Figure 40, in order to identify the distribution of the dataset (Kranzler 2003). The histogram shows the dataset has a bi-modal distribution and the Q-Q plot shows a non-normal distribution.

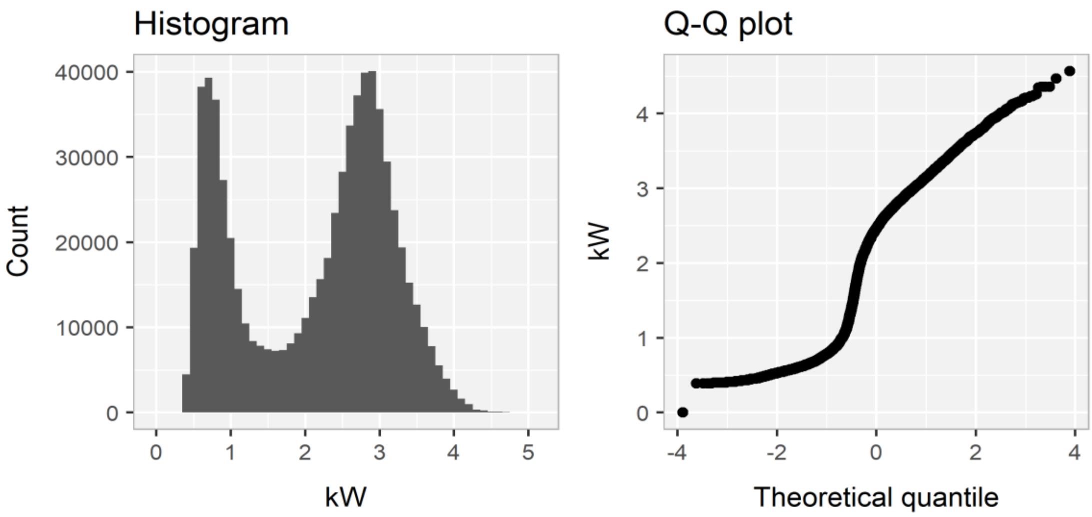

Figure 40. Histogram and Q-Q plot showing the power demand values for lighting for the combined control and intervention study groups for the study period of 1st September 2017 to 30th April 2018

Figure 41, confirms the bi-modal distribution of the full data set represents day and night time values. When separated, as expected the day time (06:00:00 - 22:59:00) values appear to have a bell curve albeit with a slight left skew due to ward lighting being dimmed for approximately an hour and a half in the morning and evening prior to being switched on during the day and off at night accounting for the slightly skewed lower values lying to the left of the mean.

The night time (23:00:00 - 05:59:00) values show a positively skewed distribution, due to (1) emergency lighting on the wards running 24-7 accounting for the majority of the values lying to the left of the mean and (2) additional lights being turned on by nursing staff as required during the night accounting for smaller amount of values to the right of the mean.

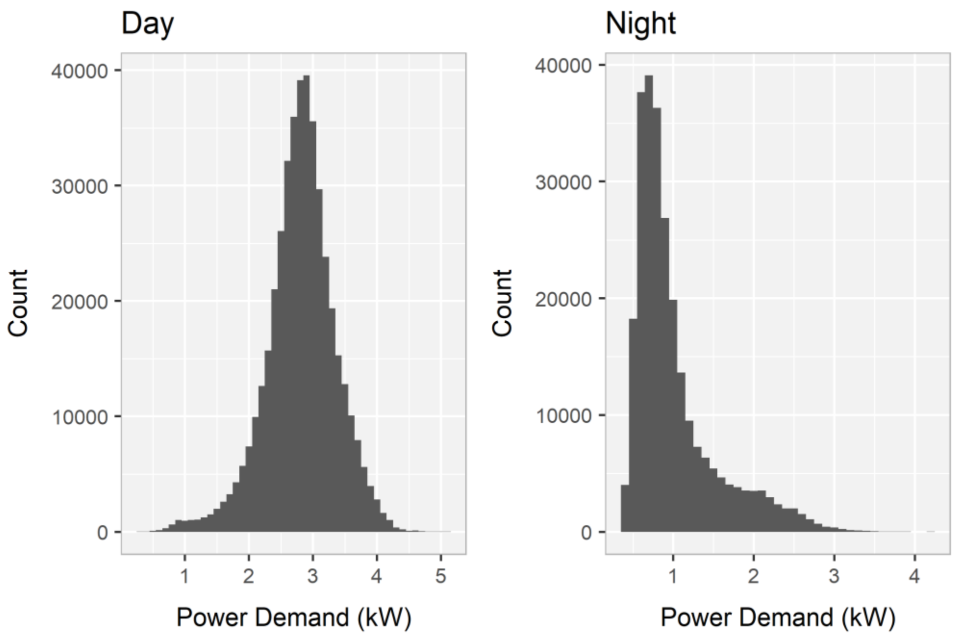

Figure 41. Histograms showing the day and night time power demand values for lighting for the combined control and intervention study groups for the study period of 1st September 2017 to 30th April 2018

The data was then organised into the main categories of interest for analysis, namely by the study periods of before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention and by study group, namely the control and intervention groups.

The measures of central tendency and variability were then calculated for these categories. As we would expect to see a difference in power demand between the day and night time, the summary data for the day time (06:00:00 - 22:59:00) values is presented in Table 9 and the night time (23:00:00 - 05:59:00) values is presented in Table 10.

Table 9. Summary of power demand values for lighting during the day time (06:00:00 - 22:59:00), comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (kW)	q25 (kW)	Mean (kW)	Median (kW)	q75 (kW)	Maximum (kW)	Standard deviation
Before	Control	54899	0.49	2.56	2.90	2.93	3.23	4.82	0.53
Before	Intervention	54899	0.26	2.42	2.70	2.69	2.91	4.15	0.38
During	Control	82857	0.44	2.63	3.00	3.04	3.40	5.07	0.60
During	Intervention	82856	0.32	2.57	2.70	2.78	2.96	4.29	0.36
After	Control	80098	0.45	2.68	3.00	3.06	3.42	4.97	0.65
After	Intervention	80096	0.52	2.37	2.60	2.66	2.92	4.31	0.49

During the day time, the power demand values for lighting in the control group ranged between 0.44 kW and 5.07 kW compared to 0.26 kW and 4.31 kW in the intervention group, showing there was a smaller range of power demand for lighting in the intervention group than in the control group during the day time.

As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003), which showed that during the day time, the intervention group had similar albeit slightly lower median power demand (kW) when compared to the control group before and during the intervention; with a 0.24kW difference before and a 0.26kW difference during the intervention. After the intervention, the intervention group had a lower median power demand of 0.4kW difference when compared to the control group.

Table 10. Summary of power demand values for lighting during the night time (23:00:00 - 05:59:00), comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (kW)	q25 (kW)	Mean (kW)	Median (kW)	q75 (kW)	Maximum (kW)	Standard deviation
Before	Control	32940	0.39	0.63	0.90	0.80	1.08	3.05	0.45
Before	Intervention	32940	0.46	0.66	0.90	0.78	0.96	2.90	0.43
During	Control	49680	0.40	0.66	1.00	0.88	1.22	3.45	0.52
During	Intervention	49680	0.43	0.65	1.00	0.78	1.02	3.04	0.51
After	Control	48060	0.38	0.71	1.10	0.96	1.34	4.18	0.59
After	Intervention	48060	0.46	0.69	1.00	0.85	1.15	3.12	0.51

During the night time, the power demand values for lighting in the control group ranged between 0.38 kW and 4.18 kW compared to 0.43 kW and 3.12 kW in the intervention group, showing there was a smaller range of power demand for lighting in the intervention group than in the control group during the night time. During the night time, the intervention group had similar albeit slightly lower median power demand (kW) when compared to the control group before the intervention; with only a 0.02 kW difference. During the intervention, the intervention group had a lower median power demand of 0.1 kW when compared to the control group and after this difference further increased to 0.11 kW lower.

As number of light fittings and luminaires were identical across the study wards, possible reasons for the difference in the range of power demand values may be due to (1) light tube failures in the patient rooms participating in the study (2) lighting may have been switched on or off in non-patient areas of the study wards, such as offices and staff mess rooms etc. that are on the same lighting distribution board and (3) different behavioural activities by ward occupants in patient areas in relation to turning lights off/on.

A visual representation of the power demand for lighting by study group and study period comparing day and night values is presented in Figure 42, which shows the intervention group had a greater number of outliers in the lower quartile in the day time during the intervention than the control group. This suggests the intervention group had more incidents of lower power demand than the control group in the day time during this period, which may be due to staff in the intervention group implementing 'quiet time' during which lights are dimmed or turned off to facilitate patient rest and recovery.

Conversely, the control group showed a greater number of outliers in the upper quartile in the night time after the intervention than the intervention group, suggesting the control group had more incidents of higher power demand than the intervention group during this period due to staff turning lights on for patient examinations or administering medicines at night.

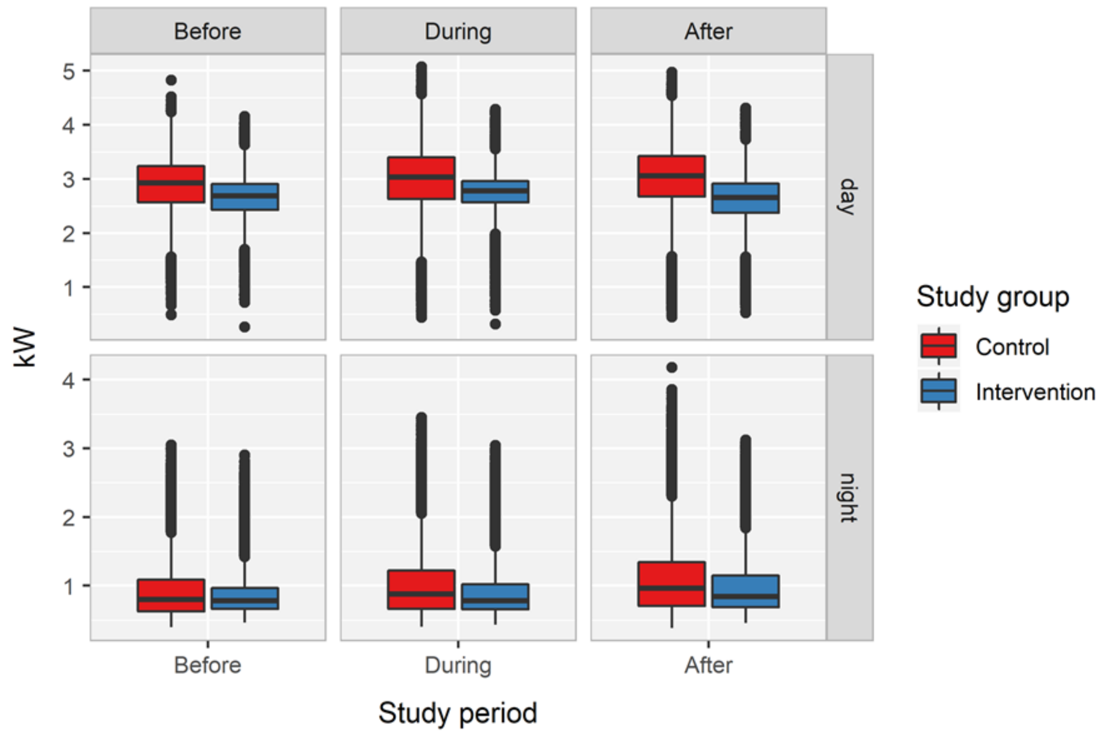

Figure 42. Box plot of day and night time minutely power demand values (kW) for lighting, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

To further examine the energy data for lighting, the minutely median data was organised into the average daily profiles for the study periods before, during and after the intervention for the study groups, shown in Figure 43, which confirms the intervention group had a lower power demand for lighting than the control group across the study periods.

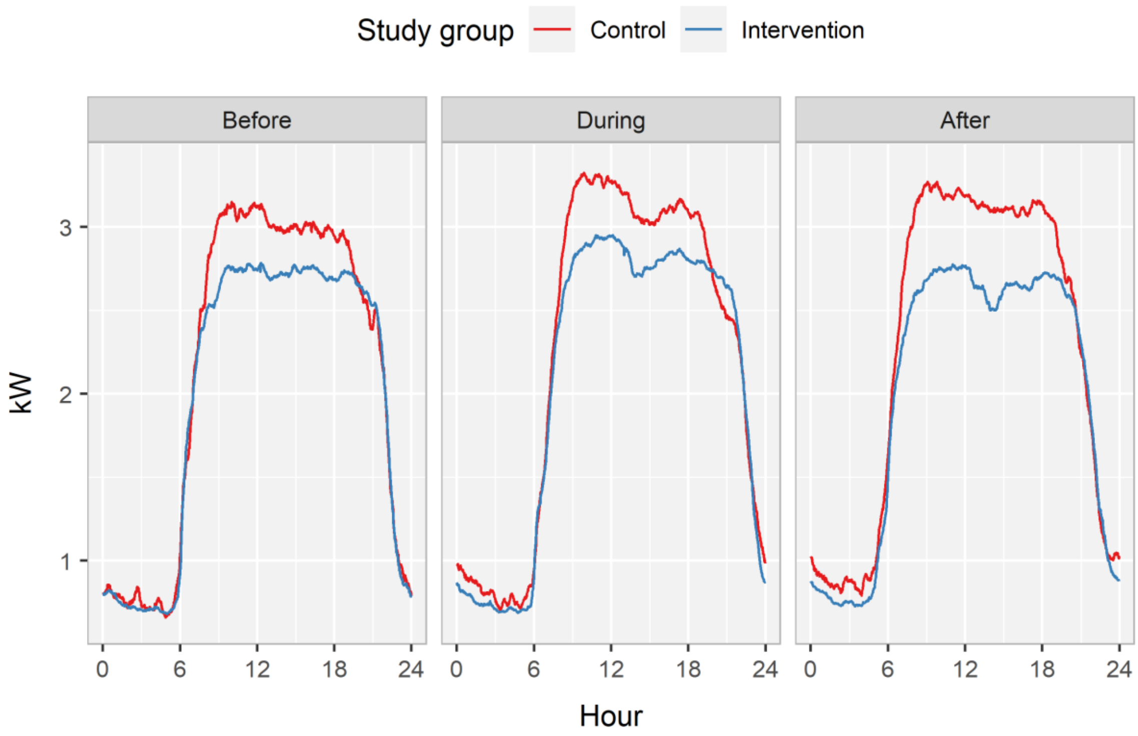

Figure 43. Average minutely median daily power demand profile for lighting, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Not only this but in the during and after study periods, the intervention group shows a distinctive drop in power demand for lighting that coincides with the implementation with Operation TLC secondary action of 'introduce a quiet time for an hour after lunch', which occurred daily between 13:30:00 - 14:30:00 during which lights are dimmed or turned off to facilitate patient rest and recovery whilst enabling staff to catch up on tasks, such as updating patient notes.

In both domestic and non-domestic settings energy behaviour change was found to diminish when feedback stopped (Dwyer et al. 1993, Darby et al. 2016), however Figure 43, showed the energy behaviour change did not diminish but rather increased further when feedback stopped. Consequently, the average daily power demand profiles for lighting were organised into the individual months across the study, presented in Figure 44, which shows the behaviour change intervention took up to a month (November 2017) to take effect.

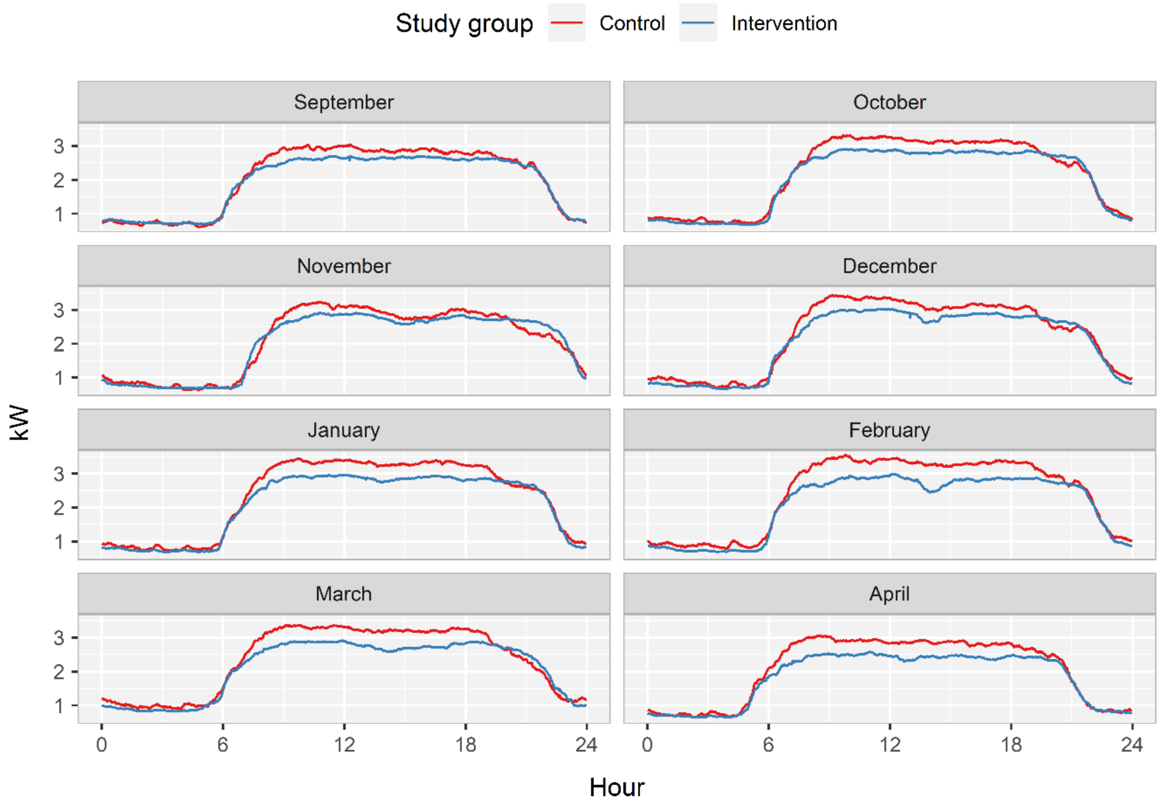

Figure 44. Average minutely median daily power demand profile for lighting, comparing the control and intervention study groups for the individual months from September 2017 to April 2018

The effects of the behaviour change intervention (reduction in energy for lighting) then appeared to continue to increase for three months (December 2017 - February 2018), peaking in the month after the feedback stopped (February 2018) showing a delay in the effect. The effect of the behaviour change intervention then appeared to diminish over the following two months (March - April 2018), although the reduction in energy for lighting was still higher in these months than in the study period before the intervention.

When the average daily power demand profiles for lighting for the months after the intervention (February - April 2018) were further examined, presented in Figure 45, it also showed that 'quiet time' was sustainable after the intervention.

Figure 45. Average minutely median daily power demand profile for lighting, comparing the control and intervention study groups for the months in the study period after (1st February - 30th April 2018) the behaviour change intervention

To further familiarize with the energy data for lighting, the power demand data was multiplied by time to produce energy consumption (kWh) for the control and intervention study groups for the study periods before, during and after the behaviour change intervention. As the study period before was a shorter period (2 months) than the during and after study periods (3 months) the energy consumption values were normalized to show energy use for lighting per day.

A summary table of energy consumption (kWh) for lighting in the control and intervention study groups for the study periods before, during and after the behaviour change intervention is presented in Table 11.

Table 11. Summary of the difference in energy consumption (kWh) for lighting, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Period	Study group	Energy consumption (kWh)	Study days (n)	Energy consumption per day (kWh/day)
Before	Control	3074.365	61	50.399
Before	Intervention	2927.967	61	47.999
During	Control	4859.690	92	52.823
During	Intervention	4638.760	92	50.421
After	Control	4912.723	89	55.199
After	Intervention	4271.867	89	47.999

Before the intervention, the control group used 50.399 kWh of energy for lighting per day and the intervention group used 47.999 kWh per day, a difference of 2.4 kWh per day. During the intervention, the control group used 52.823 kWh of energy for lighting per day and the intervention group used 50.421 kWh per day, a difference of 2.4 kWh per day. After the intervention, the control group used 55.199 kWh of energy for lighting per day and the intervention group used 47.999 kWh per day, a difference of 7.2 kWh per day. A visual representation is presented in Figure 46.

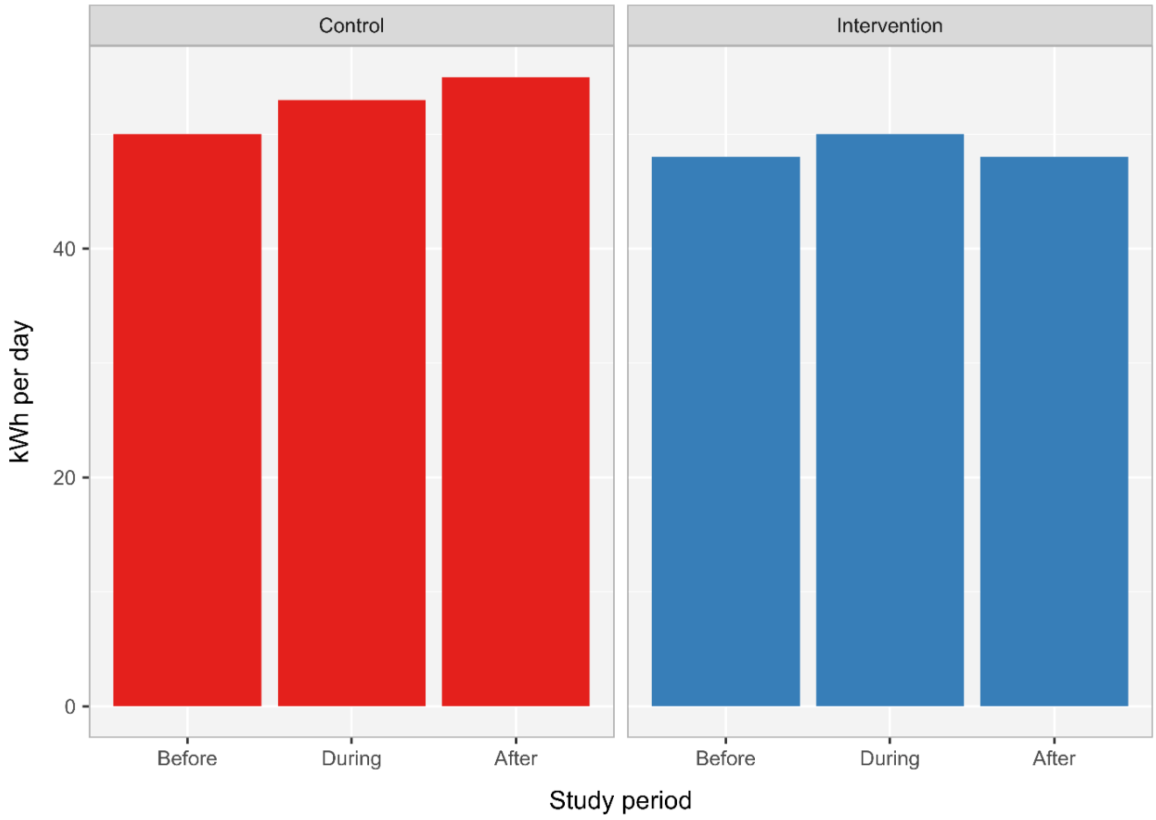

Figure 46. Energy consumption per day (kWh/day) for lighting, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

The intervention group used 5% less energy for lighting per day than the control group before the intervention, 5% less during the intervention and 13% less after the intervention. Consequently, the intervention group produced an 8% saving in energy use for lighting after the intervention. For the two intervention wards participating in this study this equated to total saving of 620 kWh and 226 $kgCO_2e$[3] for the during and after study periods (6 months).

Table 11 also shows that both study groups used more energy for lighting per day during the intervention than before the intervention, which as expected negatively correlates with the total hours of sunshine during these periods. Before the intervention (August, September, October) there was a total of 424 hours of sunshine and during the intervention (November, December, January) there was a total of 194.5 hours of sunshine (The Met Office 2018b).

[3] Calculated using UK Government emission conversion factors for greenhouse gas company reporting: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting [accessed 15/01/2019].

The Met Office (2018a) reported a total of 330.6 hours of sunshine for the period after the intervention (February, March, April), which is consistent with the findings from the intervention group that less energy was used for lighting after the intervention than during the intervention. However, the control group used more energy for lighting after study period than it had in either of the two previous study periods, which is not consistent with the reported hours of sunshine by the Met Office.

To complete the exploration of the energy data for lighting a series of inferential statistical tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the minutely data (electricity kWh) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Table 12.

Table 12. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the energy data for lighting (kWh) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the energy for lighting data (kWh) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	175678	4315700000	< 2.2e-16	<2e-16
I_2	265073	9960085667	< 2.2e-16	<2e-16
I_3	256314	9849200000	< 2.2e-16	<2e-16
I_4	440751	5409056360	< 2.2e-16	<2e-16
I_5	521387	9.029e+09	< 2.2e-16	<2e-16

The results showed there is a statistically significant difference between the medians of the minutely energy consumption data (kWh) for lighting in the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error. However, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

The results also showed there is a statistically significant difference between the medians of the minutely energy consumption data (kWh) for lighting in the intervention group across the different study periods before and during (I_4) the intervention and during and after (I_5) the intervention, which confirms the findings did not occur due to random error and are likely to have occurred due to seasonality.

4.1.2 Small power

To familiarise with the energy data from small power, first the frequency distribution of the full dataset was displayed graphically using a histogram and quantile-quantile (Q-Q) plot, shown in Figure 47, to identify the distribution of the dataset (Kranzler 2003). The histogram shows the dataset has a positively skewed distribution and the Q-Q plot shows a non-normal distribution.

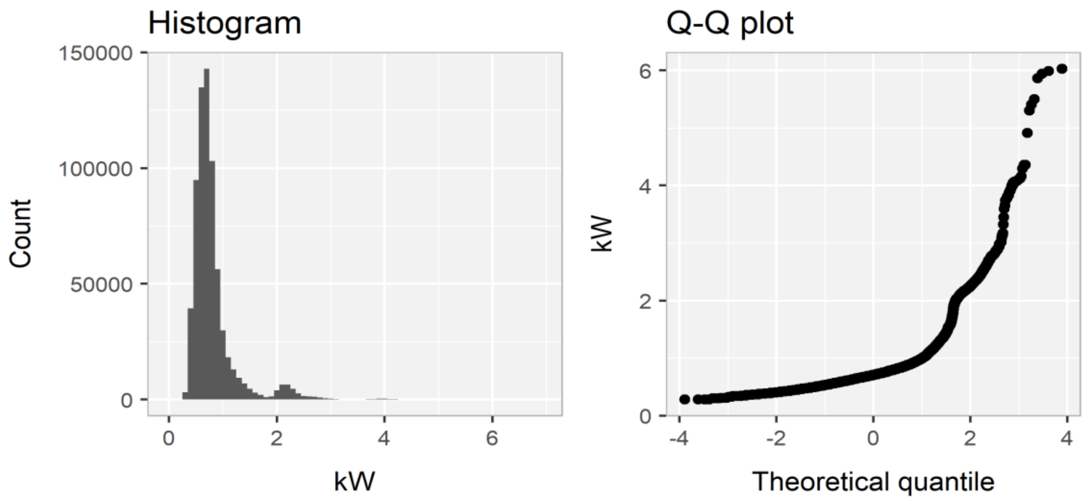

Figure 47. Histogram and Q-Q plot showing the total power demand values for small power for the combined control and intervention study groups for the study period of 1st September 2017 to 30th April 2018

Figure 48, confirms the two peaks in the distribution of the full data set was due to equipment use as it was present in both the day time (06:00:00 - 22:59:00) and night time (23:00:00 - 05:59:00) histograms. The variation between the larger peak reflects the higher power demand for small power in the day time compared to the night as expected due to the medical equipment, such as blood pressure machines etc. being used primarily during the day time. The smaller peak reflects equipment that requires a higher power demand than the medical equipment but is still required at night albeit in a smaller volume; a possibility being the pcs at the nursing station.

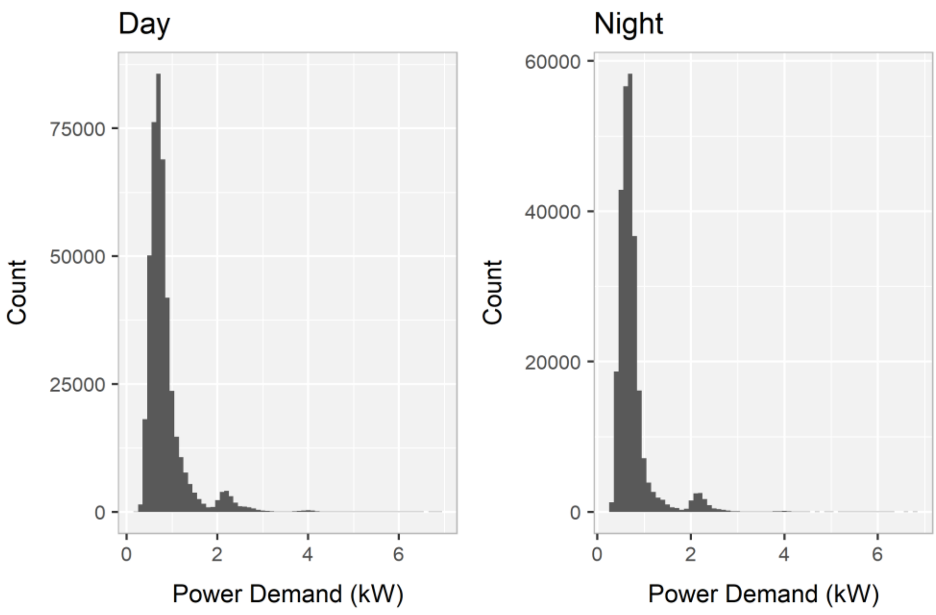

Figure 48. Histograms showing the day and night time power demand values for small power for the combined control and intervention study groups for the study period of 1st September 2017 to 30th April 2018

The data was then organised into the main categories of interest for analysis, namely by the study periods of before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention and by study group, namely the control and intervention groups.

The measures of central tendency and variability were then calculated for these categories. As we would expect to see a difference in power demand between the day and night time, the summary data for the day time (06:00:00 - 22:59:00) values is presented in Table 13 and the night time (23:00:00 - 05:59:00) values is presented in Table 14.

Table 13. Summary of power demand values for small power during the daytime (06:00:00 - 22:59:00), comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (kW)	q25 (kW)	Mean (kW)	Median (kW)	q75 (kW)	Maximum (kW)	Standard deviation
Before	Control	54899	0.42	0.77	1.00	0.87	1.01	6.92	0.43
Before	Intervention	54897	0.38	0.73	1.10	0.92	1.17	5.12	0.52
During	Control	82853	0.20	0.68	0.90	0.77	0.88	6.83	0.42
During	Intervention	82855	0.26	0.51	0.70	0.59	0.70	4.72	0.48
After	Control	80095	0.40	0.68	0.80	0.77	0.87	6.69	0.33
After	Intervention	80096	0.25	0.50	0.70	0.58	0.71	4.70	0.49

During the day time, the power demand values for small power in the control group ranged between 0.2 kW and 6.92 kW compared to 0.25 kW and 5.12 kW in the intervention group, showing there was a smaller range of power demand for small power in the intervention group than in the control group during the day time.

As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003), which showed that during the day time, the intervention group had similar albeit slightly higher median power demand (kW) when compared to the control group before the intervention with only a 0.05 kW difference. During the intervention, the intervention group had a 0.18 kW lower median power demand when compared to the control group and after the intervention, this difference further increased to 0.19 kW lower.

Table 14. Summary of power demand values for small power during the night time (23:00:00 - 05:59:00), comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (kW)	q25 (kW)	Mean (kW)	Median (kW)	q75 (kW)	Maximum (kW)	Standard deviation
Before	Control	32940	0.43	0.65	0.80	0.74	0.85	5.88	0.32
Before	Intervention	32940	0.42	0.61	0.80	0.70	0.87	4.45	0.44
During	Control	49680	0.45	0.67	0.80	0.74	0.84	6.82	0.41
During	Intervention	49680	0.26	0.47	0.70	0.54	0.63	4.65	0.43
After	Control	48059	0.42	0.65	0.80	0.73	0.82	6.08	0.32
After	Intervention	48059	0.28	0.46	0.60	0.52	0.61	4.15	0.44

During the night time, the power demand values for small power in the control group ranged between 0.42 kW and 6.82 kW compared to 0.26 kW and 4.65 kW in the intervention group, showing there was a smaller range of power demand for small power in the intervention group than in the control group during the night time.

During the night time, the intervention group had similar albeit slightly lower median power demand (kW) when compared to the control group before the intervention; with only a 0.04 kW difference. During the intervention, the intervention group had a lower median power demand of 0.2 kW when compared to the control group and after this difference further increased to 0.21 kW lower.

As the number of small power equipment was identical across the study wards, possible reasons for the difference in power demand may be due to (1) variation in patient health conditions effecting the utilisation of the medical equipment (2) small power equipment being switched on or off in non-patient areas of the study wards, such as offices and staff mess rooms etc. that are on the same small power distribution board and (3) different behavioural activities by ward occupants in patient areas in relation to turning equipment off/on.

A visual representation of the power demand for small power by study group and study period comparing day and night values is presented in Figure 49, which shows the control group had a greater number of outliers in the upper quartile than the intervention group in both the day time and night time across the study periods suggesting the control group had more incidents of high power demand than the intervention group across study periods due to staff in the control group turning on more equipment.

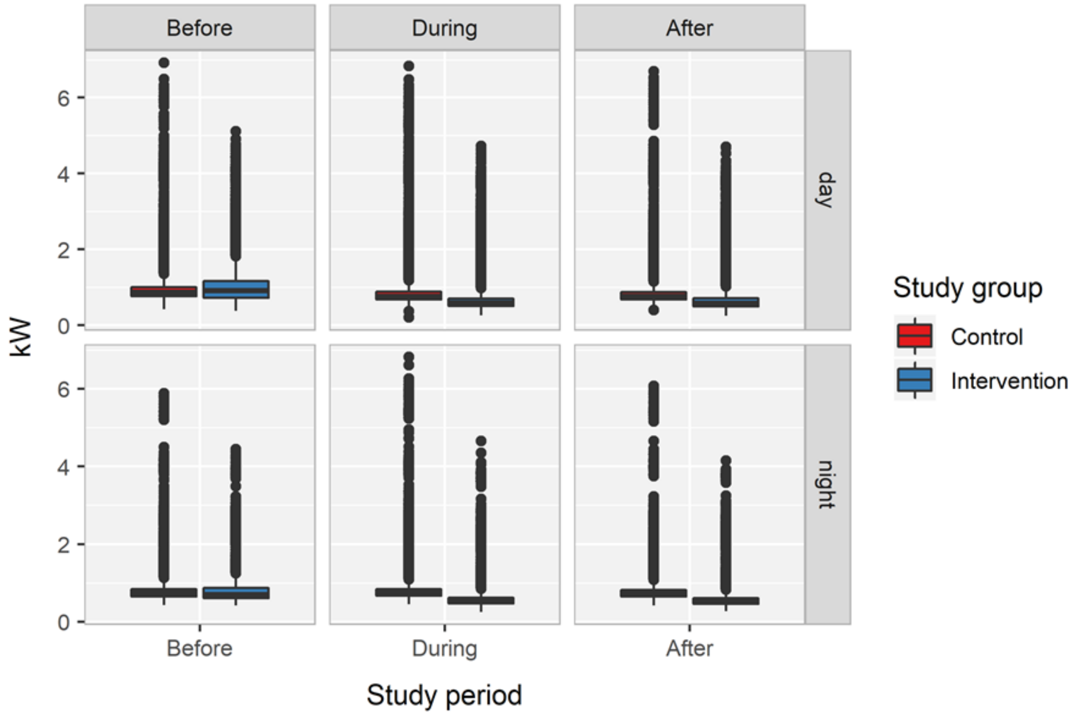

Figure 49. Boxplot of day and night time minutely power demand values (kW) for small power, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

To further examine the energy data for small power, the minutely median data was organised into the average daily profiles for the study periods before, during and after the intervention for the study groups, shown in Figure 50. As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003).

This confirmed the intervention group had a greater power demand for small power than the control group before the intervention and lower power demand for small power than the control group during and after the intervention, suggesting the introduction of the behaviour change intervention had the desired effect of reducing power demand for small power.

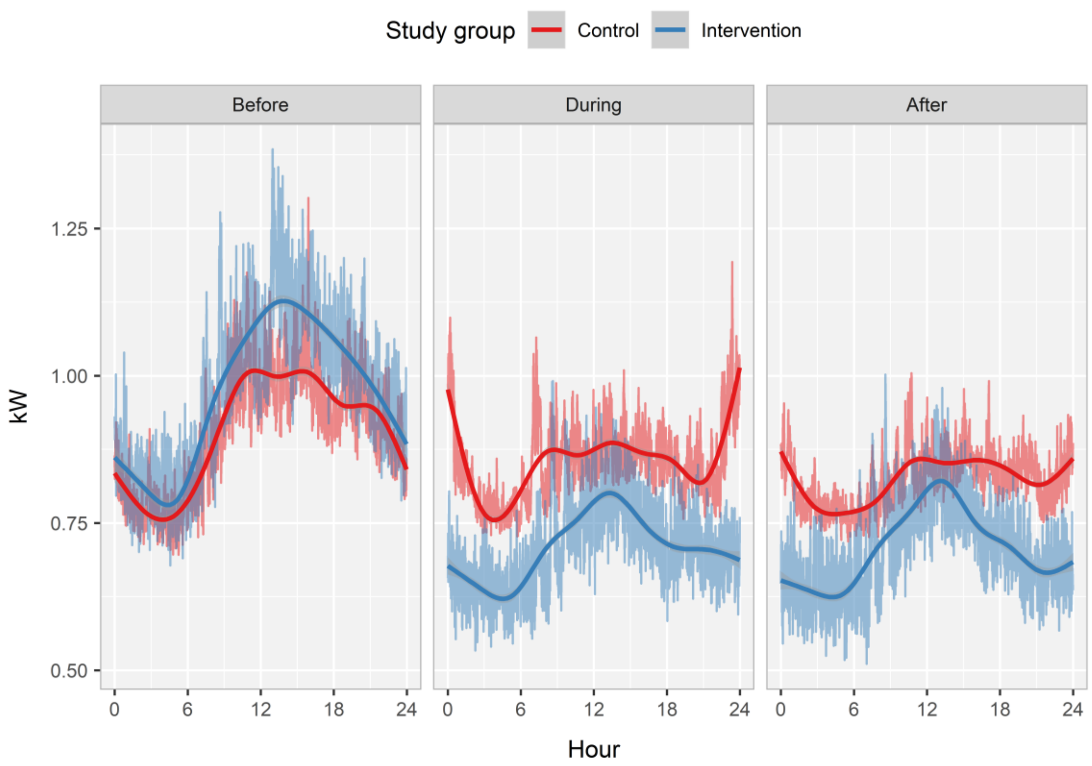

Figure 50. Average minutely median daily energy profile for small power, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

In both domestic and non-domestic settings energy behaviour change was found to diminish when feedback stopped (Dwyer et al. 1993, Darby et al. 2016), which is consistent with the findings for small power. Figure 50 also shows a distinct rise in power demand for small power during the intervention period in the control group for approximately 4 hours during the night time; starting around 22:00:00 and ending around 02:00:00. This appears to be due to the use of electrical equipment, such as space heaters in the control group that was not used in the intervention group. Use of space heaters is a common practice with nursing staff albeit prohibited in the Trust's Energy Policy due the risk of fire on the wards.

When the average daily power demand profiles for small power were organised into the individual months across the study, presented in Figure 51, it showed the effect of the behaviour change (reduction in energy for small power) took effect immediately and was sustained for four months (November 2017 - February 2018); peaking in the month after the feedback stopped (February 2018). The effect of the behaviour change intervention then diminished over the following month (March 2018) and appeared to stop by the sixth month (April 2018).

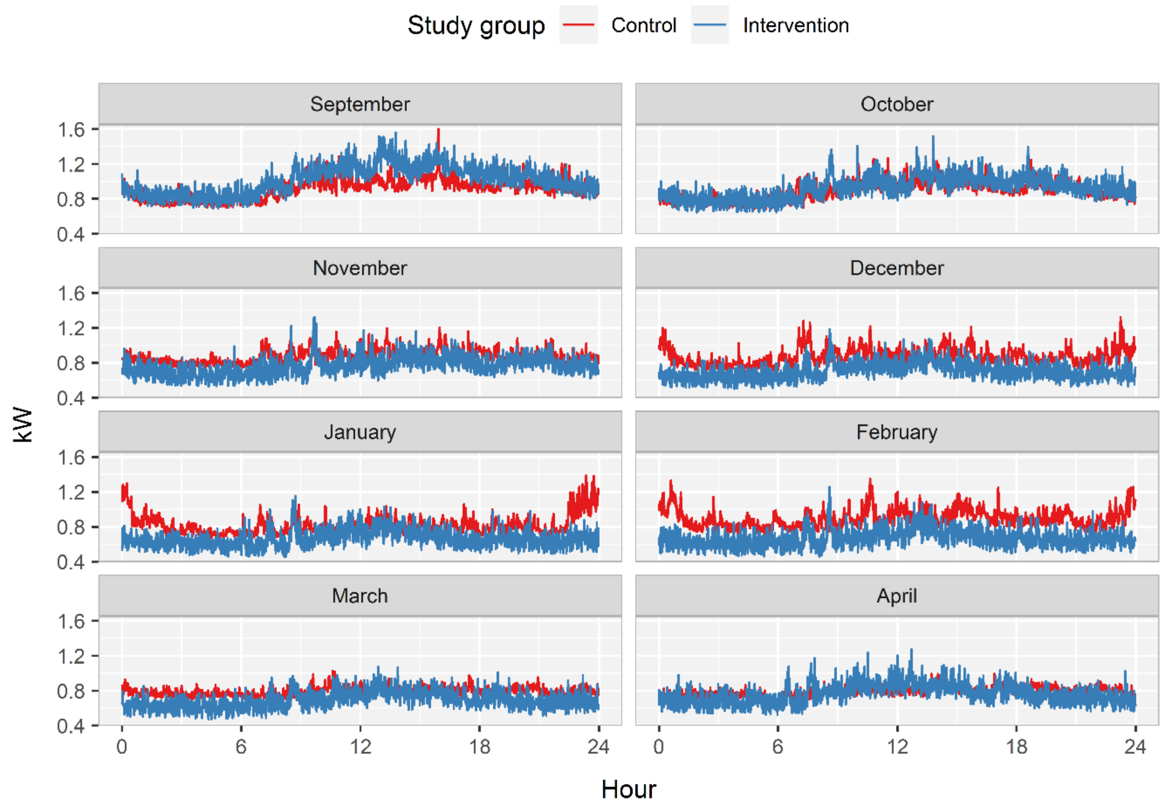

Figure 51. Average minutely median daily power demand profile for small power, comparing the control and intervention study groups for the individual months from September 2017 to April 2018

To further familiarize with the energy data for small power, the power demand data was multiplied by time to produce energy consumption (kWh) for the control and intervention study groups for the study periods before, during and after the behaviour change intervention. As the study period before was a shorter period (2 months) than the during and after study periods (3 months) the energy consumption values were normalized to show energy use for small power per day (kWh/day).

A summary table of energy consumption (kWh) for small power in the control and intervention study groups for the study periods before, during and after the behaviour change intervention is presented in Table 15.

Table 15. Summary of the difference in energy consumption (kWh) for small power, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Period	Study group	Energy consumption (kWh)	Study days (n)	Energy consumption per day (kWh/day)
Before	Control	1317.585	61	21.6
Before	Intervention	1463.95	61	23.999
During	Control	1987.995	92	21.609
During	Intervention	1546.242	92	16.807
After	Control	1708.72	89	19.199
After	Intervention	1495.142	89	16.799

Before the intervention, the control group used 21.6 kWh of energy for small power per day and the intervention group used 23.999 kWh per day, a difference of 2.4 kWh per day. During the intervention, the control group used 21.609 kWh of energy for small power per day and the intervention group used 16.807 kWh per day, a difference of 4.8 kWh per day. After the intervention, the control group used 19.199 kWh of energy for small power per day and the intervention group used 16.799 kWh per day, a difference of 2.4 kWh per day. A visual representation is presented in Figure 52.

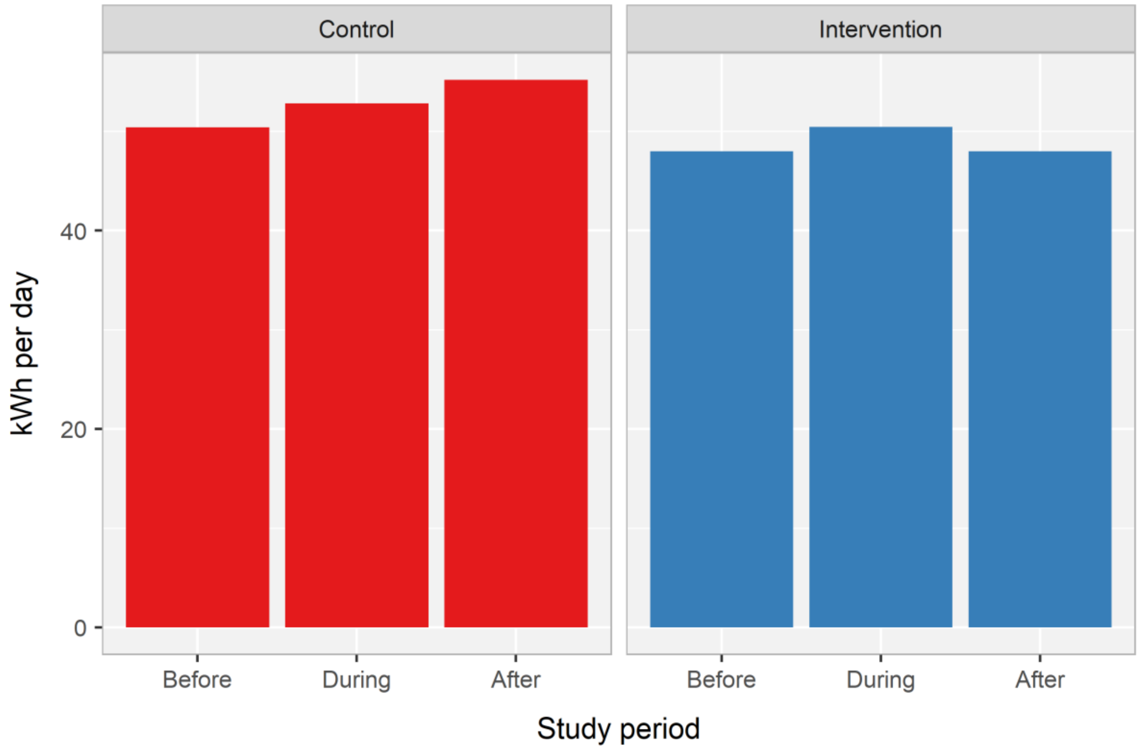

Figure 52. Energy consumption per day (kWh/day) for small power, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

The intervention group used 11% more energy for small power per day than the control group before the intervention, 22% less during the intervention and 13% less after the intervention. Consequently, the intervention produced a 33% saving in energy use for small power during the intervention and a 24% saving in energy use for small power after the intervention.

To complete the exploration of the energy data for small power a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the minutely data (electricity kWh) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Table 16.

Table 16. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the energy for small power data (kWh) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the energy for small power data (kWh) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	175676	3877800000	0.06	0.06
I_2	265068	1.404e+10	< 2.2e-16	<2e-16
I_3	256309	1.3008e+10	< 2.2e-16	<2e-16
I_4	440751	9260300000	< 2.2e-16	<2e-16
I_5	521387	8941689602	< 2.2e-16	<2e-16

The results showed that before the intervention there is a not a statistically significant difference between the medians of the minutely energy consumption data (kWh) for small power in the control and intervention groups before (I_1) the intervention. However, there is a statistically significant difference between the medians of the minutely energy consumption data (kWh) for small power in the control and intervention groups during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error and may have occurred as a result of the behaviour change intervention.

The results also showed there is a statistically significant difference between the medians of the minutely energy consumption data for small power in the intervention group across the different study periods before and during (I_4) the intervention and during and after (I_5) the intervention, which confirms the findings did not occur due to random error and may have occurred as a result of the behaviour change intervention.

4.2 Environmental data

4.2.1 Light

In order to establish the criteria to assess whether the lights in the study wards were switched on, off or dimmed, a normalised lighting value was calculated for each light sensor using a ‘lights on’ event value determined from the mean value of the sensor between the hours of 19:00:00 and 20:00:00 during the winter (representing a period of no natural light but all artificial lights will be on). Please see Appendix I for full details of the pre-processing undertaken for the light sensors.

As the light sensors do not distinguish between natural and artificial light, this approach is only valid for winter months and will over-predict the 'lights on' values during the summer months. Consequently, the data for the period before the intervention was disregarded from the study. However, as the intervention was run during the winter months this approach was suitable for analysing the light data in the periods during and after the intervention.

The lights on values were then organised into the main categories of interest for analysis, namely by the study periods of before, during and after the intervention and by study group, namely control and intervention groups, presented in Figure 53, which shows the intervention group had 11% less hours of 'lights on' values during the intervention and 8% less after the intervention, when compared to the control group.

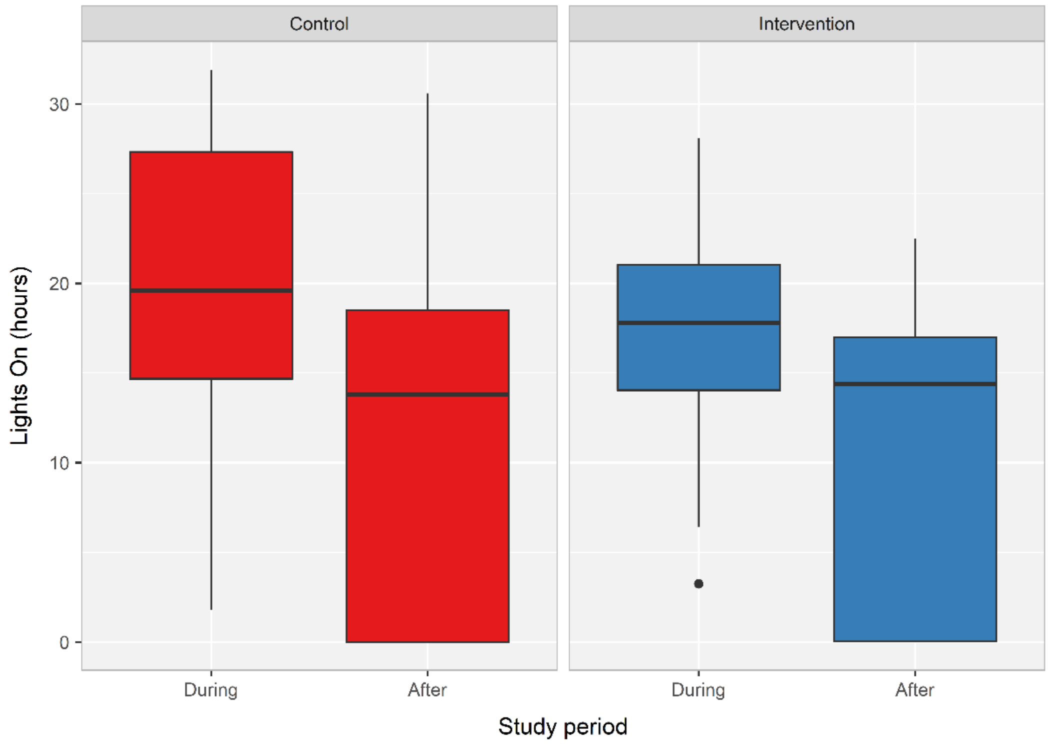

Figure 53. Count of 'lights on' hours, comparing the control and intervention study groups for the study periods during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

As previously discussed, the number of light fittings and luminaires were identical across the study wards, therefore, possible reasons for the difference in the range of power demand values may be due to (1) light tube failures in the patient rooms participating in the study (2) lighting may have been switched on or off in non-patient areas of the study wards, such as offices and staff mess rooms etc. that are on the same lighting distribution board and (3) different behavioural activities by ward occupants inpatient areas in relation to turning lights off/on.

The 'lights on' values were then organised into (1) total hours of 'lights on' values and (2) total hours of 'lights on' values per sensor per day for the main categories of interest for analysis, namely by the study periods of before, during and after the intervention and by study group, namely control and intervention groups. The summary data is presented in Table 17.

Table 17. Summary table showing the count of 'lights on' hours, comparing the control and intervention study groups for the study periods during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Total hours of lights on values	Number of days	Hours of lights on per sensor per day
During	Control	1853	92	10
During	Intervention	1644	92	9
After	Control	1083	89	6
After	Intervention	998	89	5

This shows the intervention group reduced lights on values by one hour of artificial lighting per ward per day in the intervention group when compared to the control group, in the study periods during and after the intervention, which is consistent with the anticipated results of the Operation TLC secondary action of 'introduce a quiet time for an hour after lunch' during which lights are switched off or dimmed to facilitate patient rest and recovery.

Whilst the finding for the light data showed an 11% saving during the intervention the energy data for lighting did not show any savings during this period. A possible explanation for this is that whilst the light data is explicit to the patient rooms on the ward participating in the study, the electricity for lighting (kWh) also includes lighting in the other areas of the study wards, including corridors, offices and staff rooms, which may have been left on by staff in the other ward areas as a result of the lower average hours (194.5) of sunshine during this period (The Met Office 2018a).

After the intervention the results from the light data and electricity for lighting (kWh) continue to show a positive reduction, and the amount for the light data (8% saving) is consistent when compared to the energy for lighting data (8% saving). Again, this may reflect the increase in the average hours of sunshine (330.6 hours) for this study period, which may have resulted in staff turning lights off in other non-patient areas of the study wards.

To complete the exploration of the 'lights on' hours (count) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the 'lights on' hours (count) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012).

As the data for the period before the intervention was disregarded from the study inferential tests I_1 and 1_4 were not completed for the light variable. A summary of the results from the inferential tests are shown in Table 18.

Table 18. Summary of the results of the inferential tests (I_2, I_3) completed on the 'lights on' hours (count) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_5) completed on the 'lights on' hours (count) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_2	796549	51762	< 2.2e-16	<2e-16
I_3	761420	42905	1.375e-11	1.4e-11
I_5	1038580	89432	< 2.2e-16	<2e-16

The results show there is a statistically significant difference between control and the intervention groups during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error and may have occurred as a result of the behaviour change intervention.

The results also show there is a statistically significant difference in the intervention group across the study periods during and after (I_5) the intervention period, which confirms the findings did not occur due to random error and are likely to have occurred due to seasonality.

4.2.2 Sound

Noise levels above 85 decibels (dB) are considered to be harmful to health (Schneider 2005), noise levels exceeding 60dB negatively affect sleep in hospitals (Hilton 1985) and noise rate of 30dB are the target for general wards and single occupancy wards (Chartered Institute of Building Services Engineers 2015, Department of Health 2015). The literature review also identified that background noise levels in hospitals typically measured 45-68dB and peak noise in hospitals typically measured above 85dB (Ulrich et al. 2004).

To facilitate the processing and analysis of the sound data, the raw data was aggregated to minutely mean and maximum values during the pre-processing activity. This reduced the number of observations from 200 million to 1,832,795. Whilst caution needs to be applied in such approaches as it may lead to smoothing of the datasets and reduces the influence of high values in the dataset (Fisher 1925), this was a necessary stage in order to reduce the number of observations into a processible dataset.

As this study aims to create a healthy environment in the study wards, the minutely maximum values were used for the analysis of the sound data as these values had the greatest impact on staff satisfaction and patient wellbeing. Consequently, the term sound data refers to the minutely processed maximum sound data.

In order to familiarise with the sound data, first the frequency distribution of the sound data was displayed graphically using a histogram and quantile-quantile (Q-Q) plot, shown in Figure 54, in order to identify the distribution of the dataset (Kranzler 2003). The histogram shows the dataset has a bi-modal distribution and the Q-Q plot shows a non-normal distribution.

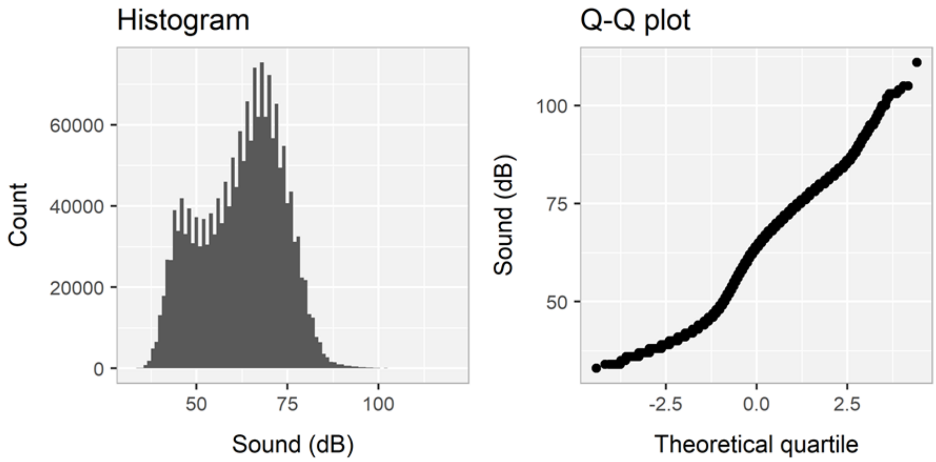

Figure 54. Histogram and Q-Q plot for sound values for the combined control and intervention study groups during the study (1st August 2017 - 30th April 2018)

Figure 55, confirms the bi-modal distribution of the full data set represents noisier day and quieter night time values. When separated, the day time (06:00:00 - 22:59:00) values appear to have a normal distribution as expected as it follows the cycle of daily ward activity in terms of staff number and activities, in that the main activities occur during the core of the day when all the ward medical rounds and visiting hours occur with quieter periods in the mornings and evenings before and after this core activity.

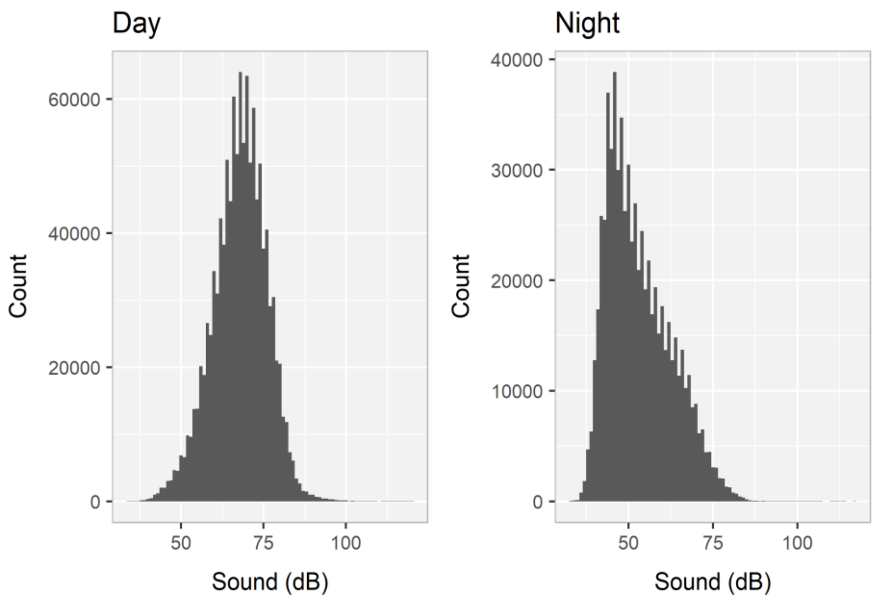

Figure 55. Histograms showing the day and night time sound values for the combined control and intervention study groups during the study (1st August 2017 - 30th April 2018)

The night time (23:00:00 - 05:59:00) values show a positively skewed distribution, due to (1) background noise from nursing staff, medical equipment and patients accounting for the majority of the values lying to the left of the mean and (2) alarms and dementia patients calling out in the night time accounting for smaller volume of higher values to the right of the mean, as identified during the 24-hour pilot study.

The data was then organised into the main categories of interest for analysis, namely by the study periods of before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention and by study group, namely the control and intervention groups.

The measures of central tendency and variability were then calculated for these categories. As we would expect to see a difference in noise levels between the day and night time, the summary data for the day time (06:00:00 - 22:59:00) values is presented in Table 19 and the night time (23:00:00 - 05:59:00) values is presented in Table 20.

Table 19. Summary of sound values during the day time (06:00:00 - 22:59:00), comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (dB)	q25 (dB)	Mean (dB)	Median (dB)	q75 (dB)	Maximum (dB)	Standard deviation
Before	Control	134173	40	63	68	68	74	116	7.871
Before	Intervention	259802	37	63	68	68	74	115	7.891
During	Control	143497	40	64	68	69	74	119	7.851
During	Intervention	255247	36	62	67	68	73	118	8.257
After	Control	107818	41	62	68	68	74	120	8.535
After	Intervention	243258	34	62	67	68	73	116	8.479

During the day time, the sound values in the control group ranged between 40dB and 120dB compared to 34dB and 118dB in the intervention group, showing there was a smaller range of noise levels in the control group than in the intervention group during the day time. As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003), which showed that during the day time, the median noise levels in the intervention group were the same as the control group before and after the behaviour change intervention, and 1 decibels (dB) less than the control group during the intervention.

Table 20. Summary of sound values during the night time (23:00:00 - 05:59:00), comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (dB)	q25 (dB)	Mean (dB)	Median (dB)	q75 (dB)	Maximum (dB)	Standard deviation
Before	Control	80203	39	46	54	51	59	105	9.008
Before	Intervention	155196	34	46	54	52	60	113	9.310
During	Control	87274	39	46	54	51	59	102	9.099
During	Intervention	155800	35	46	53	52	60	117	9.655
After	Control	64743	39	45	53	50	59	102	9.271
After	Intervention	145784	33	44	53	51	60	117	10.12

During the night time, the sound values in the control group ranged between 39dB and 105dB compared to 33dB and 117dB in the intervention group, showing there was a smaller range of noise levels in the control group than in the intervention group during the night time. During the night time, the median noise levels in the intervention group were 1 decibels (dB) less than the control group before, during and after the behaviour change intervention.

Possible reasons for the difference are (1) occupancy levels, particularly visitor occupancy as patient and nursing staff occupancy was identical across the study wards (2) differing health conditions of the patients, for example patients with dementia were observed frequently shouting and calling out during the study pilot (3) differing incidents of alarms, ward door bells and buzzers, and (4) differing behavioural activities by ward occupants in relation to switching equipment on/off, closing bins and cupboards quietly, which were the actions identified during the study pilot as creating peak noise.

A visual representation of the power demand for lighting by study group and study period comparing day and night values is presented in Figure 56. There were 40 incidents of noise levels exceeding 110dB, all of which occurred in the day time, although there were 33 incidents of noise levels exceeding 100dB during the night time, which would have been significantly impacting as back ground noise levels are lower at night (median 51dB) than the day time (median 68dB). Figure 56 shows a similar pattern of outliers in the upper quartile occurred across all the study periods with the majority occurred in the intervention group.

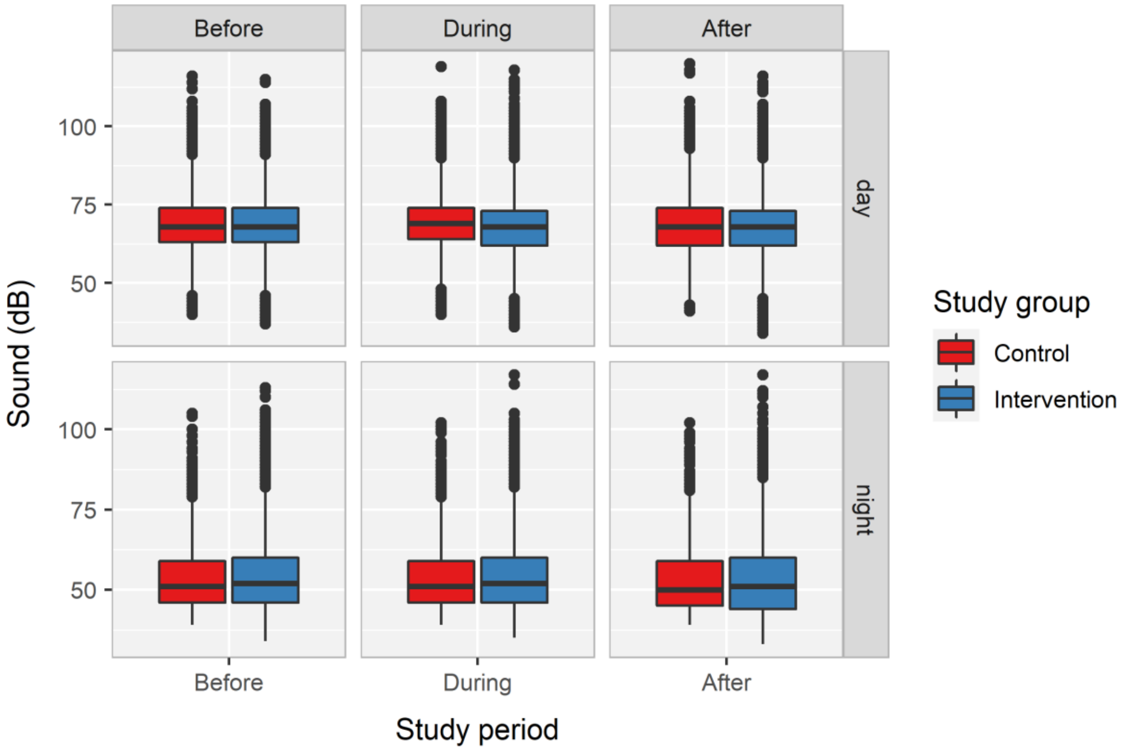

Figure 56. Boxplot of day and night time minutely sound values (dB), comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

From the 24-hour pilot study peak noise events occurred as a result of alarms, metal bins, noise from nurses' station at handover times and patients, usually those with dementia, shouting and calling out. It is likely a combination of these peak noise events occurring collectively would be required to reach the high noise levels shown by the outliers in the upper quartile.

To further examine the sound data, the minutely median data was organised into the average daily profiles for the study groups for the study periods before, during and after the intervention, shown in Figure 57. This confirmed the intervention group had implemented the Operation TLC secondary actions 'introduce a quiet time for an hour after lunch' between 13:30:00-14:30:00 and 'night time switch off' at 23:00:00.

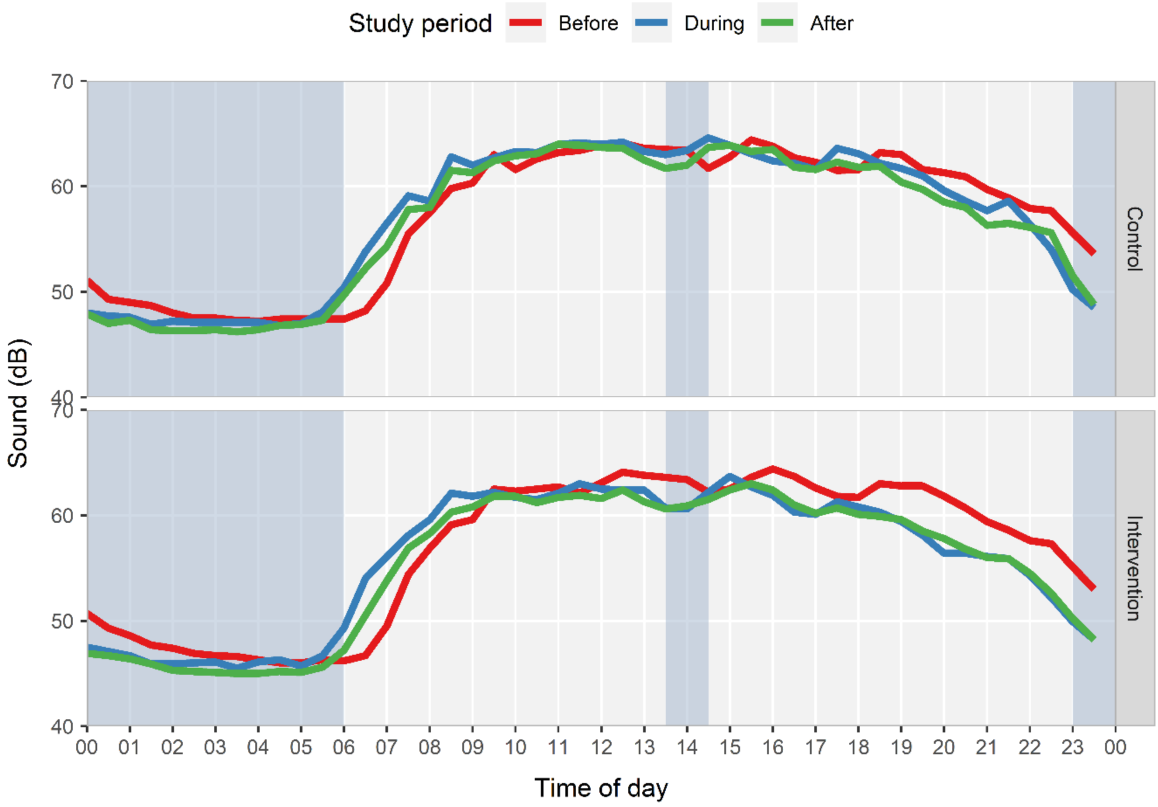

Figure 57. Average minutely median daily sound (dB) levels showing 'quiet time' period (13:30:00-14:30:00) and 'night time switch off' (23:00:00), comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

To complete the exploration of the minutely sound data (dB) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the minutely sound data (dB) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Table 21.

Table 21. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the sound data (dB) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the sound data (dB) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	796650	4.6252e+10	< 2.2e-16	<2e-16
I_2	796549	5.4408e+10	< 2.2e-16	<2e-16
I_3	761420	3.8367e+10	< 2.2e-16	<2e-16
I_4	1062208	9.5691e+10	< 2.2e-16	<2e-16
I_5	1038580	7.4705e+10	< 2.2e-16	<2e-16

The results showed there is a statistically significant difference between the medians of the minutely sound data (dB) in the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error. However, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

The results also showed there is a statistically significant difference between the medians of the minutely sound data (dB) in the intervention group across the different study periods before and during (I_4) the intervention and during and after (I_5) the intervention, which confirms the findings did not occur due to random error and may have occurred as a result of the behaviour change intervention.

4.2.3 Temperature and thermal comfort

4.2.3.1 Air temperature

To familiarise with the air temperature data, first the frequency distribution of the air temperature data was displayed graphically using a histogram and quantile-quantile (Q-Q) plot, shown in Figure 58, in order to identify the distribution of the dataset (Kranzler 2003). Although the histogram appears to show a normal distribution, the Q-Q plot shows the dataset has a non-normal distribution.

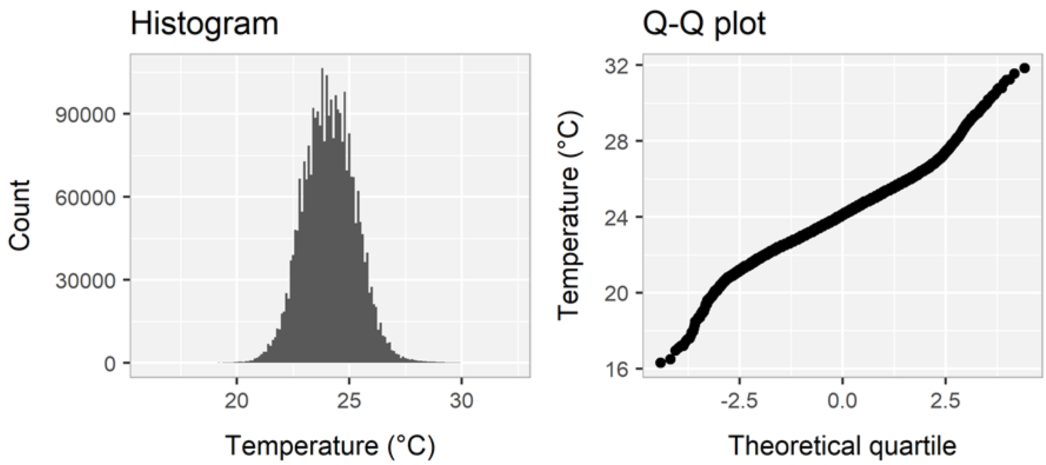

Figure 58. Histogram and Q-Q plot for air temperature values for the combined control and intervention study groups for the study (1st August 2017 - 30th April 2018)

The data was then organised into the main categories of interest for analysis, namely by the study periods of before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention and by study group, namely the control and intervention groups.

The measures of central tendency and variability were then calculated for these categories and is presented in Table 22. As the study pilot and subsequent analysis showed fairly uniformed air temperature values across a 24-hour period due high thermal mass of the hospital building alongside high ventilation rate, the summary table shows the values across the 24-hour period.

Table 22. Summary of air temperature values, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (°C)	q25 (°C)	Mean (°C)	Median (°C)	q75 (°C)	Maximum (°C)	Standard deviation
Before	Control	344100	19.2	24.3	24.9	24.9	25.5	31.1	0.856
Before	Intervention	704058	16.5	23.9	24.7	24.6	25.4	32.0	1.205
During	Control	308935	17.9	23.5	24.2	24.2	24.9	28.3	1.004
During	Intervention	669153	16.1	22.8	23.6	23.6	24.4	29.5	1.063
After	Control	268799	18.4	23.3	24.0	24.0	24.7	32.2	1.051
After	Intervention	582113	16.2	22.9	23.6	23.6	24.3	31.6	0.979

The air temperature values in the control group ranged between 17.9°C and 32.2°C compared to 16.1°C and 32°C in the intervention group, showing there was a smaller range of noise levels in the control group than in the intervention group.

As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003), which showed the intervention group had similar but slightly lower median air temperatures (°C) to the control group before the intervention with only a 0.3°C difference. During the intervention, the intervention group had lower median air temperature of 0.6°C difference, which decreased to 0.4°C difference after the intervention when compared to the control group.

The pilot study established that the nursing staff in the study wards have very little control over their environment and as the heating and ventilation systems were identical across the study wards, possible reasons for the difference in the air temperature values may be due to (1) differing window activity and (2) use of standalone heating and cooling equipment, primarily fans although space heaters have been brought into the wards by nursing staff, which is prohibited as they may pose a fire risk.

A visual representation of the power demand for lighting by study group and study period is presented in Figure 59, which shows the intervention group had more outliers in the upper and lower quartile throughout the study. As expected most of the outliers (n=602) above 30°C occurred before the intervention in the day time; most of which occurred in the intervention group. However, there were also a number (n=19) of outliers above 30°C after the intervention during the day time, which were fairly evenly spread between the control and intervention group.

Griffiths (1990) reported having the 'right temperature' was found to be the most important consideration by people in a user satisfaction survey of UK buildings, so the extreme outliers have an important impact on thermal comfort of the building occupants and consequently, the experience of the staff and patients in the wards.

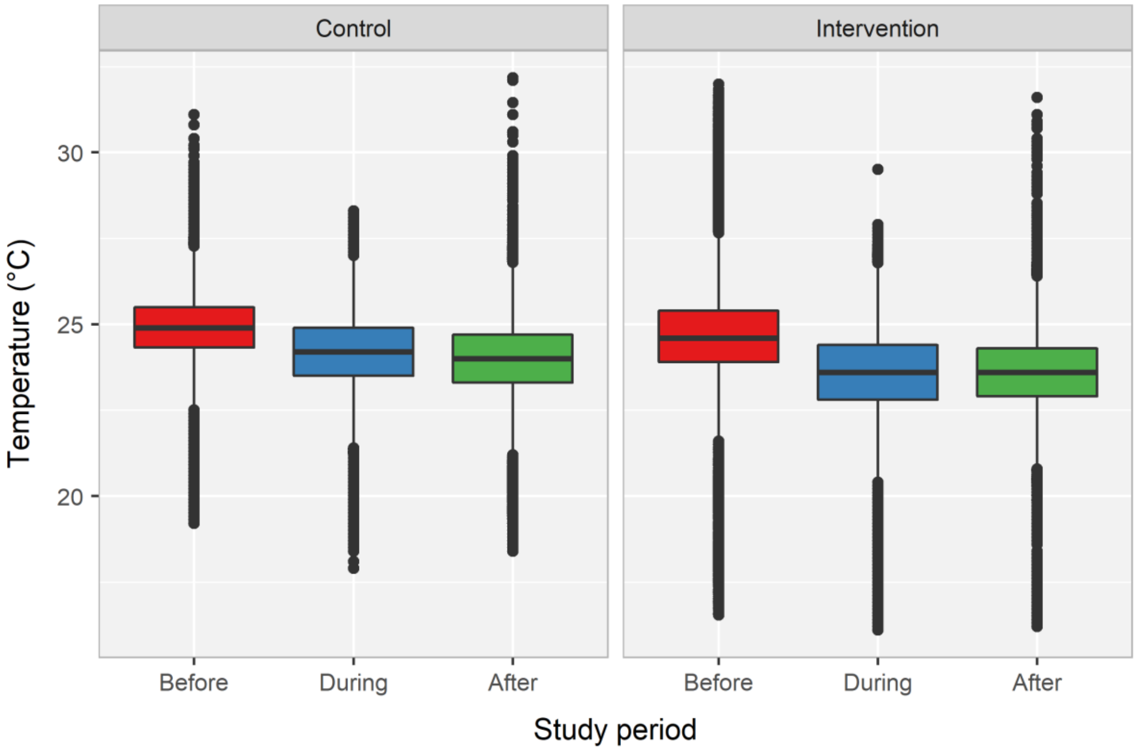

Figure 59. Boxplot of 5 minutely air temperature values (°C), comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

As the differences between the control and intervention groups were small, the median air temperature data was then organised into the individual study wards for the study periods before, during and after the behaviour change intervention and presented in Figure 60. This shows Intervention B ward had similar albeit slightly lower median air temperatures (°C) than the control ward with a 0.2°C difference in the before study period and 0.3°C difference in the study periods during and after the intervention.

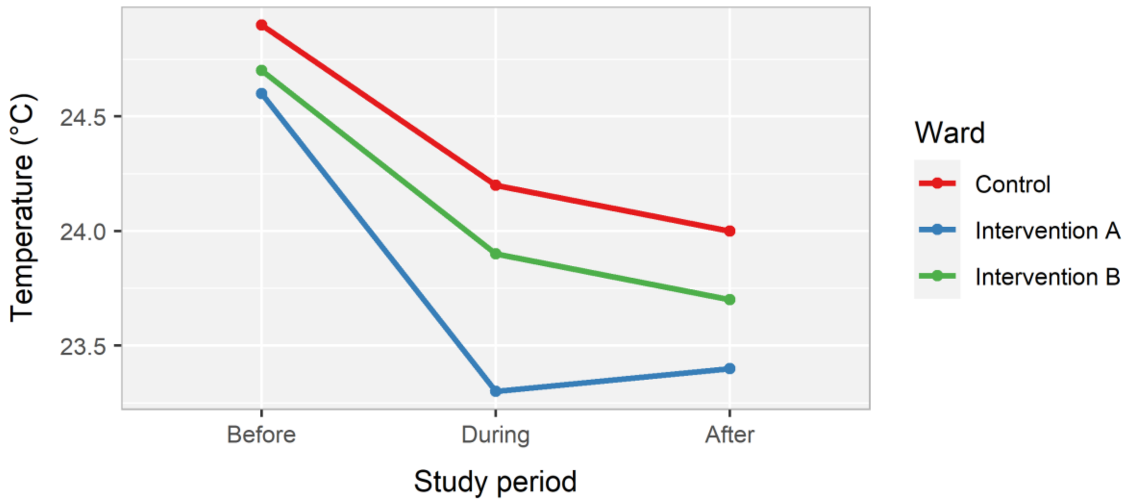

Figure 60. Summary of median air temperature (^{O}C), comparing the Control, Intervention A and Intervention B study wards for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Whilst Intervention A ward also had similar albeit slightly higher median air temperatures (^{O}C) to the control ward before the intervention with a 0.3^{O}C difference, during and after the Intervention it had noticeably lower median air temperatures (^{O}C) than the control ward, with a 0.9^{O}C difference during the intervention and a 0.6^{O}C difference after the intervention.

CIBSE recommend air temperatures for a general ward and a single ward of between 22^{O}C and 24^{O}C in the UK winter (heating) period and 23^{O}C and 25^{O}C in the UK summer (non-heating) period (Chartered Institute of Building Services Engineers 2015). Figure 61 shows the percentage of time that air temperature in the study groups spent above, within and below the CIBSE recommended air temperature targets during the study periods.

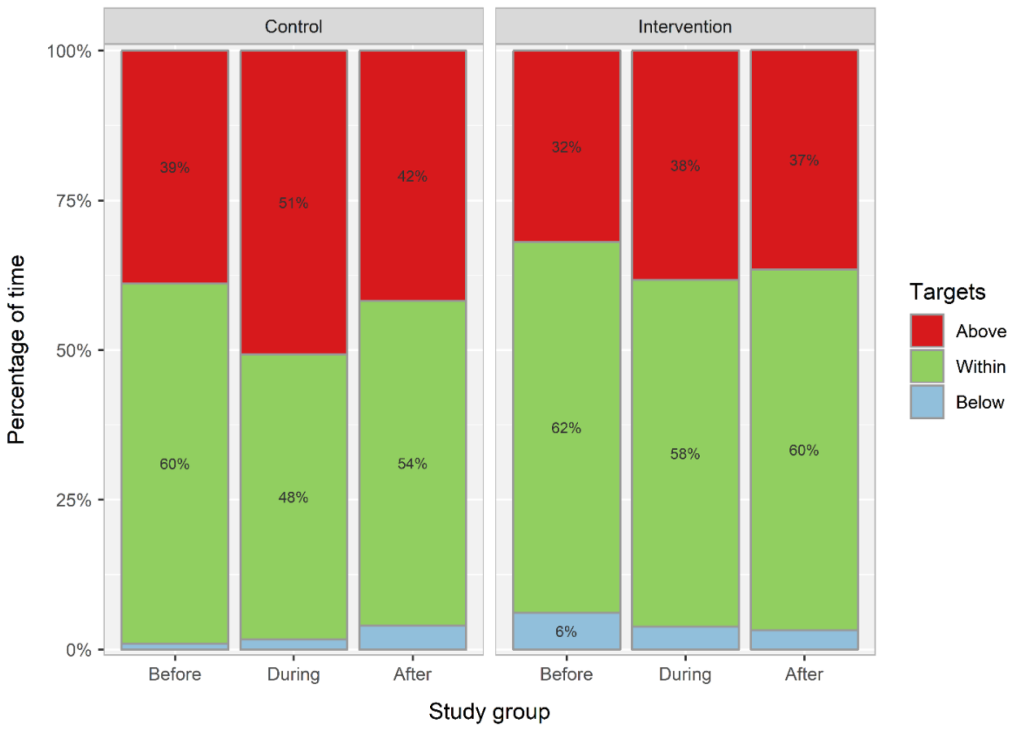

Figure 61. Percentage of time spent within CIBSE temperature targets, comparing the control and intervention groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Before the intervention, the control group and intervention group spent the highest percentage of time within the CIBSE target range for summer (60% and 62% respectively). The building has a high thermal mass alongside high ventilation rate with no air conditioning or other forms of mechanical cooling, which accounts for the air temperature values above the CIBSE (summer) target in the period before the intervention.

During the intervention, the control group spent the highest percentage of time (51%) above the CIBSE target range for winter and intervention group spent the highest percentage of time (58%) within the target. After the intervention the control and intervention groups spent the highest percentage of time within the CIBSE target range for winter (54% and 60% respectively). The study groups spent approximately 40% of the time above the recommended CIBSE targets for air temperature across the study. The building has a high thermal mass alongside high ventilation rate and mechanical heating that is difficult to control due to the lack of internal thermostats.

The British Standard (BS) EN 16798-1 sets a recommended temperature drift limit of ±3°C for mean indoor temperature to achieve a medium level of expected thermal comfort, ±2°C for a high level of expected thermal comfort and ±4°C for a moderate level of expected thermal comfort (British Standards Institute 2019). Temperature drift is defined as the variation in temperature over a set period of time, such as daily or weekly (Chartered Institute of Building Services Engineers 2015). Table 23 shows a summary of the mean daily temperature drift values for the study groups for the study periods.

Table 23. Summary of mean daily temperature drifts, comparing the control and intervention groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Mean daily temperature drift (°C)
Before	Control	±4.5
Before	Intervention	±7.7
During	Control	±4.7
During	Intervention	±5.0
After	Control	±5.2
After	Intervention	±5.7

Before, during and after the intervention, the intervention group had a higher mean daily temperature drift compared to the control group. Before the intervention, the intervention group had a significantly higher (±3.2°C difference) mean daily temperature drift compared to the control group. During the intervention, although the intervention group still had a higher mean temperature drift than the control group the difference between the two groups had lowered to ±0.3°C difference. After the intervention, the intervention group had a higher (±0.5°C difference) mean daily temperature drift compared to the control group.

A visual representation of the percentage of daily temperature drift values is presented in Figure 62, which shows that before the intervention, the intervention group had temperature drift values of ±5°C 100% of the time, which is classified as poor. Whereas, the control group spent 9% of the time in the medium range (±3°C), 35% in the moderate range (±4°C) and 56% of the time above the recommended ranges (±5°C and over). During and after the intervention both the control and intervention group spent the majority of time above the recommended temperature drift value range (±5°C and above), although the control group spent less time in the range above the recommended temperature than the intervention group.

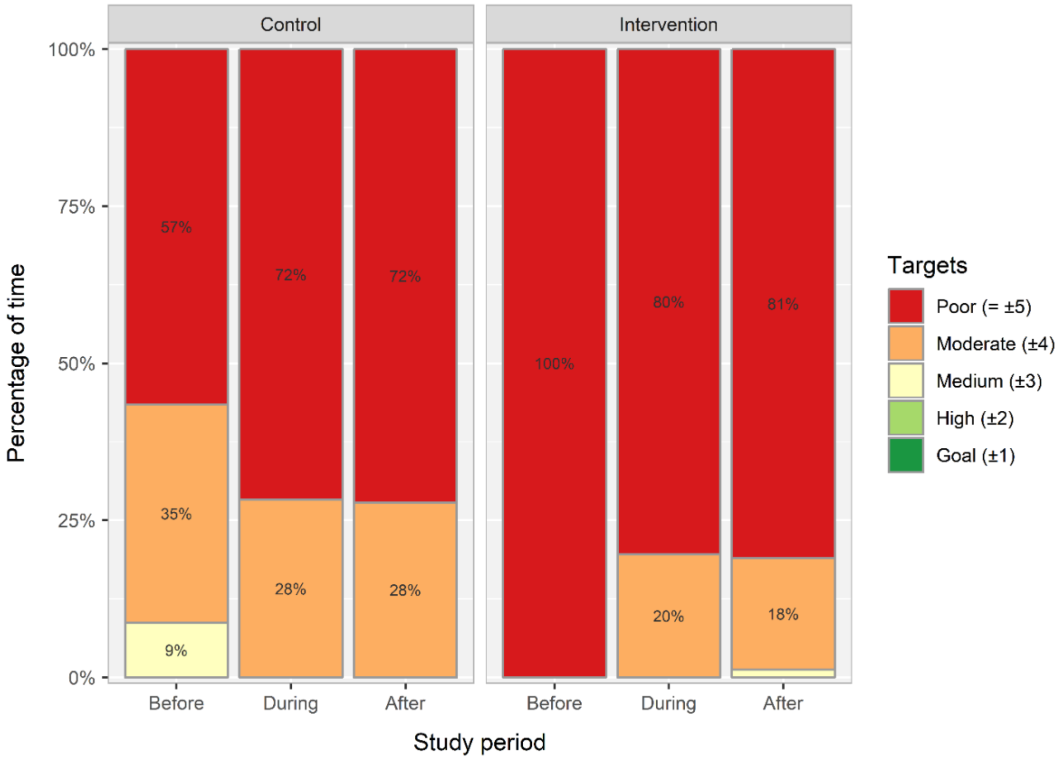

Figure 62. Percentage of time spent within the temperature drift limits, comparing the control and intervention groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

To complete the exploration of the minutely air temperature (ºC) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the minutely air temperature data (ºC) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Table 24.

Table 24. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the air temperature data (^oC) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the air temperature data (^oC) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	796650	8.1116e+10	< 2.2e-16	<2e-16
I_2	796549	8.7032e+10	< 2.2e-16	<2e-16
I_3	761420	6.8228e+10	< 2.2e-16	<2e-16
I_4	1062208	2.0759e+11	< 2.2e-16	<2e-16
I_5	1038580	1.274e+11	< 2.2e-16	<2e-16

The results showed there is a statistically significant difference between the medians of the minutely air temperature data (^oC) in the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error. However, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

The results also showed there is a statistically significant difference between the medians of the minutely air temperature data (^oC) in the intervention group across the different study periods before and during (I_5) the intervention and during and after (I_6) the intervention, which confirms the findings did not occur due to random error and are likely to have occurred due to seasonality.

4.2.3.2 Relative humidity

To familiarise with the relative humidity data, first the frequency distribution of the relative humidity data was displayed graphically using a histogram and quantile-quantile (Q-Q) plot, shown in Figure 63, in order to identify the distribution of the dataset (Kranzler 2003). The histogram shows the dataset has a bi-modal distribution and the Q-Q plot shows a non-normal distribution.

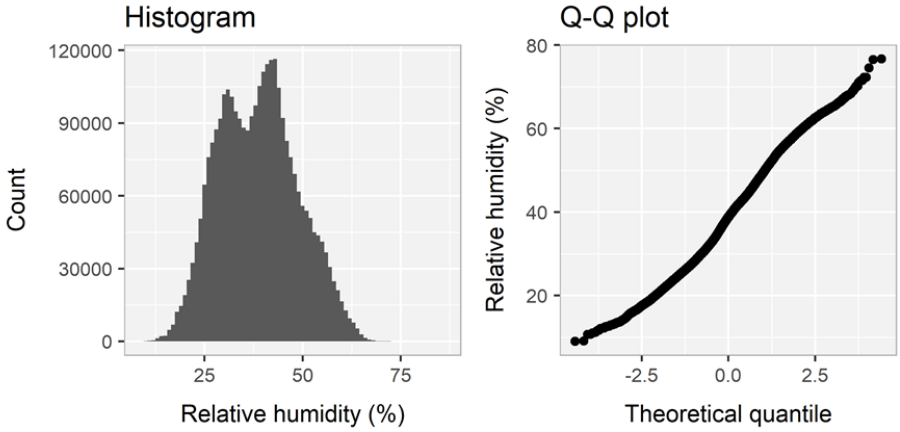

Figure 63. Histogram and Q-Q plot for relative humidity values for the combined control and intervention study groups during the study (1st August 2017 - 30th April 2018)

Figure 64, confirms the bi-modal distribution of the full data set was due to seasonality as the day time (06:00:00 - 22:59:00) and night time (23:00:00 - 05:59:00) histograms still show the same bi-modal distribution.

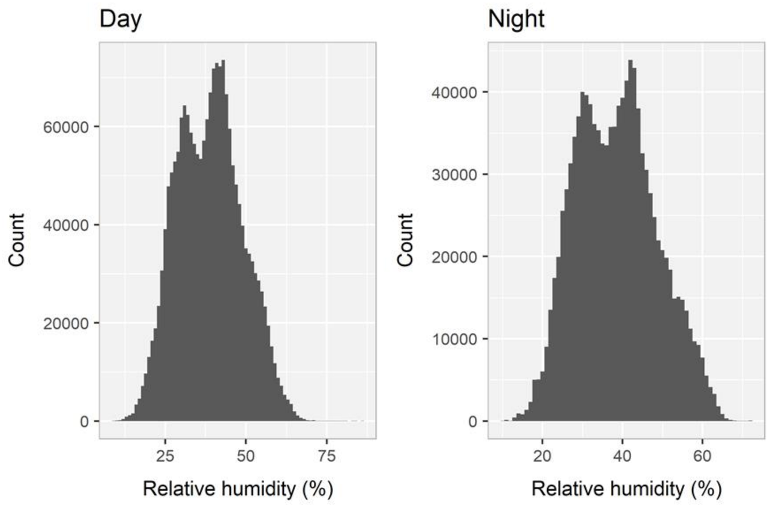

Figure 64. Histograms showing the day and night time relative humidity values for the combined control and intervention study groups during the study (1st August 2017 - 30th April 2018)

The data was then organised into the main categories of interest for analysis, namely by the study periods of before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention and by study group, namely the control and intervention groups.

The measures of central tendency and variability were then calculated for these categories and is presented in Table 25. As the day and night time histograms show no significant difference and the study pilot showed fairly uniformed relative humidity values across a 24-hour period due high thermal mass of the hospital building alongside high ventilation rate, the summary table shows the values across the 24-hour period.

Table 25. Summary of relative humidity values, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (%)	q25 (%)	Mean (%)	Median (%)	q75 (%)	Maximum (%)	Standard deviation
Before	Control	344100	24.8	41.7	47.3	47.4	52.8	72.0	7.374
Before	Intervention	704058	26.8	43.1	48.4	48.1	53.6	86.4	7.067
During	Control	308935	15.4	28.3	33.6	32.3	38.6	80.0	6.707
During	Intervention	669153	18.7	29.6	35.0	33.9	40.4	74.9	6.970
After	Control	302843	8.9	25.9	32.0	31.9	38.2	61.0	7.926
After	Intervention	654240	11.1	27.1	33.2	33.4	39.7	79.2	7.941

The relative humidity values in the control group ranged between 8.9% and 80% compared to 11.1% and 86.4% in the intervention group. The median relative humidity levels in the study groups were low in comparison to ambient humidity (The Met Office 2018b) across the study periods, as expected due to the high ventilation rates on the wards.

As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003), which showed that the intervention group had similar albeit slightly higher median relative humidity levels (%) compared to the control group before, during and after the intervention. Before the intervention, the difference was 0.7%, during the intervention the difference increased to 1.6% and after the intervention the difference decreased to 1.5%. As the heating and ventilation systems were identical across the study wards, a possible reason for the difference in the relative humidity values may be due to differing window activity, which was one of the few adaptive behaviours available to the staff in the study wards.

A visual representation is presented in Figure 65, which shows the control group had more values in the upper quartile, including 4 outliers greater than 75%, during the intervention than any other study period. The intervention group had significantly more outliers in the upper quartile than the control group, including (1) 33 outliers greater than 75% relative humidity before the intervention and (2) 3 outliers greater than 75% relative humidity after the intervention. People perceive that high humidity makes an environment feel hotter (Nicol and Humphreys 2004), so these high relative humidity values in the upper quartile are a good indicator of thermal comfort.

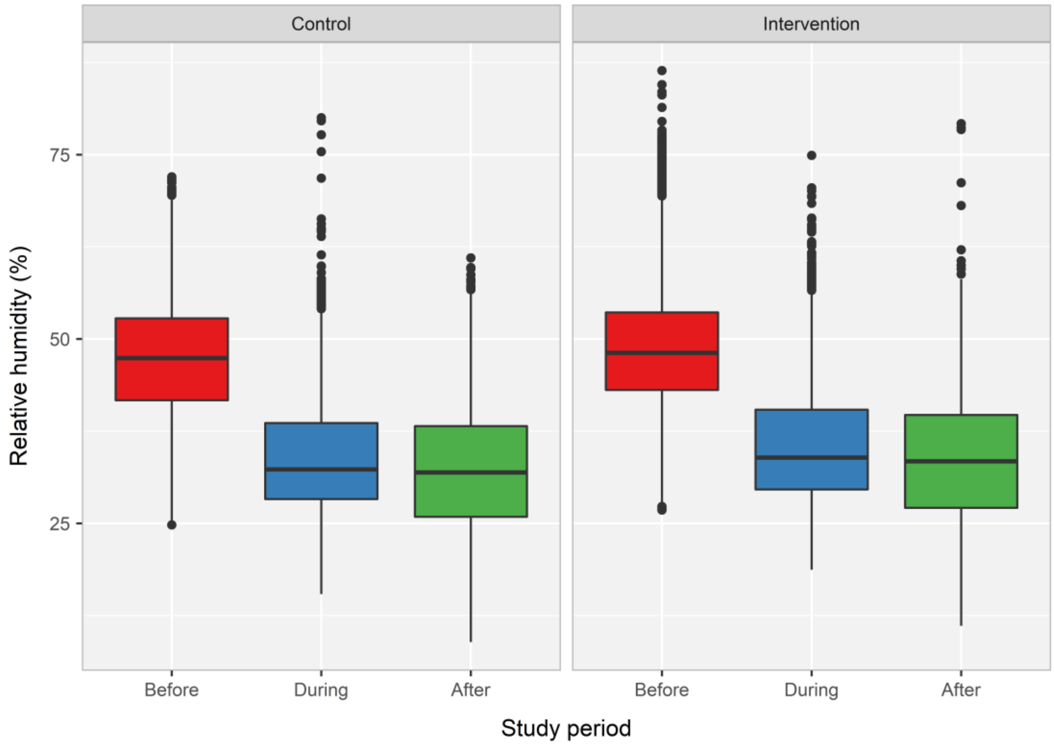

Figure 65. Boxplot of 5 minutely relative humidity values (%), comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

As the building has a high thermal mass and mechanical ventilation system with high air changes but does not have air conditioning, these outliers may have occurred due to (1) differing window activity before the intervention and (2) scheduled maintenance (including filter change) on the ventilation system that occurred at end of the year affecting the efficiency of equipment, particularly during the intervention.

As the differences between the control and intervention groups were small, the median relative humidity data was then organised into the individual study wards for the study periods before, during and after the behaviour change intervention and presented in Figure 66. This confirms that the findings show no real difference in terms of the change in relative humidity between the control and intervention groups over the study periods.

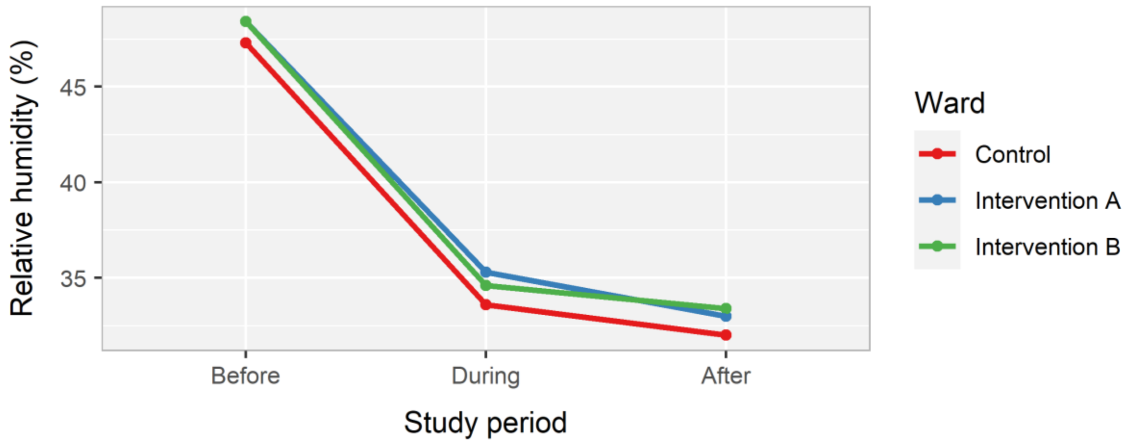

Figure 66. Summary of median relative humidity (%), comparing the Control, Intervention A and Intervention B study wards for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

CIBSE recommend relative humidity levels of between 40% to 70% humidity (Chartered Institute of Building Services Engineers 2015). Before the intervention, both the control and intervention groups remained within the recommended CIBSE relative humidity range for the greatest percentage of time (83% and 89% respectively), shown in Figure 67.

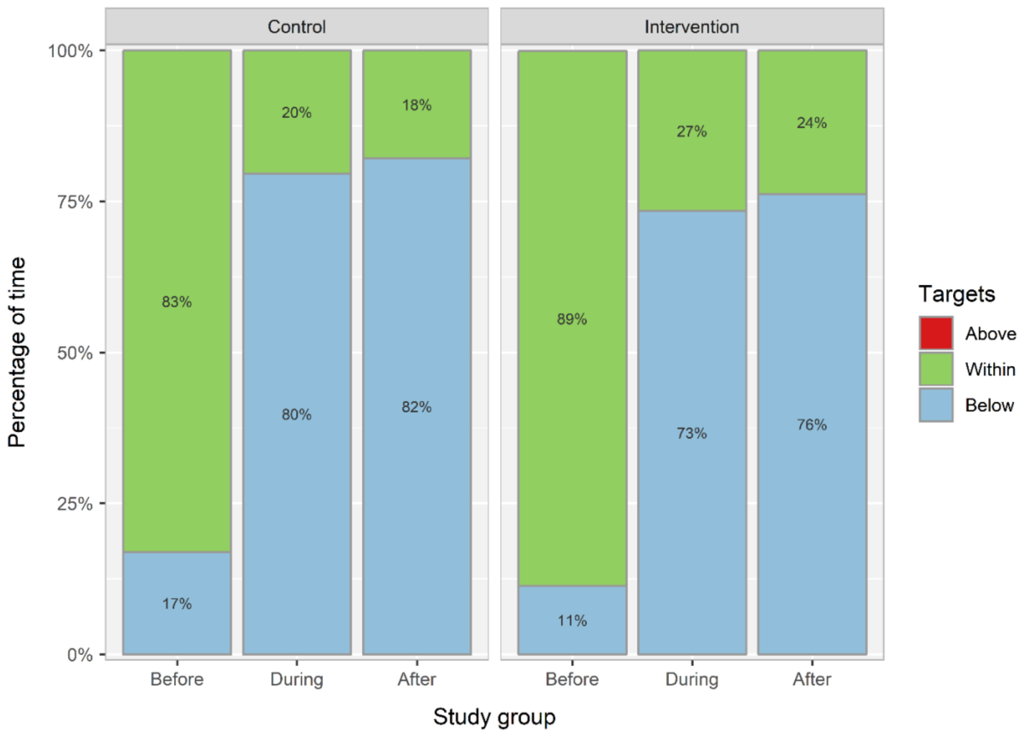

Figure 67. Percentage of time spent within CIBSE relative humidity targets, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

During and after the intervention the study groups spent the greatest percentage of time below the recommended CIBSE relative humidity range. Although the intervention group spent less time below the CIBSE target during and after (73% and 76% respectively) than the control group (80% and 82% respectively). As the heating and ventilation systems were identical across the study wards, a possible reason for the difference in the relative humidity values are likely due to seasonality.

To complete the exploration of the minutely relative humidity values (%) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the minutely relative humidity data (%) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Table 26.

Table 26. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the relative humidity data (%) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the relative humidity data (%) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	796650	6.7534e+10	< 2.2e-16	<2e-16
I_2	796549	6.799e+10	< 2.2e-16	<2e-16
I_3	761420	6.3178e+10	< 2.2e-16	<2e-16
I_4	1062208	2.5766e+11	< 2.2e-16	<2e-16
I_5	1038580	1.1994e+11	< 2.2e-16	<2e-16

The results showed there is a statistically significant difference between the medians of the minutely relative humidity data in the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error. However, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

The results also showed there is a statistically significant difference between the medians of the minutely relative humidity data in the intervention group across the different study periods before and during (I_5) and during and after (I_6) the intervention, which confirms the findings did not occur due to random error and are likely to have occurred due to seasonality.

4.2.3.3 Thermal comfort

Quantitative data was gathered from the wet bulb globe temperature sensor before and after the intervention to enable analysis of thermal comfort variables on the study wards for a summer (warm) day and a spring (cool) day. Table 27 shows a summary of the findings.

Table 27. Thermal comfort variables from the wet bulb globe tests, comparing the Control and Intervention B study wards during a pre-intervention (10:00:00 - 11:00:00 22nd August 2017) and post-intervention (13:30:00 - 14:30:00 2nd April 2018) period. Met = 1, Clo = 1.

Study period	Study ward	Relative humidity (%)	Air speed (m/s)	Wet bulb temperature (°C)	Globe thermometer temperature (°C)	Air temp (°C)	Radiant temp (°C)	Predicted mean vote	Percentage of people dissatisfied (%)
Before	Control	65	0.035	20.1	24.8	24.8	24.8	0.8	20
Before	Intervention B	66	0.008	20.1	24.5	24.7	24.4	0.8	19
After	Control	40	0.002	15.4	23.5	23.7	23.4	0.7	14
After	Intervention B	39	0.041	15.0	23.6	23.4	23.8	0.6	13

The pre-intervention test was conducted between 10:00:00 and 11:00:00 on 22nd August 2017 in the Control and Intervention B wards. As the windows on the study wards were all open, the sensor was located at the back of the room to minimise the impact of outside conditions. Outside conditions at the nearest weather station (12.3 miles straight line distance) for this date showed ambient temperature was 20.2°C, wind speed was 0.3 meters per second (m/s) and humidity was 85% (The Met Office 2018b).

The post-intervention test was conducted between 13:30:00 and 15:30:00 on 2nd April 2018 in the Control and Intervention B wards. As the windows on the study wards were all closed there was minimum impact from outside conditions, so the sensor was located by the window, which is closer to the patients. Outside conditions at the nearest weather station (12.3 miles straight line distance) for this date showed ambient temperature was 10.7°C, wind speed was 2 m/s and humidity was 93% (The Met Office 2018b).

The results show that there was very little difference between the globe thermometer, air and radiant temperatures. Air speed (airflow) was found to be low on the wards and below the sensitivity threshold (0.01 m/s) for the wet bulb globe temperature sensor used in Intervention B ward during the pre-intervention test and in the Control ward during the post-intervention test.

Predicted Percentage of Dissatisfied (PPD) was 18.8-20.0% before the intervention and 13.6-13.9% after the intervention. From the literature review, the recommended acceptable PPD range for indoor thermal comfort is less than 20% dissatisfaction (British Standards Institute 2005, American Society of Heating Refrigeration and Air-Conditioning Engineers 2017, Cannistraro and Bernardo 2017), consequently the study wards are within the required range of BS EN ISO 7730 international standard.

4.2.4 Carbon dioxide

To familiarise with the carbon dioxide (CO_2) data, first the frequency distribution of the CO_2 data was displayed graphically using a histogram and quantile-quantile (Q-Q) plot, shown in Figure 68, in order to identify the shape of the dataset (Kranzler 2003). The histogram shows the distribution has a slight positive skew and Q-Q plot shows a non-normal distribution.

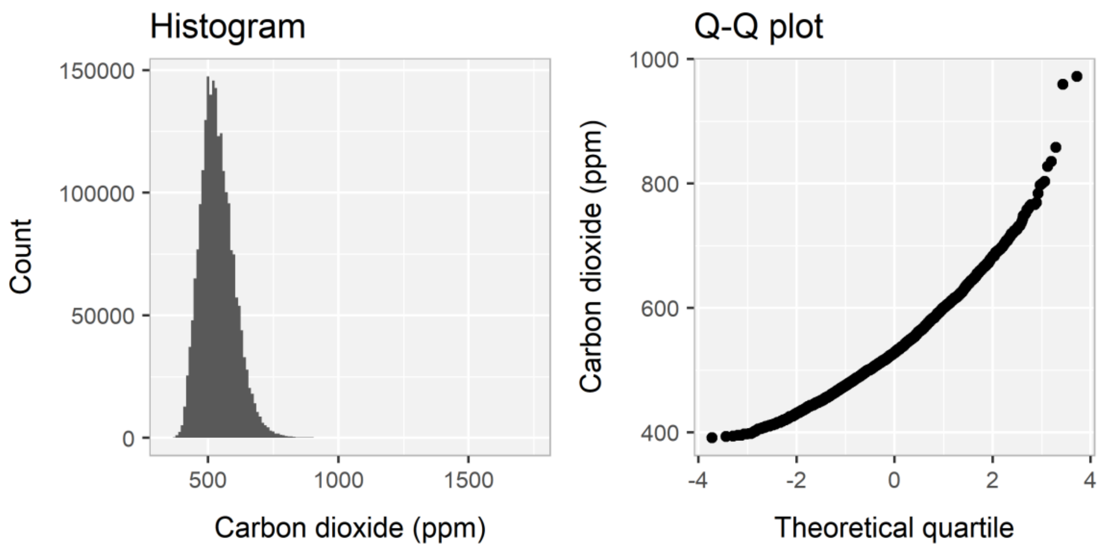

Figure 68. Histogram and Q-Q plot for CO_2 values for the combined control and intervention study groups for the study (1st August 2017 - 30th April 2018)

The data was then organised into the main categories of interest for analysis, namely by the study periods of before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention and by study group, namely the control and intervention groups. The measures of central tendency and variability were then calculated for these categories and is presented in Table 28. As the study pilot and subsequent showed analysis showed fairly uniformed CO_2 values across a 24-hour period due high thermal mass of the hospital building alongside high ventilation rate, the summary table shows the values across the 24-hour period.

Table 28. Summary of CO_2 values, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Sample (n)	Minimum (ppm)	q25 (ppm)	Mean (ppm)	Median (ppm)	q75 (ppm)	Maximum (ppm)	Standard deviation
Before	Control	241514	388	501	540.8	535	576	1175	55.624
Before	Intervention	529918	350	471	511.3	506	545	1222	57.121
During	Control	245337	414	525	574.2	567	617	1216	64.674
During	Intervention	527816	386	495	541.4	536	582	1110	65.581
After	Control	244100	355	510	556.4	550	596	1412	65.239
After	Intervention	417196	375	483	529.7	520	566	1450	69.545

The CO_2 values in the control group ranged between 355 parts per million (ppm) and 1412 ppm compared to 350 ppm and 1450 ppm in the intervention group. As the dataset was non-normally distributed, the median was used to minimise the effect of the outliers on the findings (Kranzler 2003), which showed that the intervention group had lower median CO_2 (ppm) compared to the control group before, during and after the intervention, although the difference is small. Before the intervention, the difference was 5% or 29 ppm, during the intervention the difference increased to 6% or 31 ppm and after the intervention the difference decreased to 6% or 30 ppm.

A visual representation is presented in Figure 69, which shows the control and intervention groups had similar patterns of outliers in the upper quartile although the intervention group appears to have more outliers, including 13 outliers higher than 1400 ppm, after the intervention. As the ventilation systems on the wards are identical and subject to the same pre-planned maintenance system this may suggest (1) difference in the efficiency of the ventilation systems and (2) difference in window opening activity between the control and intervention groups.

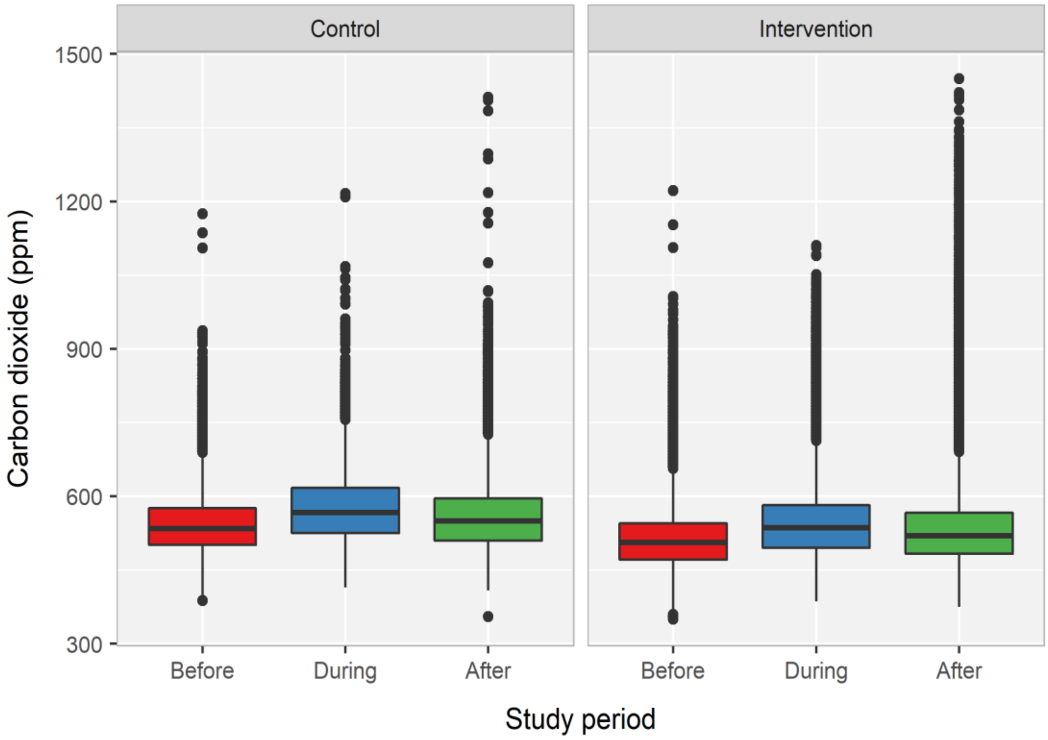

Figure 69. Boxplot of minutely CO_2 values (ppm), comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

As the differences between the control and intervention groups were small, the median CO_2 data was then organised into the individual study wards for the study periods before, during and after the behaviour change intervention and presented in Figure 70. This confirms that the findings show no real difference in terms of the change in CO_2 between the control and intervention groups over the study periods.

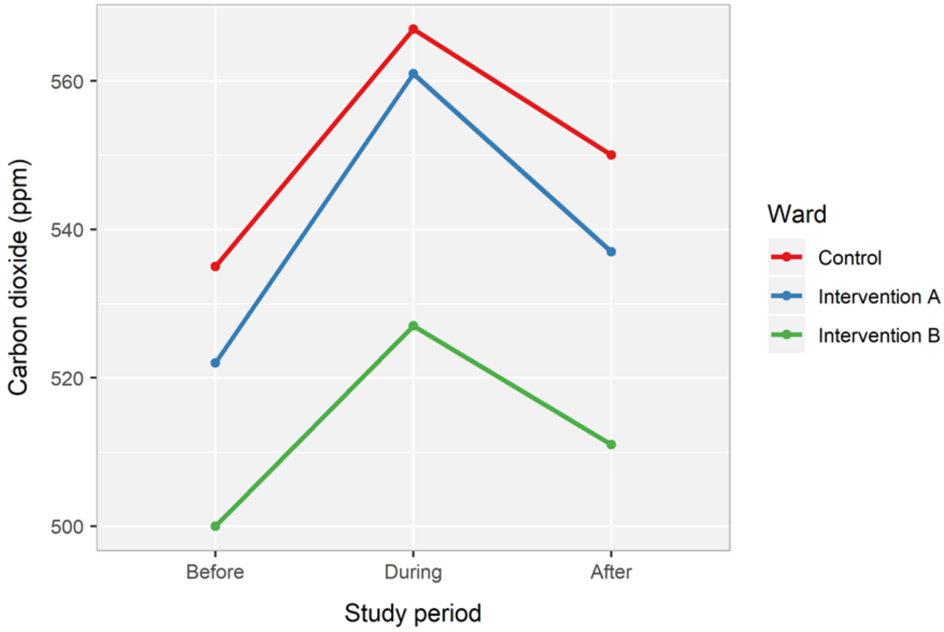

Figure 70. Summary of median CO_2 (ppm), comparing the Control, Intervention A and Intervention B study wards for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

When benchmarked against the indoor environmental quality (IEQ) levels in BS EN 16798-1 and using the average global atmospheric carbon dioxide concentrations during 2017 and 2018 of 406.5 ppm (National Oceanic & Atmospheric Administration 2019) as the outdoor CO_2 concentration figure, the CO_2 data was in the high air quality range (IEQ_I) for 99% of the study (1st August 2017 to 30th April 2018).

To complete the exploration of the minutely CO_2 data (ppm) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the minutely CO_2 data (ppm) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Table 29.

Table 29. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the CO_2 data (ppm) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the CO_2 data (ppm) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	796650	8.3477e+10	< 2.2e-16	<2e-16
I_2	796549	8.3397e+10	< 2.2e-16	<2e-16
I_3	761420	6.2675e+10	< 2.2e-16	<2e-16
I_4	1062208	1.023e+11	< 2.2e-16	<2e-16
I_5	1038580	9.5724e+10	< 2.2e-16	<2e-16

The results showed there is a statistically significant difference between the medians of the minutely CO_2 data in the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error. However, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

The results also showed there is a statistically significant difference between the medians of the minutely CO_2 in the intervention group across the different study periods before and during (I_5) and during and after (I_6) the intervention, which confirms the findings did not occur due to random error and are likely to have occurred due to seasonality.

4.2.5 Window movements

In order to establish the criteria to assess window movement normalised values were calculated for each sensor for a 'small movement', which represents the window being ajar or closed (moving to or from a 5% angle) and a 'significant movement', which represents the window being fully opened or closed (moving to or from a 10% angle) using the non-movement value of the sensor and an interactive motion dashboard. Please see Appendix J for full details of the pre-processing undertaken for the window sensors.

The window movement data was then organised into the main categories of interest for analysis, namely by the study periods of before, during and after the intervention and by study group, namely control and intervention groups. A visual representative is presented in Figure 71, which shows the intervention group had 53% more total window movement (small and significant) events before the intervention, 27% less during the intervention and 3% less after the behaviour change intervention.

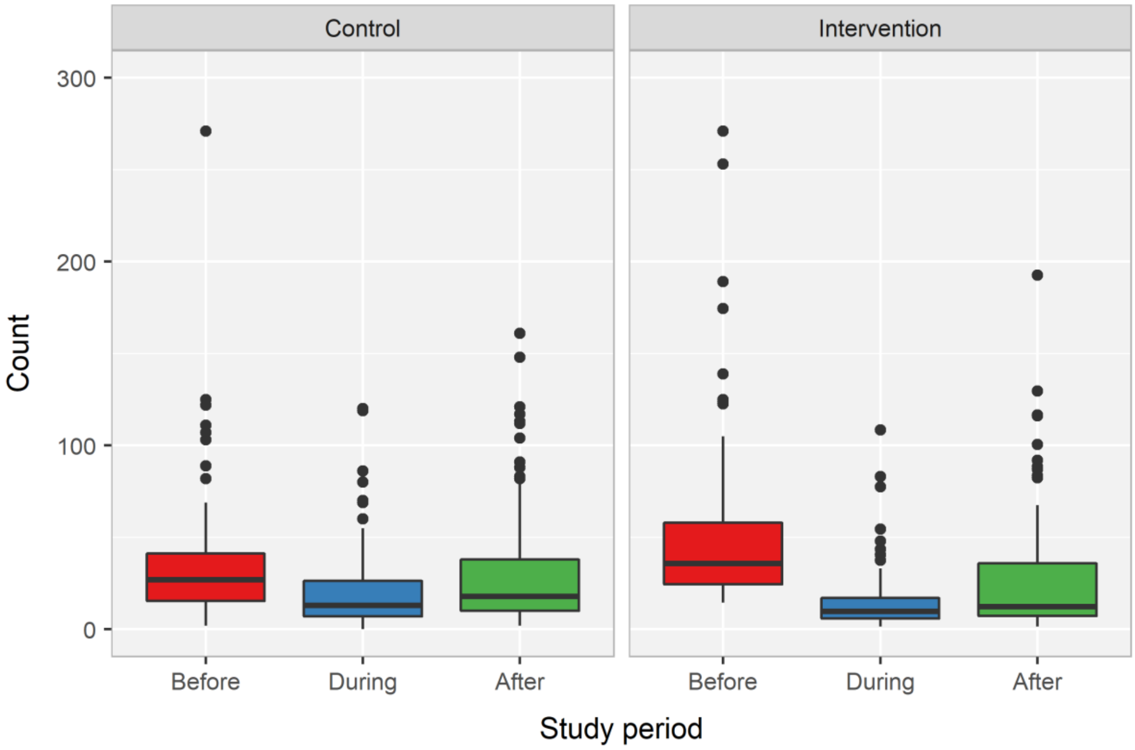

Figure 71. Box plot showing the count of window movement events, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

As number of windows were identical across the study wards, possible reasons for the difference in the frequency of window movement events may be (1) seasonal variation (2) differing health conditions and medication of the patient affecting their ability to thermal regulate (Havenith 2001) and (3) established belief and practice, for example in the intervention group one participant felt that it was essential to introduce fresh air to the ward despite being provided with evidence based information on the high air changes from the mechanical ventilation system.

The window movement values were then organised into a count of (1) total, small and significant window movement events and (2) small and significant window movement events per sensor per day for the main categories of interest for analysis, namely by the study periods of before, during and after the intervention and by study group, namely control and intervention groups. As we would expect to see a difference in window movement activity between the day and night time, the summary data for the day time (06:00:00 - 22:59:00) values is presented in Table 30 and the night time (23:00:00 - 05:59:00) values is presented in Table 31.

Table 30. Count of day time (06:00:00 - 22:59:00) window movement events, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Count of all movement events	Count of small movement events (ajar/close)	Count of significant movement events (open/close)	Number of small movement events per day	Number of significant movement events per day
Before	Control	3008	1821	1187	20	13
Before	Intervention	4734	2995	1740	33	19
During	Control	1838	1109	729	12	8
During	Intervention	1337	679	658	7	7
After	Control	3448	2433	1015	27	11
After	Intervention	3180	2084	1097	23	12

During the day time, the intervention group had 1726 more window movement events (19 per day) than the control group than the control group before the intervention, and less window movement events (1) during (n = 501, 7 per day) and (2) after (n = 268, 3 per day) the behaviour change intervention.

Table 31. Count of night time (23:00:00 - 05:59:00) window movement events, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Count of all movement events	Count of small movement events (ajar/close)	Count of significant movement events (open/close)	Count of small movement events per night	Count of significant movement events per night
Before	Control	317	200	117	2	1
Before	Intervention	340	197	143	2	2
During	Control	123	87	36	1	0
During	Intervention	86	45	41	0	0
After	Control	106	56	50	1	1
After	Intervention	253	164	89	2	1

During the night time, the intervention group had more window movement events than the control group (1) before the intervention (n = 23, 1 per day) and (2) after the intervention (n = 20, 2 per day), and less (n = 147, 1 per day) window movement events during the behaviour change intervention.

As expected, both the control and intervention groups had the most window movement events (7742 in the day time, 657 at night) before the intervention (summer), the fewest window movement events (3175 in the day time, 209 at night) during the intervention (winter), and middling window movement events (6628 in the day time, 359 at night) after the intervention (spring), as a result of seasonal variations.

A visual representation of the day and night time total count of the small and significant window movement events by control and intervention study groups during the study periods before, during and after the intervention is presented in Figure 72.

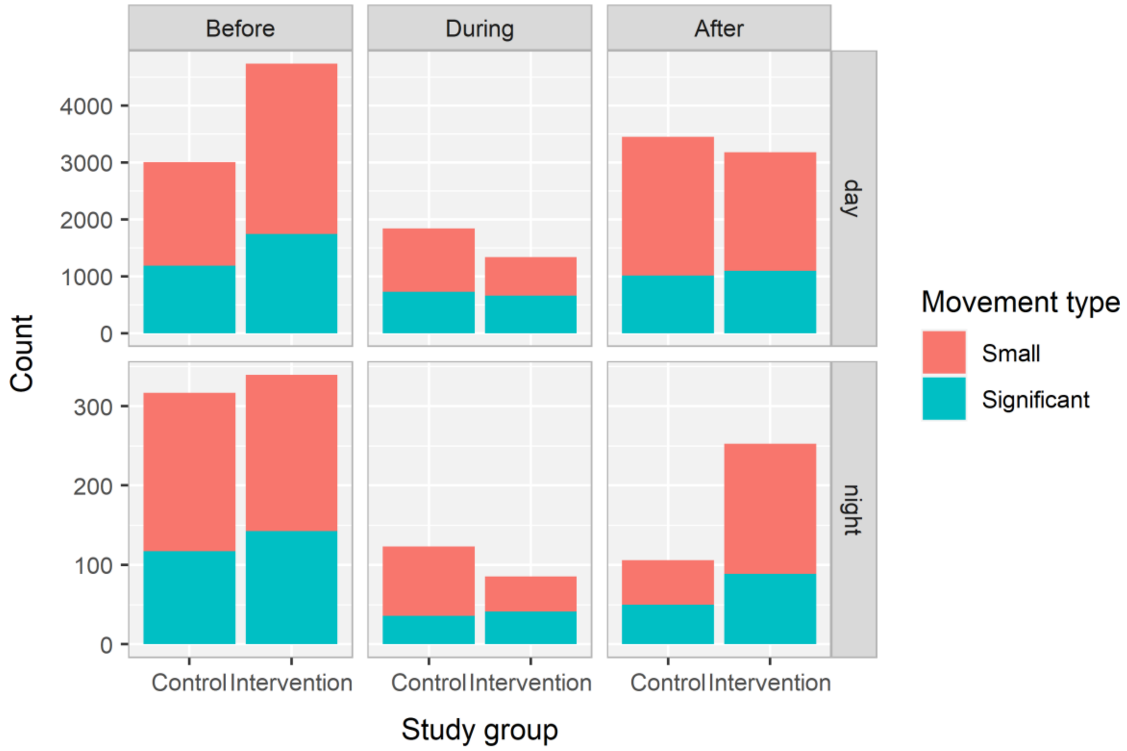

Figure 72. Total count of day and night time small and significant window movement events, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

To complete the exploration of the window movement data (count) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the window movement data (count) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Table 32.

Table 32. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the window movement data (count) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the window movement data (count) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	796650	40308449	0.0001618	0.00016
I_2	796549	3075560	< 2.2e-16	<2e-16
I_3	761420	15900902	< 2.2e-16	<2e-16
I_4	1062208	13377946	< 2.2e-16	<2e-16
I_5	1038580	5780782	< 2.2e-16	<2e-16

The results showed there is a statistically significant difference between the window movement data (count) in the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error. However, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

The results also showed there is a statistically significant difference between the window movement data (count) in the intervention group across the different study periods before and during (I_5) the intervention and during and after (I_6) the intervention, which confirms the findings did not occur due to random error and are likely to have occurred due to seasonality.

4.3 Staff and patient experience data

4.3.1 Trust primary data

Quantitative data was gathered from the Trust's Tableau management information (Tableau 2003) reporting system for the study groups during the study periods.

4.3.1.1 Staff management information

As the potential benefits of implementing an energy behaviour change intervention, adapted from Operation TLC was improved staff satisfaction in such categories as improved staff retention and levels of sickness (Daly and Large 2016). A summary of the data findings for these categories is shown in Figure 73.

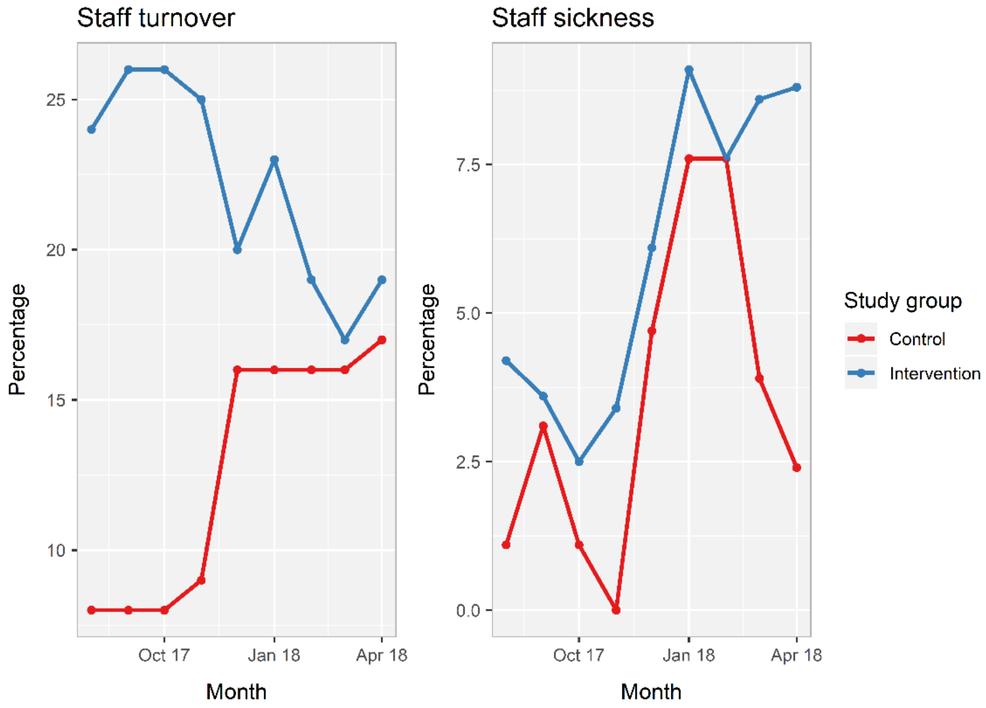

Figure 73. Monthly Trust management information showing the average monthly staff sickness data (percentage) and staff turnover data (percentage) comparing the control and intervention study groups during the study (1st August 2017 - 30th April 2018)

The results show that before, during and after the intervention, the intervention group had higher mean percentage of staff sickness (3%, 6% and 8% respectively) when compared to the control group (2%, 4% and 5% respectively).

The results also show that before, during and after the intervention, the intervention group had higher mean percentage of staff turnover (25%, 23% and 18% respectively) when compared to the control group (8%, 14% and 16% respectively). However, the findings in the intervention group, show that mean staff turnover reduced by 2% during the intervention and then by a further 5% after the intervention, whilst in the control group mean staff turnover increased by 6% during the intervention and a further 2% after the intervention.

As a person's age, gender, culture, personality and expectation of conditions based on previous experience may all influence their thermal comfort (Nicol et al. 2012) and females are more likely to adopt energy saving behaviours (Paco et al. 2015), a summary of basic mean age, gender and ethnicity management information for the staff participating in the study was gathered and is shown in Table 33.

Table 33. Trust management information showing the average staff age, gender and ethnicity comparing the control and intervention study groups during the study (1st August 2017 - 30th April 2018)

Study period	Study group	Staff (n)	Average age	Gender	Ethnicity
Before	Control	10	41	95% Female 5% Male	89% White British 11% White any other origin 0% Black / mixed Black 0% Asian / British Asian – Indian
Before	Intervention	18	49	90% Female 10% Male	88% White British 9% White any other origin 2% Black / mixed Black 1% Asian / British Asian – Indian
During	Control	10	43	89% Female 11% Male	79% White British 16% White any other origin 5% Black / mixed Black 0% Asian / British Asian – Indian
During	Intervention	18	50	90% Female 10% Male	89% White British 9% White any other origin 2% Black / mixed Black 0% Asian / British Asian – Indian
After	Control	10	43	88% Female 12% Male	75% White British 15% White any other origin 8% Black / mixed Black 2% Asian / British Asian – Indian
After	Intervention	18	51	90% Female 10% Male	88% White British 10% White any other origin 1% Black / mixed Black 1% Asian / British Asian – Indian

To complete the exploration of the (1) staff sickness data (percentage) and (2) staff turnover (percentage) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the data (percentage) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Tables 34 and 35.

Table 34. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the staff sickness data (percentage) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the staff sickness data (percentage) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	9	1	0.184	0.18
I_2	9	3	0.7	0.66
I_3	9	0.5	0.1212	0.12
I_4	18	2	0.4	0.38
I_5	18	6	0.7	0.66

Table 35. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the staff turnover data (percentage) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the staff turnover data (percentage) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	9	0	0.05935	0.059
I_2	9	0	0.07652	0.077
I_3	9	0.5	0.1101	0.11
I_4	18	8	0.184	0.18
I_5	18	0	0.07652	0.077

The results showed there is not a statistically significant difference between the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention for the staff management information, namely (1) staff sickness data (percentage) and (2) staff turnover data (percentage).

The results also showed there is not a statistically significant difference between the study periods before and during (I_5) the intervention, and during and after (I_6) the intervention for the intervention group for the staff management information, namely (1) staff sickness data (percentage) and (2) staff turnover data (percentage).

4.3.1.2 Patient management information

As the potential benefits of implementing an energy behaviour change intervention, adapted from Operation TLC was improved patient wellbeing in the category of reduced patient length of stay (Daly and Large 2016). A summary of the data findings for this category is shown in Figure 74.

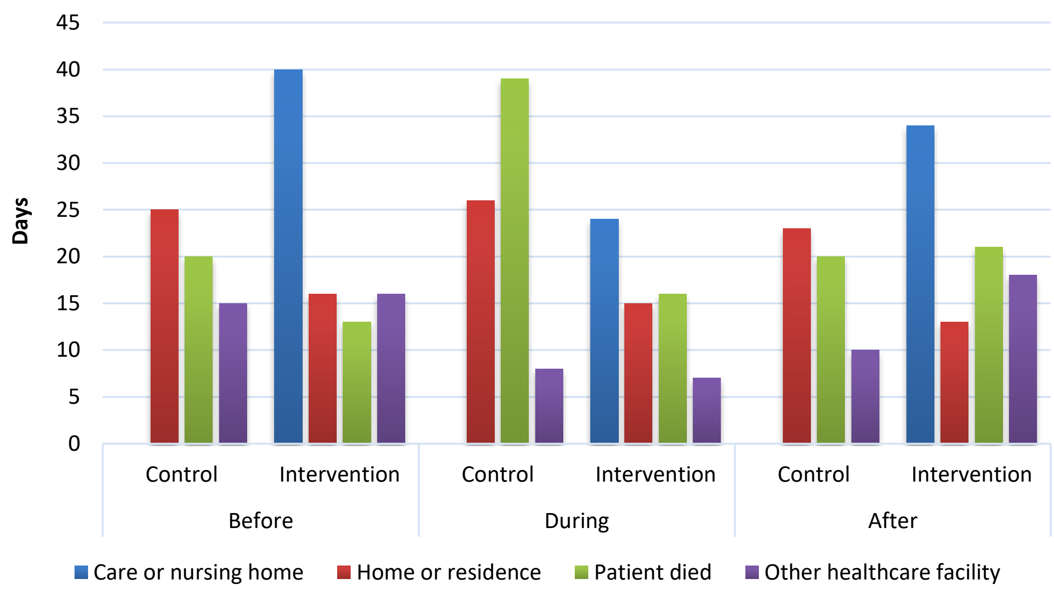

Figure 74. Trust management information showing average monthly patient length of stay (days) by discharge type comparing the control and intervention study groups during the study (1st August 2017 - 30th April 2018)

The results show that before, during and after the intervention, the intervention group had lower mean length of stay for patients returning home (16, 15, 13 days respectively) when compared to the control group (25, 27, 23 days respectively). Although the findings in the intervention group, show the mean length of stay for patients returning home reduced by 1% during the intervention and then by a further 2% after the intervention, whilst in the control group mean length of stay for patients returning home increased by 2% during the intervention and then reduced by 5% after the intervention.

As a person’s age, gender, culture, personality and expectation of conditions based on previous experience may all influence their thermal comfort (Nicol et al. 2012) a summary of basic mean age, gender and ethnicity management information for the patients participating in the study is shown in Table 36.

Table 36. Trust management information showing the average patient age, gender and ethnicity comparing the control and intervention study groups during the study (1st August 2017 - 30th April 2018)

Study period	Study group	Patients (n)	Average age	Gender	Ethnicity
Before	Control	18	64	51% Female 49% Male	92% White British 8% Not stated
Before	Intervention	42	64	47% Female 53% Male	94% White British 1% White any other origin 4% Not stated
During	Control	19	70	60% Female 40% Male	93% White British 7% Not stated
During	Intervention	42	65	32% Female 68% Male	92% White British 1% White any other origin 7% Not stated
After	Control	20	67	47% Female 53% Male	97% White British 1% White any other origin 2% Not stated
After	Intervention	41	63	40% Female 60% Male	92% White British 2% White any other origin 4% Not stated

To complete the exploration of the patient length of stay data (days) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the patient length of stay data (days) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Tables 37.

Table 37. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the patient length of stay data (days) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the patient length of stay data (days) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	9	9	0.1	0.081
I_2	9	9	0.1	0.081
I_3	9	9	0.07652	0.077
I_4	18	7	0.4	0.38
I_5	18	7	0.3758	0.38

The results showed there is not a statistically significant difference between the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention for the patient management information relating to patient length of stay (days) for patients returning home.

The results also showed there is not a statistically significant difference between the study periods before and during (I_5) the intervention, and during and after (I_6) the intervention in the intervention group for the patient management information relating to patient length of stay (days) for patients returning home.

4.3.2 Patient bed movements

In order to establish the criteria to assess patient bed movements, normalised values were calculated from the bed movement data for each sensor using the non-movement value of the sensor and an interactive motion dashboard. Please see Appendix K for full details of the pre-processing undertaken for the bed sensors.

The patient bed movement events were then organised into the main categories of interest for analysis, namely by the study periods of before, during and after the intervention and by study group, namely control and intervention groups, presented in Figure 75. This shows the intervention group had 22% more bed movement events before the intervention, 17% less during and 32% after the behaviour change intervention.

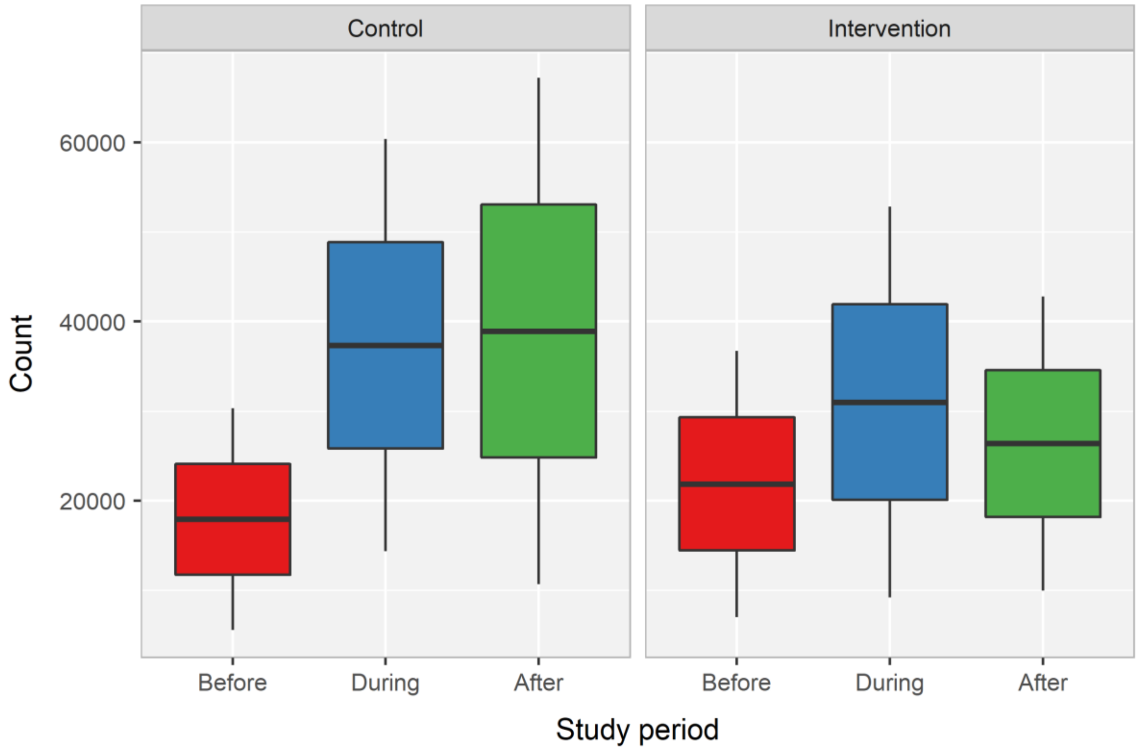

Figure 75. Count of patient bed movement events, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

As number of patients were identical across the study wards, possible reasons for the difference in the frequency of bed movement events may be (1) differing health conditions of the patient, for example, from the pilot study it was established that patients with dementia move frequently in their beds as a result of their condition (2) number of direct contacts, for example, from the pilot study it was established that patient bed movements correlated with occupancy levels, particularly with direct patient interactions (patient examinations, talking to nurses and visitors) and (3) the environmental conditions in the ward, particularly noise and thermal comfort.

In order to further examine the patient bed movement events, the data was broken down into day and night time values. As we would expect to see a difference in bed movement activity between the day and night time, the summary data for day time (06:00:00 - 22:59:00) values is presented in Table 38 and night time (23:00:00 - 05:59:00) values in Table 39.

Table 38. Count of day time (06:00:00 - 22:59:00) patient bed movement events normalised to show events per bed per day, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Count of patient bed movement events per bed per day
Before	Control	31
Before	Intervention	35
During	Control	62
During	Intervention	51
After	Control	74
After	Intervention	47

During the day time, the intervention group had 4 more bed movement events per sensor per day than the control group before the intervention, 11 less bed movement events per sensor per day during the intervention and 27 bed movement events per sensor per day, when compared to the control group.

Table 39. Count of night time (23:00:00 - 05:59:00) patient bed movement events normalised to show events per bed per night, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Count of patient bed movement events per bed per night
Before	Control	6
Before	Intervention	7
During	Control	15
During	Intervention	9
After	Control	12
After	Intervention	11

During the night time, the intervention group had 1 more bed movement events per sensor per night than the control group before the intervention, 6 less bed movement events per sensor per night during the intervention and 1 bed movement event per sensor per night after the intervention, when compared to the control group.

A visual representation of the total count of patient bed movement events per bed per day or night time in the control and intervention study groups during the study periods before, during and after the intervention is presented in Figure 76.

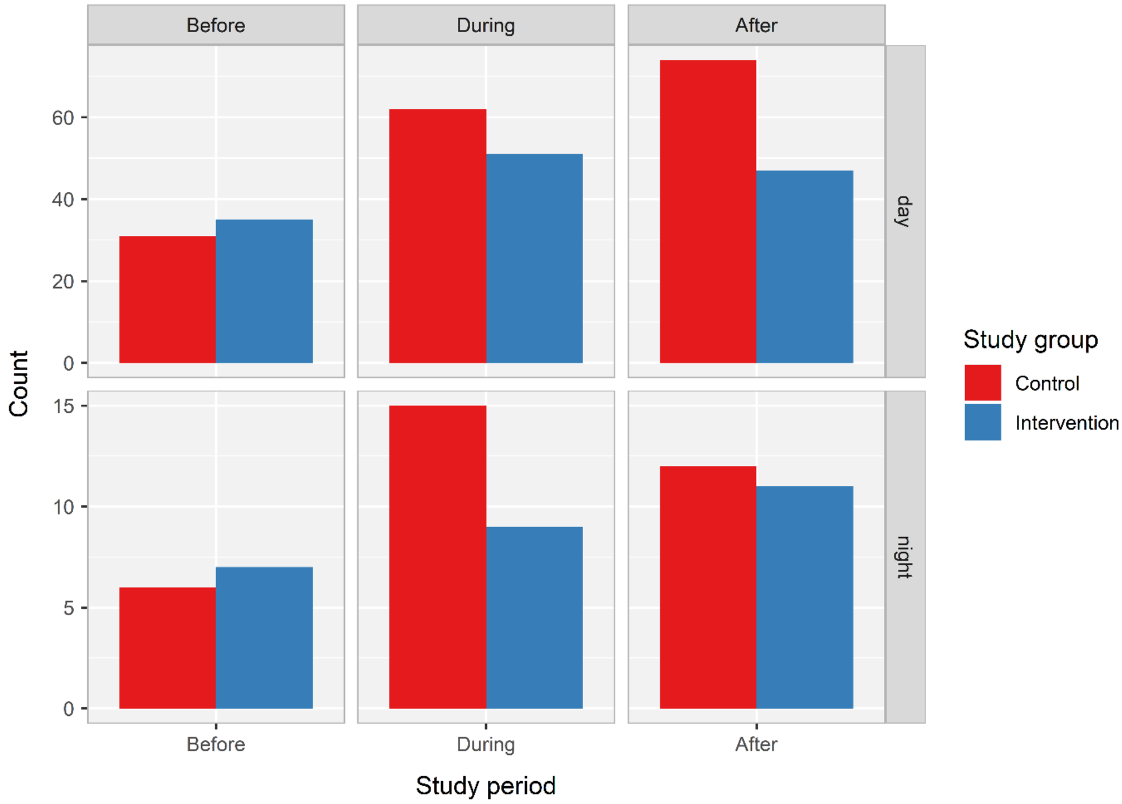

Figure 76. Total count of patient bed movement events per bed by day or night, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

During the day time, before the intervention the intervention group had 13% more bed movements than the control group, 18% less during the intervention and 37% less after the intervention. During the night time, before the intervention the intervention group had 17% more bed movements than the control group, 40% less during the intervention and 8% more after the intervention.

To complete the exploration of the patient bed movement data (count) a series of inferential tests were undertaken in line with those discussed in section 3.10, using a Mann Whitney U-test with a confidence level of 95%. The Mann Whitney U-test was chosen as the patient bed movement data (count) is numeric with a non-normal distribution and two non-paired samples (control, intervention). The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). A summary of the results from the inferential tests are shown in Table 40.

Table 40. Summary of the results of the inferential tests (I_1, I_2, I_3) completed on the patient bed movement data (count) comparing the control and intervention study groups during each of the study periods, and the inferential tests (I_4, I_5) completed on the patient bed movement data (count) for the intervention group comparing between the study periods before: during and during: after

Inferential test	Sample (n)	W value	p-value	Post hoc test
I_1	796650	335510387	0.00171	0.0017
I_2	796549	771930191	2.331e-06	2.3e-06
I_3	761420	535128626	< 2.2e-16	<2e-16
I_4	1062208	917669824	< 2.2e-16	<2e-16
I_5	1038580	1327290597	< 2.2e-16	<2e-16

The results showed there is a statistically significant difference between the medians of the bed movement data (count) in the control and intervention groups before (I_1), during (I_2) and after (I_3) the intervention, which confirms the findings did not occur due to random error. However, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

The results also showed there is a statistically significant difference between the medians of the bed movement data (count) in the intervention group across the different study periods before and during (I_5) the intervention and during and after (I_6) the intervention, which confirms the findings did not occur due to random error and are likely to have occurred due to (1) differing health conditions of the patient and (3) the environmental conditions in the ward, particularly noise and thermal comfort.

4.4 Summary of the quantitative data findings

A summary of the findings from the quantitative data analysis is presented below:

4.4.1 Energy data

Lighting	• The intervention groups used 5% less electricity for lighting before and during the intervention, compared to the control group. • The intervention group used 13% less electricity for lighting before and during the intervention, compared to the control group, which equates to an 8% saving. • There was a significant statistical difference between the control and intervention groups before, during and after the intervention.
Small power	• The intervention group reduced energy for small power by 33% during the intervention and 24% after the intervention, compared to the control group. • There was a significant statistical difference between the control and intervention groups during and after but not before the intervention.

4.4.2 Environmental data

Light	• The intervention group reduced 'lights on' hours by 11% during the intervention and 8% after the intervention, compared to the control group. • There was a significant statistical difference between the control and intervention groups during and after the intervention
Sound	• The intervention group reduced median noise levels by 1dB during the intervention, compared to the control group. • There was a significant statistical difference between the control and intervention groups before, during and after the intervention.
Air temperature	• The intervention group reduced median air temperature by 0.6°C during the intervention and 0.4°C after the intervention, compared to the control group. • Both study groups had temperature drifts of ±5°C and over for the majority of the time. • There was a significant statistical difference between the control and intervention groups before, during and after the intervention.

Relative humidity	• The findings show that the intervention had no significant impact on relative humidity. • There was a significant statistical difference between the control and intervention groups before, during and after the intervention.
Thermal comfort	• The findings show that there was a negligible difference between the globe thermometer, air and radiant temperatures. • Air speed (airflow) was found to be low on the wards.
Carbon dioxide	• The findings show that the intervention had no significant impact on carbon dioxide. • There was a significant statistical difference between the control and intervention groups before, during and after the intervention.
Window movement	• The intervention group reduced window movements by 27% during the intervention and 3% after the intervention, compared to the control group. • There was a significant statistical difference between the control and intervention groups before, during and after the intervention.

4.4.3 Staff and patient experience data

Trust data	• **Staff sickness:** the intervention group had higher staff sickness than the control ward before, during and after the intervention. • **Staff turnover:** the intervention group had higher staff turnover than the control ward before, during and after the intervention. • **Patient length of stay:** the intervention group had lower length of stay (days) for patients returning home than the control ward before, during and after the intervention. • There was not a significant statistical difference between the control and intervention groups before, during and after the intervention for (1) staff sickness (2) staff turnover and (3) patient length of stay.
Patient bed movements	• The intervention group reduced bed movements by 17% during the intervention and 32% after the intervention, compared to the control group. • There was a significant statistical difference between the control and intervention groups before, during and after the intervention.

A further discussion of the findings from this chapter may be found in Chapter 8. The findings from the qualitative data variables is explored in the next chapter.

Chapter 5 Findings: Qualitative Data

This chapter outlines the analysis carried out on the qualitative data collected during this study, which aims to test the theory that *"running a behaviour change intervention in a hospital saves energy whilst creating a healthy environment that improves patient wellbeing and staff satisfaction"*.

The qualitative data was analysed in line with the stages of analysis identified by Jirojwong et al. (2014), namely familiarisation, organisation, categorisation and exploration of the relationships between the categories. This chapter presents the results from these stages of the data analysis.

The details of the processing carried out on the individual data variables prior to analysis, are discussed in the appropriate sections below. The qualitative data was analysed using R Studio programming software (CRAN 2018).

Section 5.1 presents the findings from the staff comfort surveys (n= 30 participants, 463 surveys) completed during the study. Section 5.2 presents the findings from the staff focus group (n = 30 participants, 6 focus groups) completed during the study. A summary of the findings from the qualitative data is presented in section 5.3.

5.1 Staff comfort surveys

The staff responses from the paper questionnaires were manually input into a Microsoft Excel (Microsoft Corporation 2016a) spreadsheet before uploading into R Studio programming software (CRAN 2018). To avoid input error the Microsoft Excel spreadsheet was rechecked against the completed paper questionnaires by a Trust administrator, as advised in Marshall and Rossman (1989).

The qualitative data gathered from the staff comfort surveys (n = 30 participants, 463 surveys) was then organised into the main categories of interest for analysis, namely the control and intervention study groups across the study periods before, during and after the behaviour change intervention. The results of this data analysis is presented below.

5.1.1 Lighting

The study wards were identical in terms of (1) the type, number and location of light fittings and luminaries and (2) location, orientation and hours of sunlight. A visual representation of the summary findings for the staff comfort survey category of lighting is presented in Figure 77 by study group for the study periods before, during and after the behaviour change intervention.

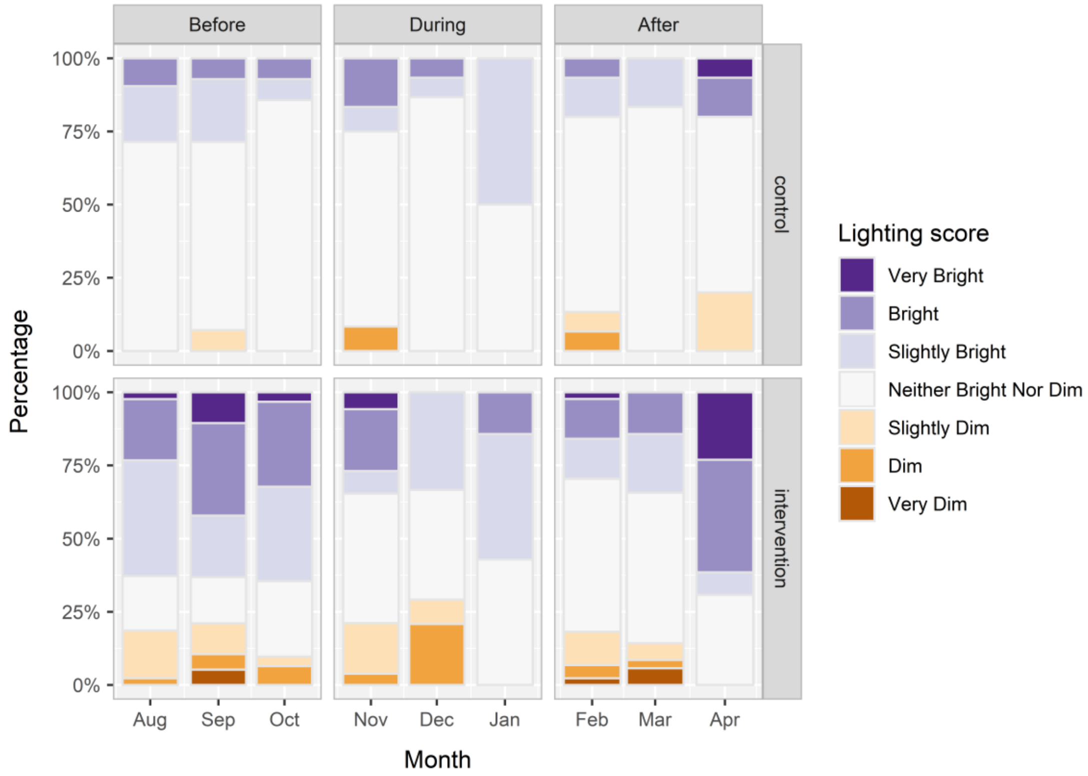

Figure 77. Percentage of staff lighting comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Before, during and after the behaviour change intervention, the control group reported the highest percentage (74%, 76%, 69% respectively) in the 'neither bright nor dim' score. Before the intervention, the intervention group reported the highest percentage (34%) in the 'slightly bright' score although this was closely followed by the 'bright' score (26%). During and after the intervention, the intervention group reported the highest percentage (42%, 49% respectively) in the 'neither bright nor dim' category.

A summary of the findings for the staff comfort survey category of 'lighting' is presented in Table 41.

Table 41. Summary of staff lighting comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Participants (n)	Completed surveys (n)	Bright comfort scores (%)	Neither bright nor dim (%)	Dim comfort scores (%)
Before	Control	10	49	24	74	2
Before	Intervention	20	93	64	20	16
During	Control	10	29	20	76	3
During	Intervention	20	90	38	42	20
After	Control	10	42	19	69	12
After	Intervention	20	92	37	49	14

This shows that before, during and after the intervention most of control group reported that the lights in the ward were neither bright not dim. Whereas the intervention group reported that the lights were (1) bright before the intervention and (2) provided a mixed response between the bright and neutral range of scores both during and after the intervention. This may be due to (1) seasonality variation with summers in England having considerably more hours of sunshine than winters (The Met Office 2018a) and (2) heightened awareness of staff in the intervention group of the impacts of light (natural and artificial) on the wards as a result of the evidence based information provided during the behaviour change intervention.

Overall, the both groups appear to be predominately neutral about the lighting on the ward although some staff in the intervention group feeling the lighting is bright.

5.1.2 Noise

The study wards were identical in terms of (1) the number and type of patients (2) number of nursing staff working the same shift patterns, (3) routines in terms of meal times, refreshment, medical and medicine rounds and (4) equipment (clinical and non-clinical). A visual representation of the summary findings for the staff comfort survey category of noise is presented in Figure 78 by study group for the study periods before, during and after the behaviour change intervention.

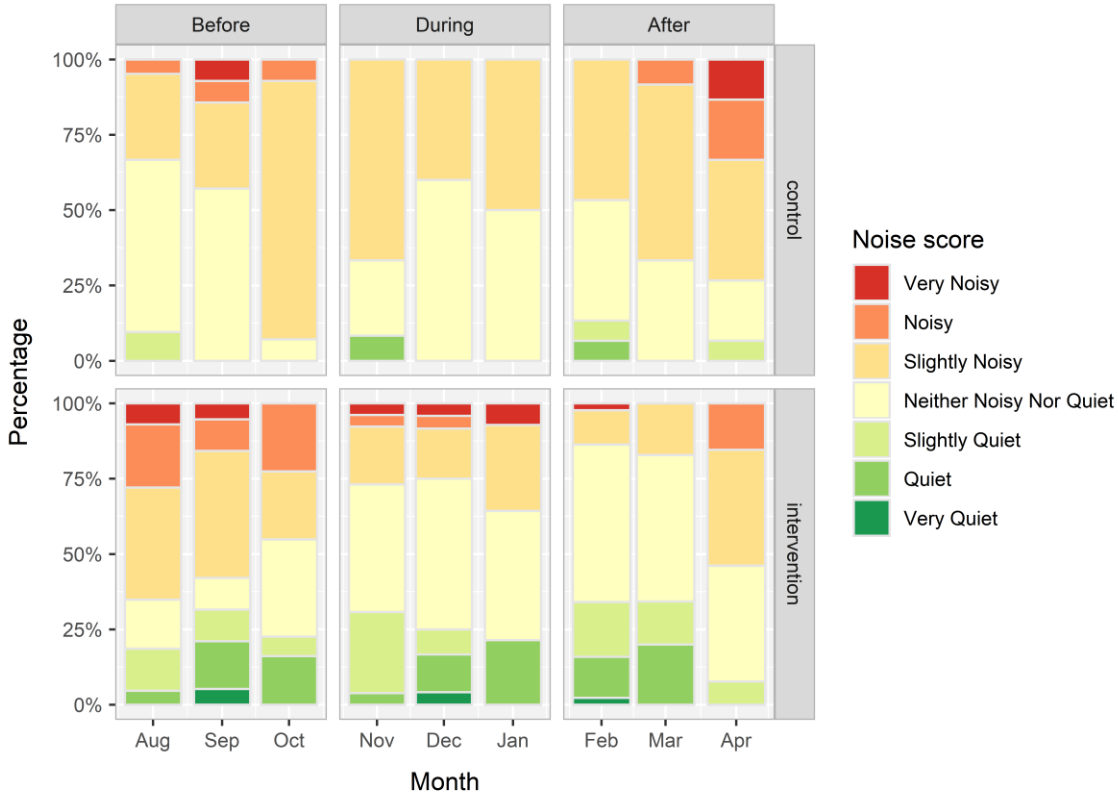

Figure 78. Percentage of staff noise comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Before, during and after the behaviour change intervention, the control group reported the highest percentage (45%, 52%, 48% respectively) in the 'slightly noisy' score, although the percentages (43%, 45%, 31% respectively) in the 'neither noisy nor quiet' score were very close. The intervention group reported the highest percentage (33%) in the 'slightly noisy' score before the intervention and in the 'neither noisy nor quiet' category during (44%) and after (49%) the intervention.

A summary of the findings for the staff comfort survey category of 'noise' is presented in Table 42.

Table 42. Summary of staff noise comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Participants (n)	Completed surveys (n)	Noisy comfort scores (%)	Neither noisy nor quiet (%)	Quiet comfort scores (%)
Before	Control	10	49	53	43	4
Before	Intervention	20	93	57	20	23
During	Control	10	29	52	45	3
During	Intervention	20	90	28	44	28
After	Control	10	42	62	31	7
After	Intervention	20	92	21	49	30

This shows that before and during the intervention the control group reported a mixed response between the noisy and neutral range of scores. After the intervention the majority of the control group reported that the ward was noisy. Whereas, the majority of the intervention group reported that the wards were noisy before the intervention but provided neutral responses during and after intervention. The intervention group reported more scores in the quiet range than the control group.

Overall, this suggest that both groups thought that the wards were noisy before the intervention, however the majority of the intervention group appear to be neutral about noise on the ward during and after the intervention whereas more of the control group still felt their ward was noisy. This may be due to a heightened awareness of staff in the intervention group of the impacts of noise on the wards and the expectation that they are required to control noise levels to create a healthy environment.

5.1.3 Temperature

The hospital building comprises of (1) high thermal mass (2) mechanical ventilation with high number of air changes and (3) no air conditioning or other forms of mechanical cooling, consequently in the summer the building is prone to summer overheating and in the winter takes a long time to warm up. The heating system in the hospital was switched on (heating season) on 1st November 2017 and remained on for the duration of the study period.

A visual representation of the summary findings for the staff comfort survey category of temperature is presented in Figure 79 by study group for the study periods before, during and after behaviour change intervention.

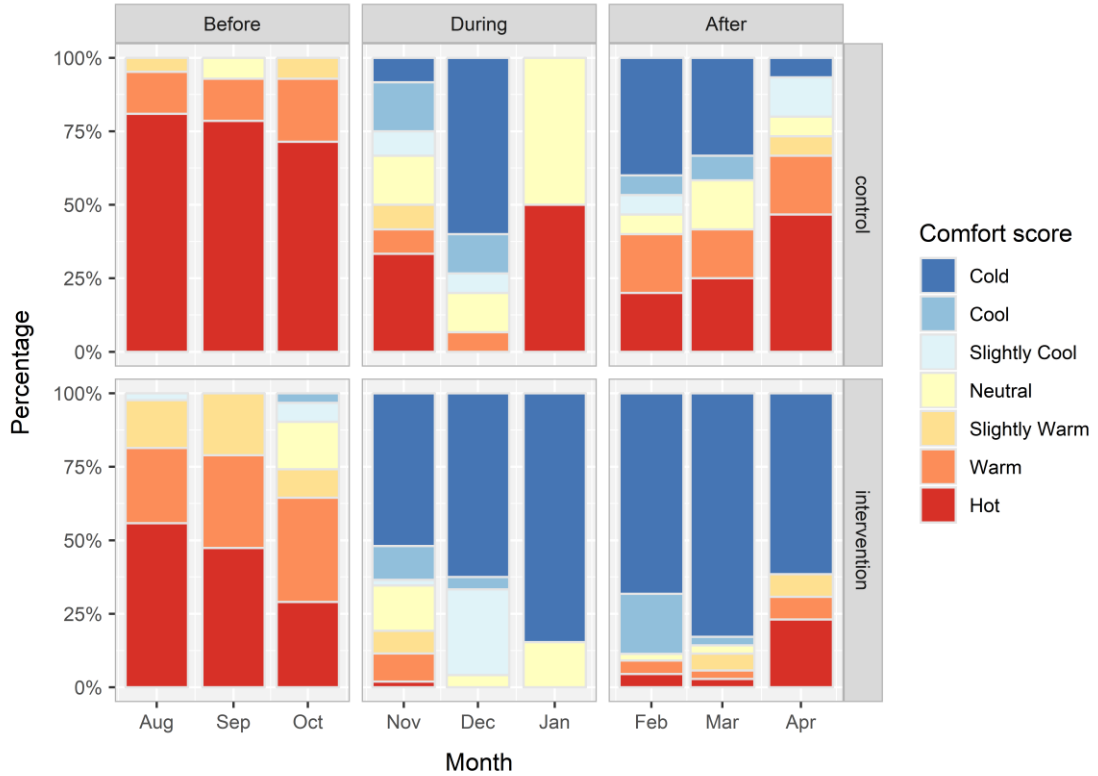

Figure 79. Percentage of staff temperature comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Before the intervention, the control group reported the highest percentage (78%) in the 'hot' category. Whilst the intervention group also reported the highest percentage (45%) in the 'hot' category, they also reported a similar percentage (30%) in the 'warm' category.

During the intervention, the intervention group reported the highest percentage (59%) in the 'cold' score. Whilst the control group also reported the highest percentage (35%) in the 'cold' category, they also reported a fairly equal spread of percentages across the 'cool' (14%), 'neutral' (17%) and 'hot' (17%) categories.

After the intervention, the intervention group reported the highest percentage (73%) in the 'cold' score. Whilst the control group reported the highest percentage (31%) in the 'hot' category, they also reported a similar percentage (26%) in the 'cold' category.

A summary of the findings for the staff comfort survey category of 'temperature' is presented in Table 43.

Table 43. Summary of staff temperature comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Participants (n)	Completed surveys (n)	Cold comfort scores (%)	Neither cold nor hot (%)	Hot comfort scores (%)
Before	Control	10	49	0	2	98
Before	Intervention	20	93	5	6	90
During	Control	10	29	56	17	27
During	Intervention	20	90	76	12	12
After	Control	10	42	38	10	52
After	Intervention	20	92	84	2	14

The intervention group consistently reported being (1) primarily hot before the intervention (summer non-heating season) due to the high thermal mass of building creating summer overheating and (2) cold during (winter heating season) and after (spring heating season) the intervention due to heightened awareness on the impacts of temperature on the wards and the need to control temperatures within the CIBSE winter operating target (22-24°C), as a result of the behaviour change intervention.

Whilst the control group primarily reported being hot before the intervention as expected, they provided a mixed response ranging between the cold and hot during and after the behaviour change intervention. The mixed response may reflect the expectation of conditions based on previous experience of the hospital (usually the hospital is always hot) versus the actual air temperatures (unusually the wards were being actively controlled within the CIBSE winter operating target).

5.1.4 Humidity

The hospital building comprises of mechanical ventilation with high number of air changes and no air conditioning or other forms of mechanical cooling supplemented by opening windows, which are restricted to a 10% opening angle. As a result, the atmosphere inside the building feels drier than ambient humidity, which being located in the south of England has a fully humid (f) climate in accordance with the Köppen classification ((Kottek et al. 2006).

A visual representation of the summary findings for the staff comfort survey category of humidity is presented in Figure 80 by study group for the study periods before, during and after the behaviour change intervention.

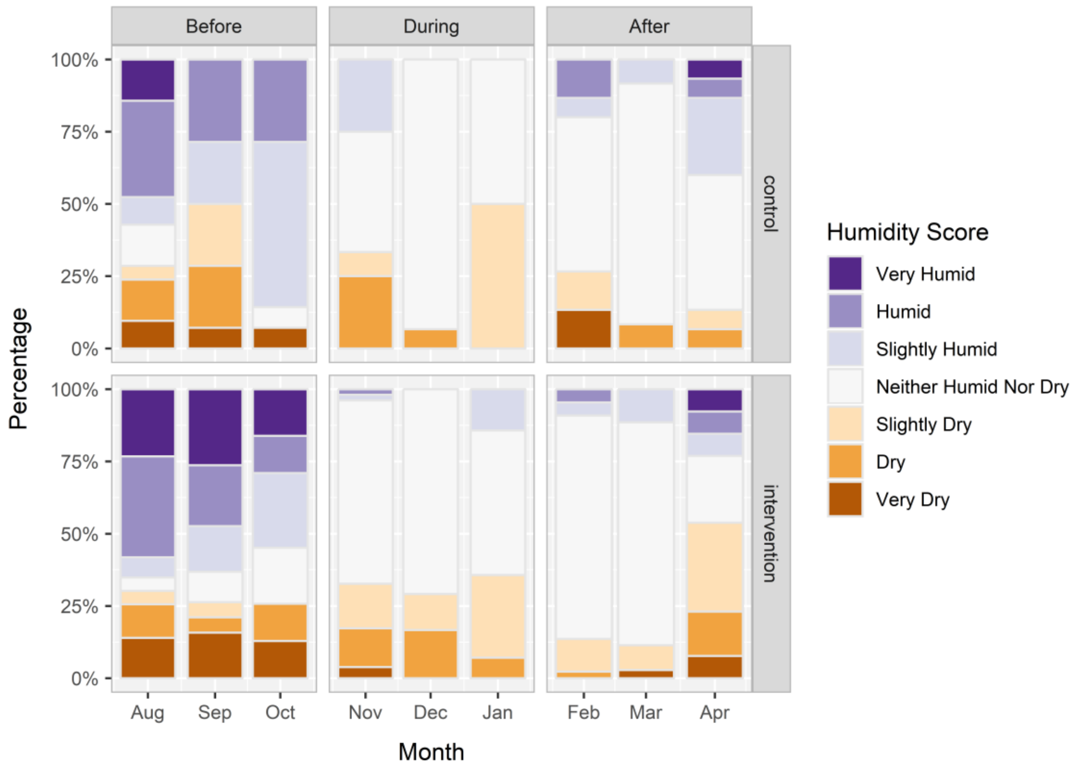

Figure 80. Percentage of staff humidity comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Before the intervention, both the control and intervention groups reported the highest percentage (31% and 25% respectively) in the 'humid' category. During and after the intervention both the control and intervention groups reported the highest percentage (before 69% and 60% respectively, after 63% and 70% respectively) in the 'neither humid nor dry' category.

A summary of the findings for the staff comfort survey category of 'humidity' is presented in Table 44.

Table 44. Summary of staff humidity comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Participants (n)	Completed surveys (n)	Humid comfort scores (%)	Neither humid nor dry (%)	Dry comfort scores (%)
Before	Control	10	49	64	8	28
Before	Intervention	20	93	61	11	28
During	Control	10	29	10	69	21
During	Intervention	20	90	5	63	32
After	Control	10	42	23	60	17
After	Intervention	20	92	12	70	18

Before the behaviour change intervention, both the control and intervention groups reported the environment was humid in the wards as expected due to seasonal variation with summers in England generally being more humid than winters (The Met Office 2018a). During and after the intervention, both the control and the intervention groups appear to be neutral about the levels of relative humidity on the ward as a result of the high ventilation rates creating fairly uniformed levels of relative humidity as found in the study pilot.

5.1.5 Air quality

The hospital building comprises of mechanical ventilation with high number of air changes supplemented by opening windows, however the windows in the study wards only open to a 10% angle, which restricts the circulation of fresh air. Additionally, the windows are top pivoted so the opening is at the same height as the patient beds, which the older patients closest to the window largely find unpleasantly draughty.

A visual representation of the summary findings for the staff comfort survey category of air quality is presented in Figure 81 by study group for the study periods before, during and after the behaviour change intervention.

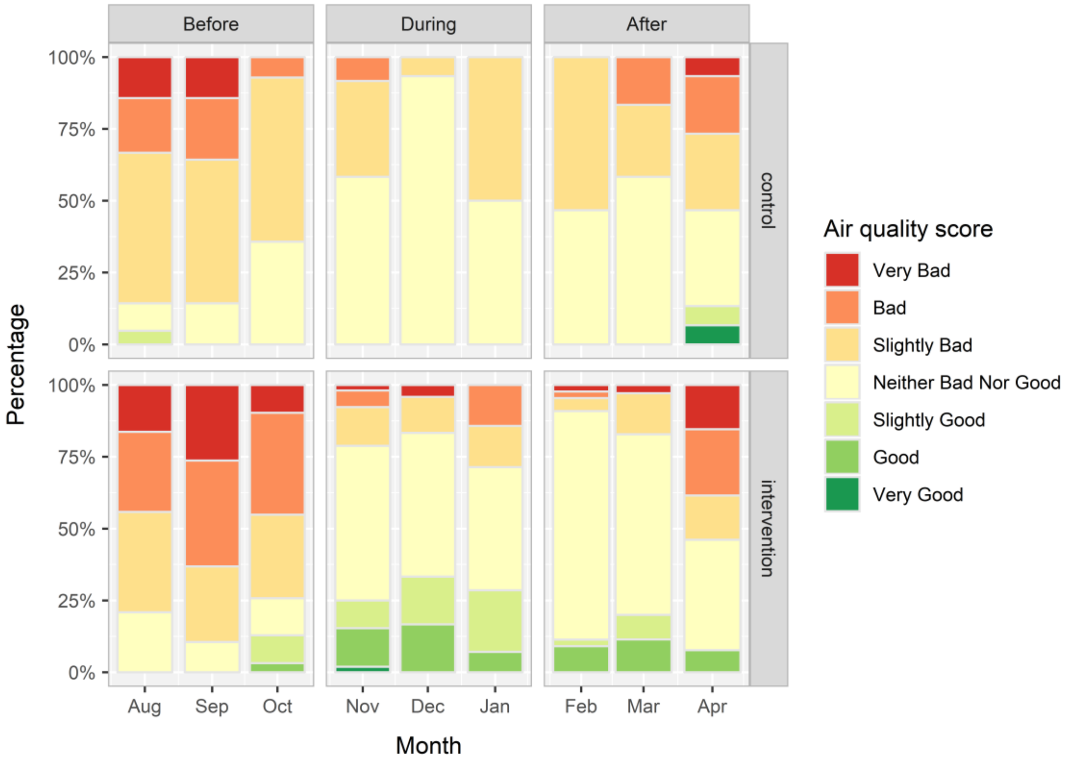

Figure 81. Percentage of staff air quality comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Before the behaviour change intervention, the control group reported the highest percentage (53%) in the 'slightly bad' score and the intervention group reported the highest percentage in the 'bad' score (33%) although the 'slightly bad' score was close at 31%. During and after the intervention, both the control and the intervention groups reported the highest percentages in the neutral category of 'neither bad nor good'.

A summary of the findings for the staff comfort survey category of 'air quality' is presented in Table 45.

Table 45. Summary of staff air quality comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Participants (n)	Completed surveys (n)	Bad comfort scores (%)	Neither bad nor good (%)	Good comfort scores (%)
Before	Control	10	49	79	19	2
Before	Intervention	20	93	80	16	4
During	Control	10	29	24	76	0
During	Intervention	20	90	21	51	28
After	Control	10	42	45	50	5
After	Intervention	20	92	18	68	14

Before the behaviour change intervention, both the control and intervention groups reported the air quality was bad in the wards as a result of the lack of air flow due to restricted window opening opportunities and summer overheating confirmed by the wet bulb thermometer tests. During and after the intervention, both the control and the intervention groups appear to be content with the air quality on the ward as a result of the high ventilation rates creating fairly uniformed levels of CO_2 as found in the study pilot.

5.1.6 Overall comfort

A visual representation of the summary findings for the staff comfort survey category of overall comfort is presented in Figure 82 by study group for the study periods before, during and after the behaviour change intervention.

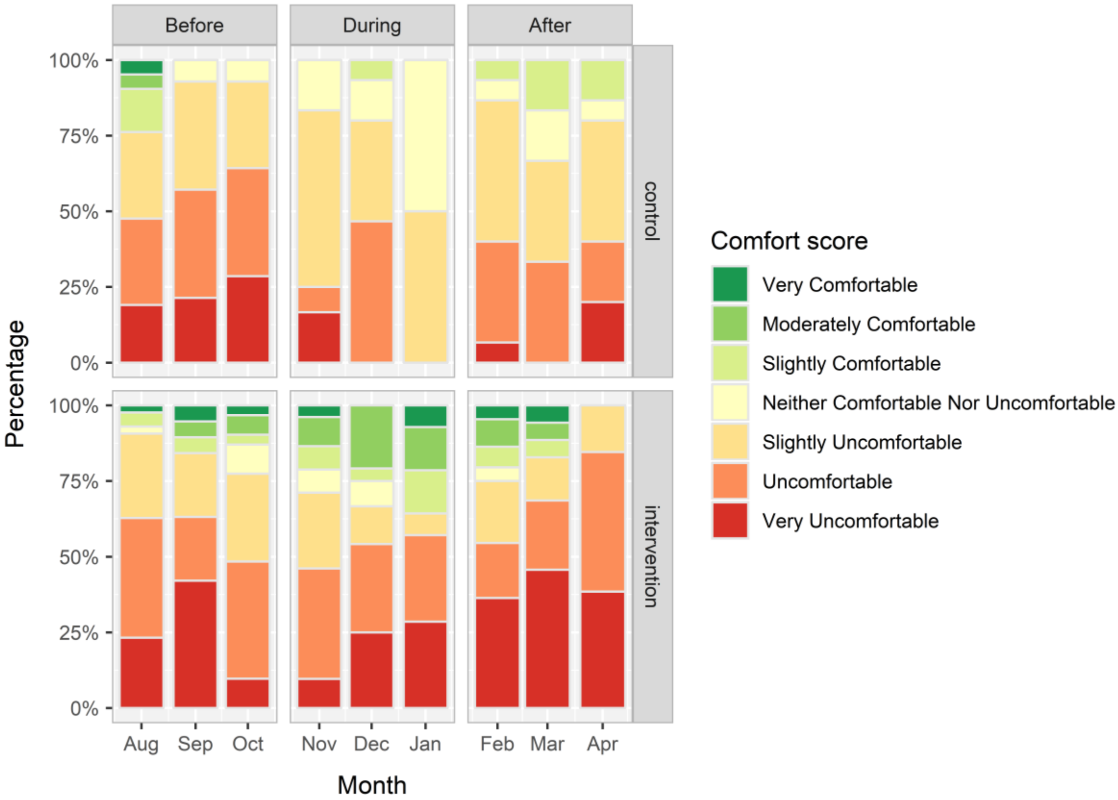

Figure 82. Percentage of staff overall comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Before the behaviour change intervention, both the control and intervention groups reported the highest percentages in the uncomfortable range of scores, with the highest percentage in the ‘uncomfortable’ category (33% and 36% respectively). During and after the intervention, the control group had the highest percentage (45% and 40% respectively) in the ‘slightly uncomfortable’ category. Whereas the intervention group had the highest percentage (33%) in the ‘uncomfortable’ category during the intervention and in the ‘very uncomfortable’ (40%) category after the intervention.

A summary of the findings for the staff comfort survey category ‘overall comfort’ is presented in Table 46.

Table 46. Summary of staff overall comfort scores, comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Study period	Study group	Participants (n)	Completed surveys (n)	Comfortable comfort scores (%)	Neither comfortable nor uncomfortable	Uncomfortable comfort scores (%)
Before	Control	10	49	10	4	86
Before	Intervention	20	93	10	4	86
During	Control	10	29	3	17	80
During	Intervention	20	90	24	7	69
After	Control	10	42	12	10	79
After	Intervention	20	92	16	2	82

Throughout the study period, both the control and intervention groups reported the wards being uncomfortable, although the intervention group appeared slightly less uncomfortable and more comfortable than the control group during the intervention. This is due to (1) high thermal mass of building producing summer overheating with (2) limited opportunities to increase air flow without creating draughts and (3) controlling temperatures on the ward to within the CIBSE winter operating target (22-24°C) during the heating system (1st November 2017 – 30th April 2018) creating colder environment than the staff have previously experienced.

5.2 Staff focus groups

Qualitative data was gathered from the staff focus groups (n = 30 participants, 6 focus groups) for each of the study wards during the study periods before and after the intervention. Each of the staff focus groups had a minimum of four attendees. Transcripts of the recorded staff focus group sessions were manually typed into a Microsoft Word (Microsoft Corporation 2016b) document and rechecked by a Trust administrator to avoid input error (Marshall and Rossman 1989). Please see Appendix H for copies of the transcripts for each focus group.

A summary of the findings for each staff focus group category is presented below. Whilst a manual summary of the findings may be subject to the bias interpretation (Marshall and Rossman 1989, Moravcsik 2014) of the researcher, the purpose of the focus groups was to identify broad themes (Morse 1994) and contextual information to supplement the findings from the staff comfort surveys and quantitative data.

5.2.1 Lighting

Common themes that came up in the staff focus groups for lighting during the day time include "bright", "dark", "difficult to use" and "makes it hot". A summary of the findings for this staff focus group is presented in Table 47.

Table 47. Summary of comments for the staff focus group category of "lighting during the day", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Too dark when we switch it off ▪ Too bright with the lights on ▪ Patients are fall risks. We need it light	▪ Low, quite oppressive ▪ Ward gets hot so we close blinds and turned off lights to reduce temperature, which makes it dark
Intervention A	▪ Bright ▪ Makes it hot ▪ When it's bright we have to put the blinds down, when it's dark we have the lights on it's a vicious circle	▪ Bright in the summer ▪ Dark in the bays at the back ▪ Good that it can be dimmed
Intervention B	▪ All right ▪ Can dim the lights ▪ Not an issue, got lots of windows ▪ Have to close the blinds to keep the temperatures down, which makes it darker	▪ Too bright, too much light ▪ Difficult to use ▪ Affects my eyes

Before the intervention, both the control and intervention groups were generally content with the lighting in the wards but reported the lights were too bright when they are all on and too dark when they are switched off. Both the control and intervention groups reported the lights were difficult to control, which is understandable as the lighting has limited controls, particularly in the 4-bed patient rooms where one switch controls all the main lights.

After the intervention, the Control and Intervention A wards reported the lights were low and dark at the back of the bays while the staff in Intervention B ward still felt the lights were too bright and appeared much more sensitive to the lighting, which be due to a heightened awareness of the negative environmental impacts of artificial lights as a result of the behaviour change intervention.

Both groups highlighted the link with lighting and temperature on the wards in that they felt the luminaries were producing heat adding to summer overheating. However, whilst the control group discussed this link before and after the intervention, the intervention group only discussed this link before the intervention as a result of the knowledge gained by the intervention group from (1) evidence information provided and (2) other stakeholders involved in the intervention, predominantly the hard facilities supplier.

The control group also highlighted the clinical requirements to have the lights on to prevent falls; a risk with the older patients in the wards, which is expected as delivery of excellent patient care is the primary driver for healthcare staff (NHS England 2014, Ryan-Fogarty et al. 2016).

Common themes that came up in the staff focus groups for lighting during the night time include “dimmed in the nurses’ bay”, “off everywhere else”, “all or nothing” and “lights above the bed too bright and hot”. A summary of the findings for this staff focus group is presented in Table 48.

Table 48. Summary of comments for the staff focus group category of “lighting at night”, comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Dimmed at nurse station. Off everywhere else ▪ Lights are not in the right position	▪ Lights not good in side rooms ▪ Lights above the bed are rubbish, yellow light, very hot ▪ Lighting is poor
Intervention A	▪ It’s all or nothing, off its too dark, on its too bright ▪ Should be more individual to the patient. ▪ Lights above the bed are too bright, patients complain, get very hot, often broken ▪ Difficult to use	▪ Dimming the lights makes it comfortable for the patients
Intervention B	▪ Lights on in nurse’s bay. Off everywhere else ▪ The lights above the beds are too bright, often broken ▪ Got to put all lights on in bay; can’t just put one on	▪ Fine ▪ Quite dark on dim ▪ Have to use light above the bed. Too bright, patients complain, gets very hot. Should be energy saving bulbs

Throughout the study, both the control and intervention groups reported (1) during the night lights were switched off in the wards except at the nurses' station, which are kept on but usually dimmed to limit patient disturbance and (2) patient reading lamps above the beds were too bright and got very hot so weren't often used.

5.2.2 Noise

Common themes that came up in the staff focus groups for noise during the day time include "noisy fans", "noisy bins" and "too many people cause noise". A summary of the findings for this staff focus group is presented in Table 49.

Table 49. Summary of comments for the staff focus group category of "noise during the day", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Really noisy with fans on ▪ Rattling crockery on trolleys ▪ Tried to stop staff congregating in corridor, echoing and noisy	▪ Lots of alarms and buzzers. We've got used to this background noise, fans, tvs, radios, alarms, telephones, buzzers ▪ Large squeaky wheelie bins ▪ Some staff very loud
Intervention A	▪ So many staff members as during the week; hideous. ▪ They all gather around the nurses station	▪ Noisy when the nurses get together ▪ Purely down to the number of people that come onto the ward ▪ Quieter on weekends ▪ Laundry trolley noisy but depends on who's pushing it ▪ Meal trolleys noisy but again down to the people not the trolley ▪ Waste bin lids bang
Intervention B	▪ Lots of people around in morning ▪ Bins a really issue for dementia patients ▪ Deafening with the fans on, causes headaches	▪ Between 13:00:00-15:30:00 horrendous, there's too many staff on, doctors, OTs, nurses hand over, then visitors start coming in

During the pre and post-intervention focus groups, both the control and intervention groups reported that the wards were noisy and predominately believed main sources of the noise were (1) people, particularly the staff and (2) trolleys, particularly the catering and laundry trolleys, which are in line with the findings from the 24-hour study pilot.

Before the intervention, both the control and intervention groups sited fans running on the wards as a source of noise, which were being used to combat summer over heating on the wards.

Common themes that came up in the staff focus groups for noise during the night time include “quieter” and “noise heightened”. A summary of the findings for this staff focus group is presented in Table 50.

Table 50. Summary of comments for the staff focus group category of “noise at night”, comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Only two staff on the ward at night so quieter ▪ All things seem loud, like using the commode ▪ Buzzer are very loud, no different than the day time	▪ Calm, quiet ▪ Get a few anxious patients making noise
Intervention A	▪ It’s really quiet so really hear every noise ▪ Alarms & buzzers more highlighted night, really affects patients Get alarms from other wards too	▪ None of participants worked nights
Intervention B	▪ No issues ▪ So quiet so really hear noise when it happens ▪ Can’t have fans on, too noisy	▪ Fine ▪ Staff too noisy at handover 20:30:00 ▪ Mainly patients calling out

Noise was the most reported cause of sleep disturbances in hospitals (Royal College of Nursing 2012, Park et al. 2014) and these sources of noise at night are in line with the findings from the study pilot. During the pre and post-intervention focus groups, both the control and intervention groups felt the wards were quiet at night but any noises that occurred were accentuated, particular from alarms and patients calling out, which will have a significant impact on patient rest.

5.2.3 Temperature

Common themes that came up in the staff focus groups for temperature during the day time include “hot”, “like a sauna” and “poor air flow”. A summary of the findings for this staff focus group is presented in Table 51.

Table 51. Summary of comments for the staff focus group category of "temperature during the day", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Very hot ▪ Like a convection oven ▪ No air flow ▪ Feel the change in temperature compared to downstairs	▪ Hot, too hot ▪ You feel it as soon as you get out of the lift, gets hotter as you go up the floors ▪ If we didn't have the fans on it would be unbearable ▪ Bathrooms are oppressive
Intervention A	▪ Hot, too hot, melting ▪ Patients say it's like a sauna ▪ As soon as you get out of the lift it hits you ▪ In the stairwell it hits you	▪ Hot, sweaty, sticky ▪ Cold this winter but I'm a cold person ▪ Corridor and stairwells extremely hot ▪ Lots of windows but don't open much
Intervention B	▪ Poor air quality ▪ Top floor is stifling ▪ Really hot, sweating, uncomfortable ▪ Get light headed and dizzy ▪ Difficult to concentrate ▪ Bathrooms are the worst ▪ Makes you intolerant ▪ Dread coming to work	▪ All right ▪ Hotter in the side rooms ▪ Dripping in sweat in the bathrooms with thick uniforms, aprons and gloves

During the pre and post-intervention focus groups, both the control and intervention groups felt the wards were extremely hot with no air flow as expected due to the hospital building having (1) no air conditioning or other forms of mechanical cooling with (2) extremely limited (10%) window opening angle and (3) high thermal mass, consequently making it prone to summer overheating.

For both groups the heat in the bathrooms exacerbated by the thick uniforms and personal protective equipment (aprons and gloves) was a particular problem for the staff during the pre and post-intervention focus groups, causing them to excessively perspire and be very uncomfortable.

Whilst both the control and intervention groups were very aware of the impacts of extreme temperature on their patients including dehydration, kidney failure and increase falls. The intervention group also showed greater awareness of the building design and heating system, including their inability to control it. Together with a heightened awareness of the impact the extreme temperatures were having on the staff, including (1) difficulty in concentrating (2) intolerable and (3) light headed and dizzy as a result of the evidence based information provided during the behaviour change intervention.

Common themes that came up in the staff focus groups for temperature during the night time include "cooler", "hot day or night" and "draughty windows". A summary of the findings for this staff focus group is presented in Table 52.

Table 52. Summary of comments for the staff focus group category of "temperature at night", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Cooler, more bearable ▪ No air flow ▪ Cool until 06:00:00 then starts to get hot	▪ Cooler, more bearable ▪ Patients complain they're cold by the windows
Intervention A	▪ Hotter, stifling ▪ Patients get cold so we close the windows, no fans, no air movement	▪ None of participants worked nights
Intervention B	▪ Still hot, the same as day ▪ Our shirts are drenched in sweat ▪ Can't have the fans on, patients get cold ▪ Harder as you can't leave the ward to cool off	▪ Cold when we had the cold weather ▪ Lots of drafts from the windows

Before and after the intervention, the control group reported it was cooler at night. Conversely before the intervention, the intervention group felt the wards were still hot although they acknowledged that their patients' were cold at night.

After the intervention, the intervention group felt their ward was cold due to (1) seasonal variation and (2) heightened awareness of the impacts of temperature on the wards and the need to control temperatures to within the CIBSE winter operating target (22-24°C), as a result of the behaviour change intervention.

Both the control and intervention groups during the pre and post-intervention focus groups reported the windows were draughty, which caused the patients to be cold. Although this theory was tested by putting air temperature sensors near the windows, which showed the cold sensation felt by the staff and patients was the result of the colder outside temperature at night radiating from the glass and aluminium frame of the windows and not draughts from ill-fitting windows.

Common themes that came up in the staff focus groups for temperature across the seasons include "no real difference", "still hot" and "no control over the heating system". A summary of the findings for the questions relating to this staff focus group are presented in Table 53 and Table 54.

Table 53. Summary of comments for the staff focus group category of "temperature comparing summer to winter", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Not a lot of difference ▪ When the heating's on in the winter its stifling, hot & humid ▪ No control over the heating system ▪ Even with the fans on its hot	▪ It's never cold, even in the winter it's hot, always hot ▪ Heating does not respond to changes outside ▪ Patients say it's cold even when it's hot
Intervention A	▪ Not as hot as summer but still hot when the heating's on	▪ Found it cold this winter ▪ Been different because it's been cold this year
Intervention B	▪ It doesn't differ ▪ Heating system is pumping out heat and we have to open the windows ▪ Cooler but still hotter than anywhere else	▪ Found it cold this year ▪ No difference, hot

Table 54. Summary of comments for the staff focus group category of "temperature comparing autumn to spring", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Little more bearable	▪ Not a great deal of difference ▪ Heating doesn't respond to the seasons
Intervention A	▪ It's still hot up here	▪ No comment
Intervention B	▪ Hot when the heating kicks in. It's boiling hot then about 02:00:00 in the morning its freezing cold	▪ Unbearable in the bathrooms all year round, thick uniforms, aprons, gloves, no windows, no extractor

Before the intervention, both the control and intervention groups reported there was no difference between the seasons; the hospital was hot all year round causing them to open the windows in winter when the heating was on. Both groups reported a lack of control over the heating systems and felt it did not react to the temperatures inside the building, as expected due to the building having a high thermal mass alongside a high ventilation rate and a heating system that is difficult to control due to the lack of internal thermostats and zonal control.

After the intervention, the control group again reported that there was no difference between the seasons; the hospital was hot all year round. Some of the staff in the intervention group reported feeling cold during the winter and spring, which they acknowledged was different from previous years whilst others continue to report there was no difference between the seasons. The mixed response may reflect (1) results of controlling temperature within the CIBSE winter operating target (22-24°C) during and after the intervention and (2) expectation of conditions based on previous experience the hospital (usually the hospital is always hot).

5.2.4 Patient wellbeing and recovery

Common themes that came up in the staff focus groups for patient experience include "link to the environment", "lack of sleep", "overheating", "dehydration" and "cold". A summary of the findings for this staff focus group is presented in Table 55.

Table 55. Summary of comments for the staff focus group category of "patient wellbeing & recovery", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Yes, physical environment effects patients wellbeing & recovery ▪ Some patients in bays not getting good night's sleep because of other patients calling out ▪ Main problem is dehydration, keeping fluid levels up is difficult ▪ Blankets heavy, which puts pressure on their legs and feet and may cause sores	▪ Yes, physical environment effects patients wellbeing & recovery ▪ Staff & patients suffering from respiratory problems due to severe heat ▪ Have huge problems trying to bathe patients, hot, no ventilation, thick uniforms, aprons, gloves ▪ Have had patients feint in the shower room ▪ Patients suffer from isolation in side rooms, think they're being punished
Intervention A	▪ Yes, physical environment effects patients wellbeing & recovery ▪ Patients overheat, don't drink enough, dehydrate, effects kidneys ▪ When dehydrated, weak more likely to pick up infections ▪ Windows silly, don't give enough breeze	▪ Yes, physical environment effects patients wellbeing & recovery ▪ If patients are happy with the environment they recover quicker
Intervention B	▪ Yes, significantly effects patients wellbeing & recovery ▪ Hot weather we get lots of problems with dehydration ▪ COPD patients struggle with heat & dry conditions ▪ Heat makes them vulnerable to infections ▪ Patients coating in sweat, makes them feel cold even though they're baking	▪ Yes, physical environment effects patients wellbeing & recovery ▪ Patients are cold at night, particularly by windows, have to have more blankets, heavy, effecting circulation ▪ Warm temperature breeds germs. We see patients regularly coming back within 12 hours because they've pick up a bug here.

Before the intervention, both the control and intervention groups talked about how the excessive temperatures on the wards were negatively impacting on the health of the patients, particularly from (1) dehydration effecting their kidneys (2) respiratory problems (3) increased vulnerability to infections, which reflects the particular seasonal issues they were experiencing due to the summer overheating in the building.

After the intervention, the control group continued to talk about the heat related medical impacts on the patients and the difficulty of bathing patients due to the excessive heat in the bathroom, which do not have windows and only have an extractor fan. Similarly, the intervention group talked about patients regularly returning to hospital after picking up germs bred in the warm environment of the hospital.

The intervention group also discussed how the patients get cold at night, which may create circulation problems and pressure sores when additional blankets are given to the patients.

5.2.5 Patient experience

Common themes that came up in the staff focus groups for patient experience include "link to the environment", "irritable", "isolated" and "frequent fliers". A summary of the findings for this staff focus group is presented in Table 56.

Table 56. Summary of comments for the staff focus group category of "patient experience", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Yes, social side as important ▪ No communal area, patients have to shout across the ward ▪ Side rooms people feel isolated	▪ Yes, environment effects patients experience ▪ Some patients annoyed by other patients calling out
Intervention A	▪ Yes, environment effects patients experience ▪ When hot and bothered get irritable, effects staff and patients experience ▪ Staff get irritable with patients, patients get worse experience	▪ Yes, environment effects patients experience ▪ Yes, but don't think they think about it ▪ If staff not happy this affects them, all rub off on each other ▪ They would complain more ▪ Have sprinkling of frequent fliers
Intervention B	▪ Yes, environment effects patients experience ▪ Uncomfortable, irritable, get angry feel worse about their stay ▪ Number of calls increases significantly in hot weather	▪ No they love it, like a hotel ▪ Happy apart from being cold ▪ More bothered when don't getting attention

Before the intervention, both the control and intervention groups talked about how the heat was making the patients uncomfortable and irritated, which in turn effects their experience of the hospital. The control group also talked about the patients feeling isolated and bored in the single rooms, which is exacerbated by the lack of a communal area leading to a poor hospital experience for the patients.

After the intervention, the control group talked again about the isolation experienced by patients in the single rooms and stated the patients felt they were being punished, whereas the intervention group reported the patient had a happy experience as it felt like staying in a hotel and they talked about "frequent fliers". This may be due to the staff in the intervention group having a heightened awareness that the Trust was trying to create a healthier environment for the patients through the behaviour change intervention.

5.2.6 Changing the environment

Common themes that came up in the staff focus groups for changing the environment include "air conditioning", "fix draughty windows", "lighter uniforms" and "replace noisy bins & alarms". A summary of the findings for this staff focus group is presented in Table 57.

Table 57. Summary of comments for the staff focus group category of "what you would like to change?", comparing the Control, Intervention A and Intervention B study wards, before and after the behaviour change intervention

Study ward	Before the intervention	After the intervention
Control	▪ Air con, cooler ▪ Better control of environment ▪ Communal area ▪ Ventilation in the bathrooms	▪ Air con, cooler ▪ Windows you can open
Intervention A	▪ Air con, cooler ▪ Lighter uniforms ▪ Windows that open at top so they can be opened wider ▪ Extractor fans in the bathrooms ▪ Improve air flow	▪ Cooler, still too hot ▪ Stop feeling cold ▪ Make everyone comfortable
Intervention B	▪ Air con, it's like a greenhouse ▪ Better control of environment ▪ Windows we can open properly ▪ Lighter uniforms ▪ Replace noisy bins ▪ Reduce noise from all buzzers & alarms	▪ Air con, cooler ▪ Fix draughty windows ▪ Better lighting; too complicated, too dangerous (lamps above beds) ▪ Replace noisy bins

As expected, both the control and intervention groups during the pre and post-intervention focus groups primarily talked about wanting air conditioning and better windows that aren't draughty and open further to mitigate the building being too hot. Both groups requested lighter uniforms and better ventilation in the bathrooms, which reflects the particular seasonal issues they were experiencing due to the summer overheating. The nursing staff were provided with lighter uniforms following the study.

After the intervention, the intervention group also talked about mitigating noise on the ward from bins and having better lighting, alarms and buzzers together with a discussion about feeling cold, as a result of knowledge gained through Operation TLC about creating a healthy environment through (1) **T**urning off equipment and unwanted noise (2) **L**ights out and (3) **C**ontrolling temperatures. The bins and cupboards in the wards were fitting with soft close-mechanisms following the study.

5.3 Summary of the qualitative data findings

A summary of the findings from the qualitative data analysis is presented below:

5.3.1 Staff comfort surveys

Staff comfort survey	• **Light:** during and after the intervention, the intervention and control groups reported the highest percentage in the "neither bright nor dim" score. • **Noise:** during and after the intervention, the intervention group had more scores in the quiet range than the control group. • **Temperature:** during and after the intervention, the intervention group reported being cold whereas the control group reported mixed responses ranging between hot and cold. • **Humidity:** during and after the intervention, the intervention and control groups reported the highest percentage in the "neither humid nor dry" score. • **CO_2:** during and after the intervention, the intervention and control groups reported the highest percentage in the "neither bad nor good" score. • **Overall comfort:** during and after the intervention, the intervention group had more scores in the comfortable range than the control group.

5.3.2 Staff focus groups

Staff focus groups	• **Lighting:** before the intervention, the control group reported the ward was dark and staff in the intervention group reported the wards were bright. After the intervention, the intervention and control groups reported mixed results. Both groups thought the lighting was difficult to control. • **Noise**: the intervention and control groups reported the wards were noisy before and after the intervention. Both groups reported that the wards were quieter at night but any noise that occurred was accentuated. • **Temperature:** before the intervention, the intervention and control groups reported the wards were hot during the day and night, winter and summer. After the intervention, staff in the intervention group reported it was cooler at night and during the winter. Both groups were very aware of the impacts extreme temperature had on the health of their patients. • **Patient experience:** the control group reported that patients felt isolated in the single rooms, particularly without access to a communal lounge. The intervention group reported their patients felt the hospital was like a hotel. • **Changing the environment:** both groups asked for air conditioning, lighter uniforms and better windows that opened more and weren't draughty.

A further discussion of the findings from this chapter may be found in Chapter 8. The findings from an exploration of the relationships between the data variables is explored in the next chapter.

Chapter 6 Examining relationships between the variables

In order to analyse the relationships between the variables; the quantitative and qualitative datasets were aggregated to average minutely values and then merged into a single dataset, discussed in Chapter 3, section 3.10. The following inferential analyses were completed on the merged dataset across the study (1st August 2017 - 30th April 2018) using R Studio software programme (CRAN 2018).

This chapter presents the results of analysing the relationships between the numerical environmental variables (air temperature, relative humidity and CO_2) in section 5.1 and between the categorical variables (patient bed movement events, light events and window movement events) in section 5.2. Section 5.3 presents the results of analysing the relationships between the categorical variables (patient bed movement events, comfort surveys and window movement events) and numerical variables (air temperature, relative humidity, CO_2 and sound data). A summary of the relationship findings is presented in section 5.4.

6.1 Numerical variables

Correlation coefficients are used to look at associations between quantitative or numerical variables in a dataset (Kranzler 2003). The Spearman's rho method is used to measure the relationship between two numerical variables with non-normal distributions and a large sample size (Kranzler 2003, Field et al. 2012).

Therefore, Spearman's rho correlation test was run on the quantitative variables to identify whether there was an association between the relevant quantitative variables in the study, namely air temperature, relative humidity and carbon dioxide (CO_2).

The results show there was a positive association between air temperature and relative humidity ($p = <2.23\text{-}16$), and air temperature and CO_2 ($p = <2.23\text{-}16$), although the correlation was weak between air temperature and CO_2 ($r_s = 0.20$) and moderate between air temperature and humidity ($r_s = 0.32$). There was a negative association between relative humidity and CO_2 ($p = <2.23\text{-}16$), although the correlation was weak ($r_s = -0.24$) The association between the environmental variables is the result of the building operation, which comprises of mechanical ventilation with a high air exchange rate (6 air changes per hour) and a central heating system distributing heat during the heating season (1st November 2017 until 30th April 2018) through radiant panels in the ceiling; both HVAC systems are controlled by a building management system (BMS).

6.2 Categorical variables

For categorical variables, non-parametrical statistical tests are used to look at associations between the categorical variables in a dataset (Kranzler 2003, Field et al. 2012). The Pearson's Chi-square test is used to measure the relationship between two (binary) categorical variables with a large sample size (<20) (Field et al. 2012).

6.2.1 Patient bed movements events and light events

Natural light creates a reduction in sleep disturbances (Bartick et al. 2010) and an increased levels of artificial light creates disruption to the circadian rhythm (Bartick et al. 2010, Amundadottir et al. 2016). Consequently, a Pearson's Chi-square test was run to analyse whether there was an association between the patient bed movement events and light events across the study (1st August 2017 - 30th April 2018). The results are shown in Table 58.

Table 58. Results of the Pearson's Chi-square test for the association between patient bed movement events and light events across the study (1st August 2017 - 30th April 2018)

Patient bed movements	X-squared	Degrees of freedom	p-value	Odds ratio
Light	17582	2	< 2.2e-16	2.33

The results show there was a significant relationship between patient bed movement events and light events, and the odds of the patients moving in their beds when the light is on is 2.33 times the odds of the patient not moving in their beds when the lights are on.

Increased levels of bright synthetic light creates disruption to the circadian rhythm, which affects sleep patterns (Bartick et al. 2010, Amundadottir et al. 2016). Therefore, this result is expected which is why staff were given the secondary Operation TLC actions of 'introduce a quiet time for an hour after lunch' (13:30:00-14:30:00) and 'night time switch off' (23:00:00) during which lights were switched off or dimmed to increase patient rest.

6.2.2 Patient bed movements events and window movement events

A Pearson's Chi-square test was undertaken to analyse whether there was an association between the patient bed movement events and window movement events across the study (1st August 2017 - 30th April 2018). The results are shown in Table 59.

Table 59. Results of the Pearson's Chi-square test for the association between patient bed movement events and window movement events across the study (1st August 2017 - 30th April 2018)

Patient bed movements	X-squared	Degrees of freedom	p-value	Odds ratio
Window movements	555.9	1	< 2.2e-16	1.47

The results show there was a significant relationship between patient bed movement events and window movement events, and the odds of the patients moving in their beds when there is a window movement event is 1.47 times the odds of the patient not moving in their beds when there is a window movement event.

Feedback from staff during the focus groups confirmed that their patients were particularly sensitive to draughts, which caused them feel cold when the windows were open on the wards even when the nursing staff though the environment was hot.

6.3 Categorical and numerical variables

6.3.1 Staff comfort surveys and their associated quantitative variable

An examination of an indoor environment can be simply achieved using an occupancy enquiry about the comfort of the environment in conjunction with concurrent measurement of the thermal environment (Humphreys et al. 2016). Therefore, this section analyses the relationship between the results of the qualitative comfort surveys and the quantitative variables.

Regression analysis is used to assess the extent to which an outcome (dependent) variable can be predicted from a predictor (independent) variable, and an ordered logistic regression analysis is used to assess whether there is a relationship between an ordinal (dependent) variable and a numerical (independent) variable (Field et al. 2012). This section examines the relationship between the staff comfort scores (ordinal dependent variable) and their associated quantitative variable (continuous independent variable). A 95% confidence level was used for all the regression analyses. For each ordered logistic regression analysis, trend lines were produced for the study period before, during and after the behaviour change intervention. Each trend line was calculated using the following equation:

$$Y = ax+b$$

where 'a' is the slope, 'b' is the y-intercept, 'x' is the value from air temperature data and y is value from the staff comfort scores for temperature.

6.3.1.1 Sound

An ordered logistic regression analysis was conducted to identify the association between the scores (ordinal) from question relating to noise in the staff comfort survey and the numerical (continuous) data from the sound sensors. The results are presented in Figure 83.

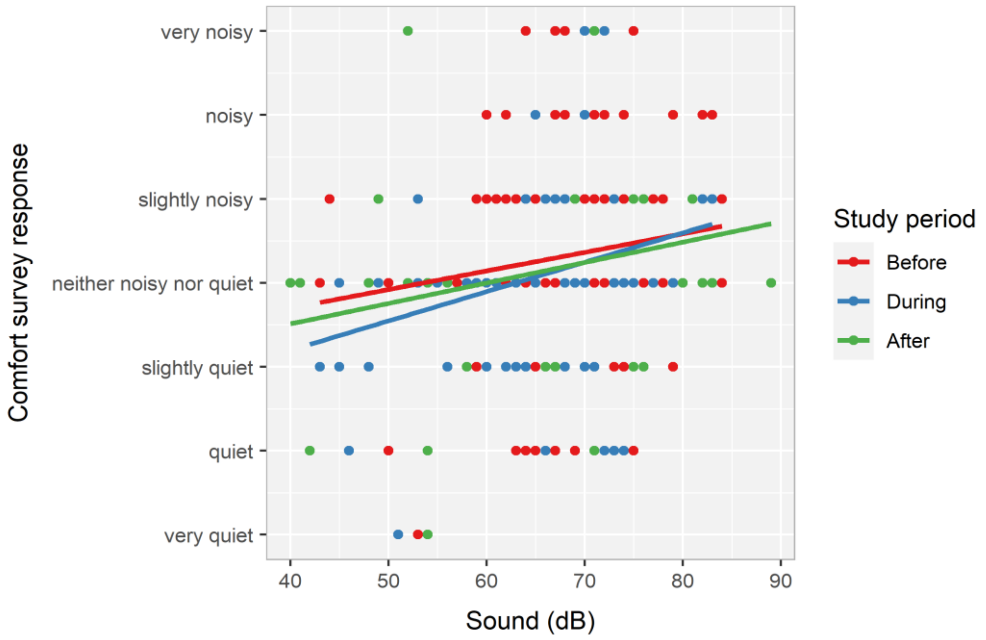

Figure 83. Ordered logistic regression model showing the correlation between the staff comfort survey scores for noise and the data (dB) gathered from the sound sensors across the study (1st August 2017 - 30th April 2018)

A comparison of the slope, intercept and p-values for the study period before, during and after the intervention is shown in Table 60.

Table 60. Results of the ordered logistic regression analysis on the scores (ordinal) from the staff comfort survey question relating to noise and the numerical (continuous) sound data (dB); comparing the slope (a), intercept (b) and p-values for the study period before, during and after the intervention

Study period	Estimate a	Estimate b	p-value
Before	0.05309389	4.96887873	0.1628
During	0.0573597	3.2972388	0.00276
After	0.04722748	4.06806617	0.04028

As expected, the results of the ordered logistic regression model showed there was a positive association between the responses in the staff comfort survey relating to noise and the data (dB) from the sound sensors in the study periods during and after the intervention but not an association before the intervention. This may be as result of staff in the intervention group, which had twice as many participants as the control ward, having an increased awareness of the impacts of noise on the wards as a result of the evidence based information used during the intervention.

For the during study period the confidence intervals for the intercept ranged between 0.29781764 (2%) and 3.2972388 (97.5%) and the confidence intervals for the slope ranged between 0.01261764 (2%) and 0.0573597 (97.5%). For the after study period the confidence intervals for the intercept ranged between 1.009950773 (2%) and 4.06806617 (97.5%) and the confidence intervals for the slope ranged between 0.001452813 (2%) and 0.04722748 (97.5%). This shows the model is not a particularly good estimator of association between the scores (ordinal) from question relating to noise in the staff comfort survey and the numerical (continuous) data from the sound sensors.

6.3.1.2 Air temperature

An ordered logistic regression analysis was conducted to identify the association between the scores (ordinal) from question relating to temperature in the staff comfort survey and the numerical (continuous) data from the air temperature sensors. The results are presented in Figure 84.

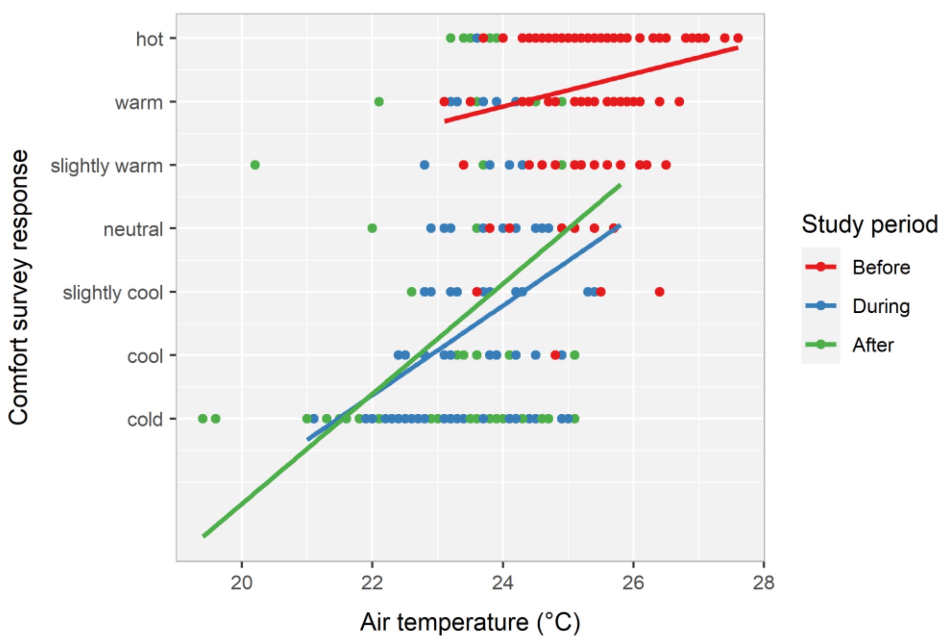

Figure 84. Ordered logistic regression model showing the correlation between the staff comfort survey scores for temperature and the data (°C) gathered from the air temperature sensors across the study (1st August 2017 - 30th April 2018)

A comparison of the slope, intercept and p-values for the study period before, during and after the intervention is shown in Table 61.

Table 61. Results of the ordered logistic regression analysis on the scores (ordinal) from the staff comfort survey question relating to temperature and the numerical (continuous) air temperature data (°C); comparing the slope (a), intercept (b) and p-values for the study period before, during and after the intervention.

Study period	Estimate a	Estimate b	p-value
Before	0.4477926	4.5217218	0.00832
During	1.030364	-6.527339	4.07e-05
After	1.195596	-10.008828	7.47e-07

As expected, the results of the ordered logistic regression model showed there was a positive association between the responses in the staff comfort survey relating to temperature and the data from the air temperature sensors before, during and after the intervention. For cooler climates like the UK, it is broadly accepted that air temperature is the most important factor affecting thermal comfort (Angus 1968) and Griffiths (1990) reported having the 'right temperature' was found to be the most important consideration by people in a user satisfaction survey of UK buildings.

For the before study period the confidence intervals for the intercept ranged between -5.08516992 (2%) and 4.5217218 (97.5%) and the confidence intervals for the slope ranged between 0.06923125 (2%) and 0.4477926 (97.5%). For the during study period the confidence intervals for the intercept ranged between -21.7935313 (2%) and -6.527339 (97.5%) and the confidence intervals for the slope ranged between 0.3816824 (2%) and 1.030364 (97.5%). For the after study period the confidence intervals for the intercept ranged between -25.4061674 (2%) and -10.008828 (97.5%) and the confidence intervals for the slope ranged between 0.5408413 (2%) and 1.195596 (97.5%).

This shows the model is not a particularly good estimator of association between the scores (ordinal) from question relating to temperature in the staff comfort survey and the numerical (continuous) data from the air temperature sensors.

6.3.1.3 Relative humidity

An ordered logistic regression analysis was conducted to identify the association between the scores (ordinal) from question relating to humidity in the staff comfort survey and the numerical (continuous) data from the relative humidity sensors. The results are presented in Figure 85.

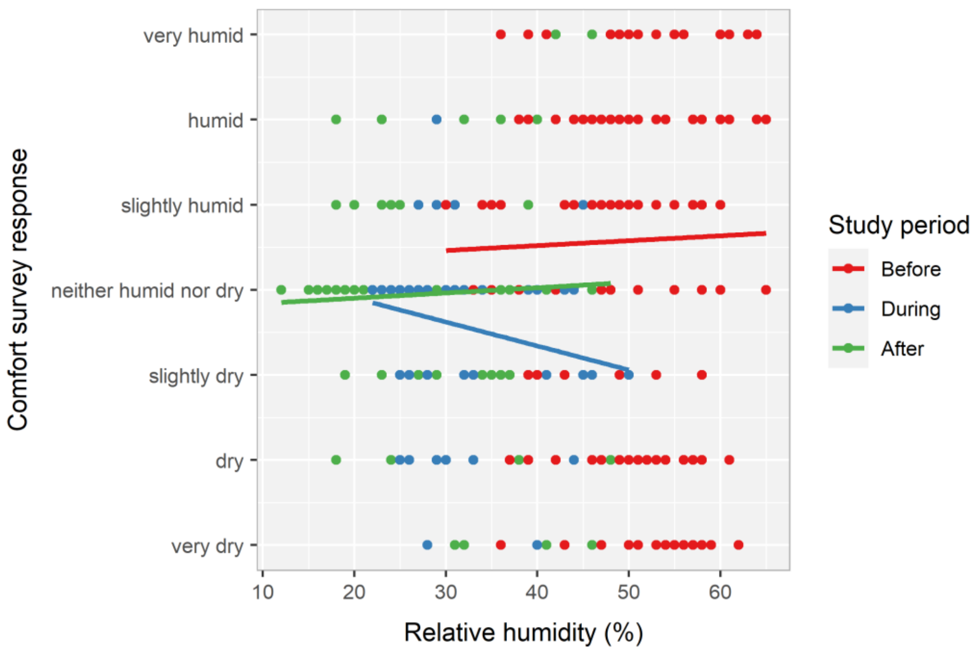

Figure 85. Ordered logistic regression model showing the correlation between the staff comfort survey scores for humidity and the data (%) gathered from the relative humidity sensors across the study (1st August 2017 - 30th April 2018)

A comparison of the slope, intercept and p-values for the study period before, during and after the intervention is shown in Table 62.

Table 62. Results of the ordered logistic regression analysis on the scores (ordinal) from the staff comfort survey question relating to humidity and the numerical (continuous) relative humidity data (%); comparing the slope (a), intercept (b) and p-values for the study period before, during and after the intervention.

Study period	Estimate a	Estimate b	p-value
Before	0.04792489	6.41870595	0.789366
During	-0.005004252	5.195390235	0.0188
After	0.02528774	4.35029041	0.53

The results of the ordered logistic regression model show there was a negative association between the responses in the staff comfort survey relating to humidity and the data from the relative humidity sensors during the behaviour change intervention but not an association before or after the intervention. People perceive that high humidity makes an environment feel hotter (Nicol and Humphreys 2004), so the staff may have associated feeling colder with decreasing humidity levels.

During the intervention, the confidence intervals for the intercept ranged between 3.741847 (2%) and 5.195390235 (97.5%) and the confidence intervals for the slope ranged between -0.051352 (2%) and -0.005004252 (97.5%), which shows the model is a reasonably good estimator of association between the scores (ordinal) from question relating to humidity in the staff comfort survey and the numerical (continuous) data from the relative humidity sensors for this study period.

6.3.1.4 Air quality

An ordered logistic regression analysis was conducted to identify the association between the scores (ordinal) from question relating to air quality in the staff comfort survey and the numerical (continuous) data from the CO_2 sensors. The results are presented in Figure 86.

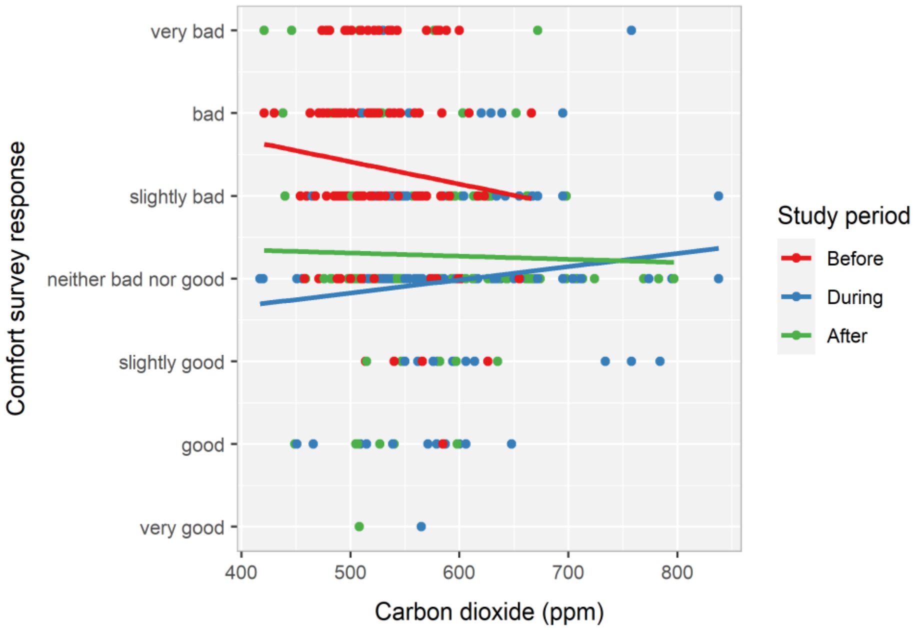

Figure 86. Ordered logistic regression model showing the correlation between the staff comfort survey scores for air quality and the data (ppm) gathered from the CO_2 sensors across the study (1st August 2017 - 30th April 2018)

A comparison of the slope, intercept and p-values for the study period before, during and after the intervention is shown in Table 63.

Table 63. Results of the ordered logistic regression analysis on the scores (ordinal) from the staff comfort survey question relating to air quality and the numerical (continuous) CO_2 data (ppm); comparing the slope (a), intercept (b) and p-values for the study period before, during and after the intervention.

Study period	Estimate a	Estimate b	p-value
Before	0.001251338	8.848000282	0.183
During	0.003828713	4.369943657	0.166
After	0.002097164	5.924145748	0.764

The results of the ordered logistic regression model show there was not an association between the responses in the staff comfort survey relating to air quality and the data from the CO_2 sensors before during and after the intervention. Previous studies (Bedford and Warner 1939, Angus 1968) reported that occupants associated poor air quality with a build-up of disagreeable heat moisture and odour rather than CO_2, which may explain the reason for the lack of association.

6.3.2 Patient bed movement events and the other variables

6.3.2.1 Patient bed movements and the quantitative environmental variables

As the outcome variable was categorical (binary) and the predictor variables were numerical (continuous) with a non-normal distribution, a logistic regression analysis (95% confidence level) was run to identify whether there was an association between patient bed movement events and the environmental variables (air temperature, relative humidity and CO_2) across the study (1st August 2017 - 30th April 2018). The results are shown in Tables 64-66.

Table 64. Results of the logistic regression analysis (95% confidence level) run to identify the association between patient bed movement events and air temperature across the study (1st August 2017 - 30th April 2018)

Patient bed movement events	Estimate	Standard error	t-value	p-value
Air temperature	-0.213	0.037	-5.704	1.17e-08

The results show there was a significant relationship between patient bed movement events and air temperature, which is expected as age reduces the ability to thermo-regulate (Havenith 2001), so coupled with lower activity levels and lower clothing insulation it is reasonable to assume that older patients will require higher temperatures to achieve thermal comfort than the healthcare staff (van Hoof and Hensen 2006). During the focus groups, staff reported that the patients often felt cold on the wards, even when the staff felt the environment was hot.

Table 65. Results of the logistic regression analysis (95% confidence level) run to identify the association between patient bed movement events and relative humidity across the study (1st August 2017 - 30th April 2018)

Patient bed movement events	Estimate	Standard error	t-value	p-value
Relative humidity	-0.042	0.004	-10.711	< 2e-16

The results show there was a significant relationship between patient bed movement events and relative humidity, which is expected as relative humidity is one of the factors that influences the regulation of body temperature (Brown 1959 cited in Angus 1968) and is consequently one of the influencing factors for thermal comfort.

Table 66. Results of the logistic regression analysis (95% confidence level) run to identify the association between patient bed movement events and CO_2 across the study (1st August 2017 - 30th April 2018)

Patient bed movement events	Estimate	Standard error	t-value	p-value
CO_2	0.012	0.001	20.462	< 2e-16

The results show there was a significant relationship between patient bed movement events and CO_2. Whilst the study wards had a high air change rate in the building that created a fairly uniformed volume of CO_2 in the study wards the significant relationship between patient bed movement events and CO_2 emphasises the sensitivity of patients to their environment.

6.3.2.2 Patient bed movements and peak noise (>85dB)

Peak noise levels in hospitals typically measured above 85 decibels (dB) (Ulrich et al. 2004). As the two variables being analysed were categorical (count of binary variables), a Pearson's Chi-square test was run to analyse whether there was an association between the patient bed movement events and sound data exceeding peak noise levels (85dB) across the study (1st August 2017 - 30th April 2018). The results are shown in Table 67.

Table 67. Results of the Pearson's Chi-square test for the association between patient bed movement events and peak noise (>85dB) across the study (1st August 2017 - 30th April 2018)

Patient bed movement events	X-squared	Degrees of freedom	p-value	Odds ratio
Sound >85dB	10.51	1	0.001	1.68

The results show there was a significant relationship between patient bed movement events and noise levels exceeding peak noise (85dB), which confirms previous studies that noise was the primary concern for patients about the hospital environment (Royal College of Nursing 2012) and the findings from the study pilot.

The odds of the patients moving in their beds when there is a peak noise event (<85dB) is 1.68 times the odds of the patients not moving in their beds when there is a peak noise event (<85dB).

6.3.2.3 Patient bed movements and noise levels exceeding the upper limit for background noise (68dB) during the day time

Background noise levels in hospitals typically measured 45-68dB (Ulrich et al. 2004). As the two variables being analysed were categorical (count of binary variables), a Pearson's Chi-square test was undertaken to analyse whether there was an association between the patient bed movement events and noise levels exceeding the upper limit for background noise (68dB) in hospitals during the day time across the study (1st August 2017 - 30th April 2018). The results are shown in Table 68.

Table 68. Results of the Pearson's Chi-square test for the association between patient bed movement events and noise levels exceeding the upper limit for background noise (68dB) in hospitals during the day time across the study (1st August 2017 - 30th April 2018)

Patient bed movement events	X-squared	Degrees of freedom	p-value	Odds ratio
Sound >68dB	97.876	1	< 2.2e-16	1.48

The results show there was a significant relationship between patient bed movement events and noise levels exceeding the upper limit for background noise (68dB) in a hospital during the day time, which confirms previous findings that noise is the most reported cause of sleep disturbances (Royal College of Nursing 2012, Park et al. 2014) in hospitals and the findings from the study pilot.

The odds of the patients moving in their beds when noise levels exceed 68dB during the day time is 1.48 times the odds of the patients not moving in their beds when noise levels exceed 68dB during the day time.

6.3.2.4 Patient bed movements and noise levels above 60dB at night time

Noise levels exceeding 60dB negatively affects sleep in hospitals (Hilton 1985). As the two variables being analysed were categorical (count of binary variables), a Pearson's Chi-square test was undertaken to analyse whether there was an association between patient bed movement events and sound levels exceeding 60dB at night across the study (1st August 2017 - 30th April 2018). The results are shown in Table 69.

Table 69. Results of the Pearson's Chi-square test for the association between patient bed movements and noise levels exceeding 60dB at night across the study (1st August 2017 - 30th April 2018)

Patient bed movement events	X-squared	Degrees of freedom	p-value	Odds ratio
Sound >60dB at night	52.653	1	3.979e-13	2.45

The results show there was a significant relationship between bed movement events and sound levels exceeding 60dB at night, which confirms previous findings that noise disturbs sleep patterns (Mazer 2012, Basner et al. 2014) and 86% of patients surveyed reported having "bad sleep" as a direct consequence of noise on the ward (Park et al. 2014). This also confirms the findings from the study pilot.

The odds of the patients moving in their beds when noise levels exceed 60dB during the night time is 2.45 times the odds of the patients not moving in their beds when noise levels exceed 60dB during the night time.

6.3.3 Window movement events and the quantitative environmental variables

As the outcome variable was categorical (binary) and the predictor variables were numerical (continuous) with a non-normal distribution, a logistic regression analysis (95% confidence level) was run to identify whether there was an association between window movement events and environmental variables (air temperature, relative humidity and CO_2) across the study (1st August 2017 - 30th April 2018). The results are shown in Table 70-72.

Table 70. Results of the logistic regression analysis (95% confidence level) run to identify the association between window movement events and air temperature across the study (1st August 2017 - 30th April 2018)

Window movement events	Estimate	Standard error	t-value	p-value
Air temperature	-0.201	0.027	-7.355	1.95e-13

As expected, the results show there was a significant relationship between window movement events and air temperature. The staff in the study wards had very little control over air temperature, relative humidity, carbon dioxide and lighting in the ward for which the controls were too limited and opening windows was one of the only environmental controls available to them, particularly for combating overheating, which the staff reported in comfort surveys and discussed frequently in the focus groups.

Table 71. Results of the logistic regression analysis (95% confidence level) run to identify the association between window movement events and relative humidity across the study (1st August 2017 - 30th April 2018)

Window movement events	Estimate	Standard error	t-value	p-value
Relative humidity	-0.018	0.003	-5.749	9.03e-09

As expected, the results show there was a significant relationship between window movement events and relative humidity, which is the only adaptive behaviour available for the staff in the wards. People perceive that high humidity makes an environment feel hotter (Nicol and Humphreys 2004) and opening windows is the most common adaptive behaviour used by people for circulating air and cooling indoor temperatures (Rijal et al. 2007).

Table 72. Results of the logistic regression analysis (95% confidence level) run to identify the association between window movement events and CO_2 across the study (1st August 2017 - 30th April 2018)

Window movement events	Estimate	Standard error	t-value	p-value
CO_2	-0.001	0.0004	-1.294	0.196

The results show there was not a significant relationship between window movement events and CO_2 as the result of the high air change rate in the building masking the effects of the window opening activity in the study wards.

6.4 Summary of the relationships between the variables

A summary of the findings from statistically analysing the relationships between the numerical and categorical data variables is presented below:

6.4.1 Numerical variables

Quantitative variables	• There was a weak positive correlation between air temperature & CO_2, a moderate positive correlation between air temperature & relative humidity and weak negative correlation between relative humidity & CO_2.

6.4.2 Categorical variables

Patient bed movement v artificial light	• There was a significant relationship between patient bed movement events and lights events.
Patient bed movement events v window movement events	• There was a significant relationship between patient bed movement events and window movement events.

6.4.3 Categorical and numerical variables

Comfort survey v quantitative variable	• There was a positive association between the responses in the comfort surveys relating to noise and the sound data from the sensors during and after the intervention only. • There was a positive association between the responses in the comfort surveys relating to temperature and the air temperature data from the sensors across the study periods. • There was negative association between the responses in the comfort surveys relating to humidity and the relative humidity data from the sensors during the intervention only. • There was not an association between the responses in the comfort surveys relating to air quality and CO2 data from the sensors.
window movement events v quantitative variable	• There is a significant relationship between window movement events and the environmental variables air temperature and relative humidity. • There is not a significant relationship between window movement events and CO_2.
Patient bed movement events v quantitative variable	• There is a significant relationship between patient bed movement events and the variables air temperature, relative humidity and CO_2. • There is a significant between patient bed movement events and sound levels exceeding peak noise levels (85dB), sound levels exceeding the upper limit for background noise (68dB) during the day time and sound levels exceeding 60dB at night time.

The findings from an exploration of the research questions and hypotheses is explored in the next chapter.

Chapter 7 Research questions and hypotheses

It was anticipated that the study may potentially realise the following sustainability benefits of implementing an energy behaviour change intervention, adapted from Operation TLC:

- Reduced energy consumption and lower carbon emissions,
- improved patient wellbeing in such categories as improved rest and comfort, together with reduced length of stay, and
- increased staff satisfaction in such categories such as improved staff retention and levels of sickness (Daly and Large 2016).

This chapter analyses whether the study realised these sustainability benefits. Section 7.1 presents the results from a series of research hypotheses designed to help answer research question one (RQ1): In what ways and to what extent does running a behaviour change intervention in a hospital reduce energy consumption? Section 7.2 presents the results from a series of research hypotheses designed to help answer research question two (RQ2): In what ways and to what extent does running a behaviour change intervention in a hospital improve patient well-being? Section 7.3 presents the results from a series of research hypotheses designed to help answer research question three (RQ3): In what ways and to what extent does running a behaviour change intervention in a hospital improve staff satisfaction? A summary of the findings from this chapter is presented in section 7.4.

The following inferential statistical analyses were completed using the merged dataset discussed in Chapter 3, section 3.10.

7.1 RQ1: In what ways and to what extent does running a behaviour change intervention in a hospital reduce energy consumption?

From the literature review, it was identified that the potential benefits of implementing an energy behaviour change intervention, adapted from Operation TLC was reduced energy consumption and lower carbon emissions (Daly and Large 2016).

7.1.1 H1: The intervention group did not switch off equipment more than the control group

The associated Trust Operation TLC actions were:

- Turn off any unwanted medical equipment where possible,
- Turn off computers, monitors and TVs that are not being used.

As the outcome variable (electricity for small power kWh) is numerical with a non-normal distribution and two non-paired samples (control, intervention), the null hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 73.

Table 73. Results of the Mann Whitney U-test (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H1: The intervention group did not switch off equipment more than the control group

Study period	Sample (n)	W value	p-value	Post hoc test
Before	175676	3877800000	0.06	0.06
During	265068	1.404e+10	< 2.2e-16	<2e-16
After	256309	1.3008e+10	< 2.2e-16	<2e-16

The results showed that before the intervention there is a not a statistically significant difference between the medians of the minutely energy consumption data (kWh) for small power in the control and intervention groups before the intervention.

However, there is a statistically significant difference between the medians of the minutely energy consumption data (kWh) for small power in the control and intervention groups during (I_2) and after (I_3) the intervention. Consequently, the hypothesis is rejected for the during and after study periods confirming the intervention group did switch off equipment more than the control group as a consequence of the behaviour change intervention.

7.1.2 H2: The intervention group did not switch off lights more than the control group

The associated Trust Operation TLC actions were:

- Switch off lights in unoccupied rooms.
- Open blinds and make the most of natural light by switching main lights off.

During the study artificial lighting in the study wards was measured using numerical variables (1) electricity for lighting (kWh) and (2) ‘lights on’ hours.

As the outcome variables (1) electricity for lighting (kWh) and (2) ‘lights on’ hours are numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%.

The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Tables 74-75.

Table 74. Results of the Mann Whitney U-test (95% confidence level) and Bonferroni-Dunn post hoc tests analyses to test research hypothesis H2: The intervention group did not switch lights off more than the control group for the variable electricity for lighting

Study period	Sample (n)	W value	p-value	Post hoc test
Before	175678	4315700000	< 2.2e-16	<2e-16
During	265073	9960085667	< 2.2e-16	<2e-16
After	256314	9849200000	< 2.2e-16	<2e-16

The results showed there is a statistically significant difference between the medians of the minutely energy consumption data (kWh) for lighting in the control and intervention groups before, during and after the intervention. Consequently, the null hypothesis is rejected for each study period confirming the intervention group did use less electricity for lighting than the control group. However, as this occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

As the light sensors do not distinguish between natural and artificial light, this approach is only valid for winter months and will over-predict the 'lights on' values during the summer months. Consequently, the data for the period before the intervention was disregarded from the study.

Table 75. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H2: The intervention group did not switch lights off more than the control group for the variable 'lights on' hours

Study period	Sample (n)	W value	p-value	Post hoc test
Before	796549	51762	< 2.2e-16	<2e-16
During	761420	42905	1.375e-11	1.4e-11

The results show there is a statistically significant difference between control and the intervention groups during and after the intervention. Consequently, the null hypothesis is rejected for the during and after study periods confirming the intervention group did switch off lights more than the control group as a consequence of the behavior change intervention.

7.1.3 H3: The intervention group did not implement night time switch off

The associated Trust Operation TLC action was:

- Switch lights off at night.

As the data (light on/off events) is categorical with two non-paired samples (control, intervention) of over 20 units the hypothesis was tested using a Pearson's Chi-square test. As the light sensors do not distinguish between natural and artificial light, this approach is only valid for winter months and will over-predict the 'lights on' values during the summer months. Consequently, the data for the period before the intervention was disregarded from the study. The results of the Pearson's Chi-square and odd ratio tests are shown in Table 74.

Table 76. Results of the Pearson's Chi-square and odd ratio tests run to test research hypothesis H3: The intervention group did not implement night time switch off

Study group	Sample (n)	X^2 value	df	p-value	Odds ratio
During	81159	1427.8	1	<2.2e-16	1.67
After	59391	302.42	1	<2.2e-16	1.36

The results show there is a statistically significant difference between control and the intervention groups during and after the intervention. Consequently, the null hypothesis is rejected confirming the intervention group did switch off lights during night time switch off as a consequence of the behaviour change intervention.

During the intervention the odds of the intervention group switching lights off is 1.67 times the odds of control group switching lights off for night time switch off. After the intervention the odds of the intervention group switching lights off is 1.36 times the odds of control group switching lights off for night time switch.

7.1.4 H4: The intervention group did not save more energy than the control group

As the outcome variable (electricity kWh) is numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 77.

Table 77. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H4: The intervention group did not save more energy than the control group

Study period	Sample (n)	W value	p-value	Post hoc test
Before	351354	1.5928e+10	< 2.2e-16	<2e-16
During	530141	4.3176e+10	< 2.2e-16	<2e-16
After	512623	4.0406e+10	< 2.2e-16	<2e-16

The results show there is a statistically significant difference between the medians of the control and the intervention groups before, during and after the behaviour change intervention. Consequently, the null hypothesis is rejected confirming the intervention group did save more energy than the control group. However, as this occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

7.2 RQ2: In what ways and to what extent does running a hospital improve patient wellbeing?

From the literature review, it was identified that the potential benefits of implementing an energy behaviour change intervention, adapted from Operation TLC was improved patient wellbeing in such categories as improved rest and comfort, together with reduced length of stay (Daly and Large 2016).

7.2.1 H5: The intervention group did not reduce noise levels more than the control group

The associated Trust Operation TLC action was:

- Close doors, cupboards and bins quietly.

As the outcome variable (noise levels dB) is numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 78.

Table 78. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H5: The intervention group did not reduce noise levels more than the control group

Study period	Sample (n)	W value	p-value	Post hoc test
Before	796650	4.6252e+10	< 2.2e-16	<2e-16
During	796549	5.4408e+10	< 2.2e-16	<2e-16
After	761420	3.8367e+10	< 2.2e-16	<2e-16

The results show there is a statistically significant difference between the medians of the control and the intervention groups before, during and after the behaviour change intervention. Consequently, the null hypothesis is rejected confirming the intervention group did reduce noise levels more than the control group. However, as this occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

7.2.2 H6: The intervention group did not control temperature more than the control group

The associated Trust Operation TLC actions were:

- Close window when heating is on.
- Close door when rooms aren’t occupied.
- Layer up if cold.
- Encourage patients or visitors remain active.

Consequently, the control of temperatures was measured using the numerical variables (1) air temperature (°C) and (2) window movement events (count). As both outcome variables are numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Tables 79 and 80.

Table 79. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H6: The intervention group did not control temperature more than the control group for the variable air temperature (°C)

Study period	Sample (n)	W value	p-value	Post hoc test
Before	796650	8.1116e+10	< 2.2e-16	<2e-16
During	796549	8.7032e+10	< 2.2e-16	<2e-16
After	761420	6.8228e+10	< 2.2e-16	<2e-16

The results show there is a statistically significant difference between the medians of the control and the intervention groups before, during and after the behaviour change intervention. Consequently, the null hypothesis is rejected confirming the intervention group did control temperature more than the control group. However, as this occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

Table 80. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H6: The intervention group did not control temperature more than the control group for the variable window movement events (count)

Study period	Sample (n)	W value	p-value	Post hoc test
Before	796650	40308449	0.0001618	0.00016
During	796549	3075560	< 2.2e-16	<2e-16
After	761420	15900902	< 2.2e-16	<2e-16

The results show there is a statistically significant difference between the medians of the control and the intervention groups before, during and after the behaviour change intervention. Consequently, the null hypothesis is rejected confirming the intervention group did control temperature in relation to window movement events more than the control group. However, as this occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

7.2.3 H7: The intervention group did not implement quiet time

The associated Trust Operation TLC action was:

- Introduce a quiet time for an hour or two after lunch.

Quiet time involves (1) turning lights off or dimming them and closing curtains, and (2) reducing noise on the wards to giving patients a peaceful time to (3) rest and recover together with time for staff to catch up on other tasks.

As the data (1) light on/off events is categorical with two non-paired samples (control, intervention) of over 20 units the hypothesis was tested using a Pearson's Chi-square test. As the light sensors do not distinguish between natural and artificial light, this approach is only valid for winter months and will over-predict the 'lights on' values during the summer months. Consequently, the data for the period before the intervention was disregarded from the study. The results of the Pearson's Chi-square and odd ratio tests are shown in Table 81.

Table 81. Results of the Pearson's Chi-square and odd ratio tests run to test research hypothesis H7: The intervention group did not implement quiet time for the variable lights (on/off)

Study group	**Sample (n)**	**X^2 value**	**df**	**p-value**	**Odds ratio**
During	24917	819.83	1	<2.2e-16	1.58
After	22094	973.49	1	<2.2e-16	3.31

The results show there is a statistically significant difference between control and the intervention groups during and after the behaviour change intervention. Consequently, the null hypothesis is rejected during the intervention group confirming the intervention group did switch off lights during quiet time as a consequence of the behaviour change intervention.

During the study the odds of the intervention group switching lights off is 1.58 times the odds of control group switching lights off for quiet time. After the study the odds of the intervention group switching lights off is 3.31 times the odds of control group switching lights off for quiet time.

As the outcome variable (2) noise levels (dB) is numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 82.

Table 82. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn hoc analyses run to test research hypothesis H7: The intervention group did not implement quiet time for the variable noise levels (dB)

Study period	Sample (n)	W value	p-value	Post hoc test
Before	33177	81516941	6.713e-06	6.7e-06
During	33228	94110275	< 2.2e-16	<2e-16
After	31726	60420263	3.804e-13	3.8e-13

The results show there is a statistically significant difference between the medians of the control and the intervention groups before, during and after the behaviour change intervention. Consequently, the null hypothesis is rejected confirming the intervention group did reduce noise levels (dB) during quiet time. However, as this occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

As the outcome variable (3) count of bed movements is numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 83.

Table 83. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H7: The intervention group did not implement quiet time for the variable bed movement events (count)

Study period	Sample (n)	W value	p-value	Post hoc test
Before	33177	764824	0.616	0.62
During	33228	1795280	0.02879	0.029
After	31726	1366862	0.04571	0.046

The results show there is not a statistically significant difference between the medians of the control and the intervention groups before the behaviour change intervention but there was a statistically significant difference between the medians of the control and the intervention groups during and after the behaviour change intervention. Consequently, the null hypothesis is rejected confirming the intervention group did increase patient rest during quiet time as a consequence of the behaviour change intervention.

From the results of the above hypotheses, it may be concluded that the intervention group did implement quiet time as the intervention group switch off lights, reduced noise and increased patient rest during quiet time more than the control group. From the inferential statistical analysis, it may be concluded that switching off lights and the increase in patient rest during quiet time occurred as a consequence of the behaviour change. However, as the difference for noise levels occurred across all three periods there is no statistical evidence that the difference in noise levels during quiet time occurred as a consequence of the behaviour change intervention.

7.2.4 H8: The intervention group did not have more patient rest than the control group?

From the literature review, it was identified that the potential benefits of implementing an energy behaviour change intervention, adapted from Operation TLC was improved patient wellbeing through improved rest and comfort (Daly and Large 2016).

As the outcome variable (count of bed movements) is numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 84.

Table 84. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H8: The intervention group did not have more patient rest than the control group

Study period	Sample (n)	W value	p-value	Post hoc test
Before	796650	335510387	0.00171	0.0017
During	796549	771930191	2.331e-06	2.3e-06
After	761420	535128626	< 2.2e-16	<2e-16

The results show there is a statistically significant difference between the medians of the control and the intervention groups before, during and after the behaviour change intervention. Consequently, the null hypothesis is rejected confirming the intervention group did reduce noise levels more than the control group. However, as this occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

7.2.5 H9: The intervention group did not have lower patient length of stay than the control group?

From the literature review, it was identified that the potential benefits of implementing an energy behaviour change intervention, adapted from Operation TLC was improved patient wellbeing in the category of reduced length of stay (Daly and Large 2016).

As the outcome variable (length of stay in days) is numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 85.

Table 85. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H9: The intervention group did not have lower patent length of stay than the control group

Study period	Sample (n)	W value	p-value	Post hoc test
Before	9	9	0.1	0.081
During	9	9	0.1	0.081
After	9	9	0.07652	0.077

The results show the null hypothesis is accepted as the results show no significant difference between the medians of the control and intervention study groups in study periods before, during and after the behaviour change intervention. Consequently, it may be assumed that patients in the intervention group did not have a reduced length of stay (for those returning home) than patients in the control group.

7.3 RQ3: In what ways and to what extent does running a behaviour change intervention in a hospital improve staff satisfaction?

From the literature review, it was identified that the potential benefits of implementing an energy behaviour change intervention, adapted from Operation TLC was increased staff satisfaction and wellbeing in such categories such as improved staff retention and levels of sickness (Daly and Large 2016).

7.3.1 H10: The intervention group did not have lower staff sickness than the control group

As the outcome variable (percentage of staff sickness) is numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 86.

Table 86. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H10: The intervention group did not have lower sickness than the control group

Study period	Sample (n)	W value	p-value	Post hoc test
Before	9	1	0.184	0.18
During	9	3	0.7	0.66
After	9	0.5	0.1212	0.12

The results show the null hypothesis is accepted as the results show no significant difference between the medians of the control and intervention study groups in study periods before, during and after the behaviour change intervention. Consequently, it may be assumed that the intervention group did not have lower staff sickness than the control group.

7.3.2 H11: The intervention group did not have lower staff turnover than the control group

As the outcome variable (percentage of staff turnover) is numerical with a non-normal distribution and two non-paired samples (control, intervention), the hypothesis was tested using a Mann Whitney U-test with a confidence level of 95%. The Bonferroni-Dunn procedure was chosen as the post hoc method of analysis as it provides the highest adjusted p-values in a pairwise non-parametric test (Trawiński et al. 2012). The results of these tests are shown in Table 87.

Table 87. Results of the Mann Whitney U-tests (95% confidence level) and Bonferroni-Dunn post hoc analyses run to test research hypothesis H11: The intervention group did not have lower staff turnover than the control group

Study period	Sample (n)	W value	p-value	Post hoc test
Before	9	0	0.05935	0.081
During	9	0	0.07652	0.081
After	9	0.5	0.1101	0.077

The results show the null hypothesis is accepted as the results show no significant difference between the medians of the control and intervention study groups in study periods before, during and after the behaviour change intervention. Consequently, it may be assumed that the intervention group did not have lower staff turnover than the control group.

7.4 Summary of research questions and hypotheses

A summary of the results from the research questions and hypotheses is presented below:

7.4.1 RO1: In what ways and to what extent does running a behaviour change intervention in a hospital reduce energy consumption?

Null hypothesis rejected	• H1: The intervention group did not switch off equipment more than the control group, during and after the intervention • H2: The intervention group did not switch lights off more than the control group, during and after the intervention • H3: The intervention group did not implement night time switch off • H4: The intervention group did not save more energy than the control group before, during and after the intervention
Null hypothesis accepted	• H1: The intervention group did not switch off equipment more than the control group, before the intervention

7.4.2 RO2: In what ways and to what extent does running a hospital improve patient wellbeing?

Null hypothesis rejected	• H5: The intervention group did not reduce noise levels more than the control group before, during and after the intervention • H6: The intervention group did not control temperature more than the control group before, during and after the intervention • H7: The intervention group did not implement quiet time • H8: The intervention group did not have more patient rest than the control group before, during and after the intervention
Null hypothesis accepted	• H9: The intervention group did not have lower patent length of stay than the control group

7.4.3 RO3: In what ways and to what extent does running a behaviour change intervention in a hospital improve staff satisfaction?

Null hypothesis accepted	• H10: The intervention group did not have lower sickness than the control group • H11: The intervention group did not have lower staff turnover than the control group

A further discussion of the findings from this chapter may be found in Chapter 8.

Chapter 8 Discussion

This chapter will critically analyse the main findings of the research study, drawing on the key information identified during the literature review, and the findings from the descriptive and inferential statistical analyses of the quantitative and qualitative data. Section 8.1 discusses the applicability of running the behaviour change intervention. Section 8.2 critically analyses the findings from the energy data, section 8.3 critically analyses the findings from the environmental data and section 8.4 critically analyses the findings from the patient and staff experience data. Section 8.5 presents the limitations of running the behaviour change intervention and section 8.6 presents the recommendations for future work. A summary of the key findings from this chapter are presented in section 8.6.

8.1 Applicability of the case study

The hospital site chosen is a private finance initiative (PFI) and consequently, the Trust does not employ or have direct control over the hard and soft facilities provision on site. Often energy improvements are difficult to implement in a PFI built hospital as the PFI owners and the NHS occupants have to agree the funding of these projects through negotiation. This study has shown that energy behaviour change can be successfully implemented in partnership in a PFI building without affecting contractual arrangements.

This study used an information-based behaviour change approach adapted from Triandis' Theory of Interpersonal Behaviour, shown in Figure 13, incorporating the key organisational, contextual and social factors identified during the literature review.

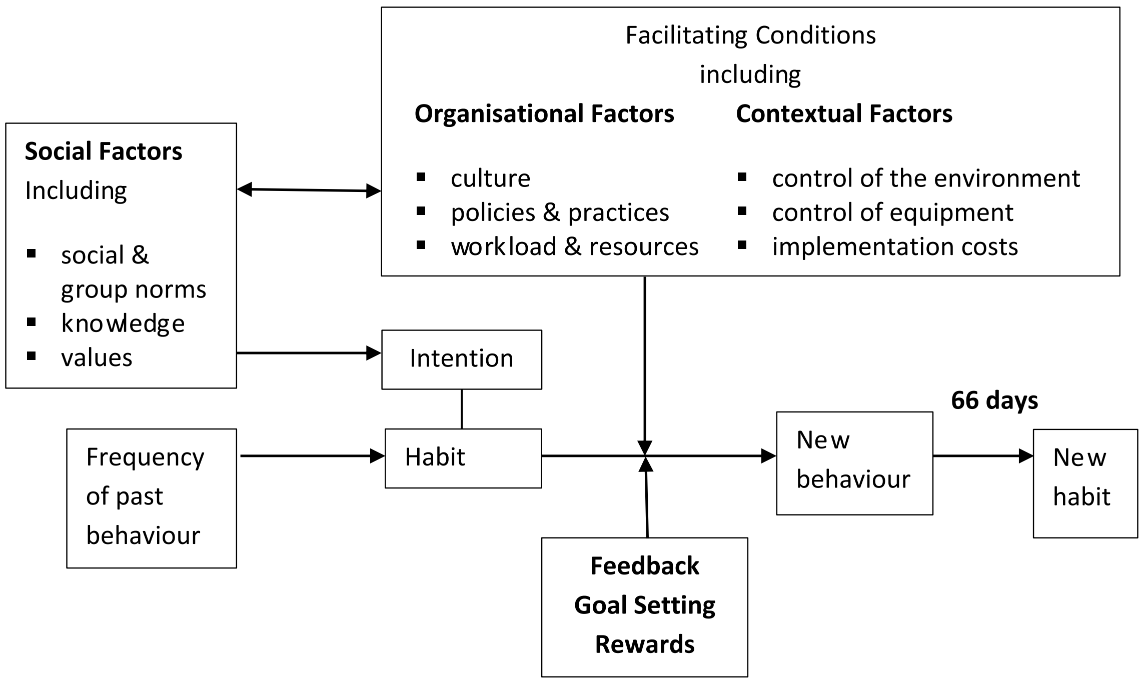

Figure 13. Model of the behaviour change approach used in a NHS community hospital adapted from the revised version of Triandis' Theory of Interpersonal Behaviour reproduced in Chatterton (2011)

The specifics of the intervention were based on an adapted version of GAP's Operation TLC behaviour change intervention, which was adapted to link to the respective hospital building, processes and interfaces with the occupants (Manika et al. 2016) by the intervention facilitator, whom for this study was the researcher, and the Trust Operation TLC champions to ensure the intervention complemented the processes and interfaces of the occupants (Manika et al. 2016) in the older-persons' acute-care wards involved in the study.

From the literature review, Daly and Large (2016) identified four key barriers that may prevent hospital staff from completing the required Operation TLC actions, these included:

1) Lack of knowledge: staff are unfamiliar with how the building and its systems work.
2) Lack of expectation: staff did not know they were expected to or allowed to take actions to control their environment.
3) Habit and memory: staff knew what to do but were too busy and simply forgot.
4) Facilities maintenance: staff identified old and broken equipment that had not been fixed or replaced.

8.1.1 Social factors

To mitigate the social factor of lack of knowledge and encourage nursing staff to participate in the behaviour change intervention, credible evidence-based information was required (Jolley 2009) to demonstrate the benefits of implementing the individual Operation TLC actions together with rewards, goal setting and feedback to encourage staff participation (Staddon et al. 2016, Mulville et al. 2017). Whilst the posters provided a useful source of knowledge for the participants at the beginning of the intervention, the staff did not appear to look at them after the initial training, although patients and visitor were seen reading the posters throughout the during and after study periods. Workload of the staff and the abundance of other information notices and posters throughout the wards appears to have limited the effectiveness of this tool to provide information.

Involving other key stakeholders (Tudor 2011, McGain and Naylor 2014) in the intervention, particularly the soft and hard facilities providers was also found to be essential to the success of the behaviour change intervention as it helped to mitigate (1) lack of knowledge about how the building and its systems work and (4) issues around facilities maintenance (Daly and Large 2016).

The soft facilities staff provide housekeeping on the wards, so have a significant impact on the ward environment, particularly in relation to noise from moving trolleys, serving food and beverages, to cleaning and emptying bins, which staff identified in the focus groups as a main source of peak noise. The hard facilities providers are responsible for the mechanical, electrical and water systems on the wards, so also have a significant impact on the ward environment from maintaining the heating, lighting, electrical systems to mending toilets, taps and broken windows.

Social norm was identified in previous studies as a motivator or barrier for staff to save energy (Bedwell et al. 2014, Staddon et al. 2016), consequently energy saving was only referred to as a secondary outcome as clinical staff had previously identified it as a low-priority and as potentially being in conflict with their main priority of delivering excellent patient care (Dunphy 2014, McGain and Naylor 2014), which may lead to tensions between those running the energy conservation intervention (Bedwell et al. 2014, McGain and Naylor 2014, Morgenstern, Raslan, et al. 2016).

The researcher found the social norm in the intervention group was one of openness with a positive willingness to improve the environment for the wellbeing of the patients and experience of the staff as expected due to healthcare staff having a strong propensity to care (Harris et al. 2009, Ryan-Fogarty et al. 2016). The only exception being one participant who would not follow the secondary action of ‘close windows when the heating is on’, as they ardently believed it was essential to introduce fresh air to the ward despite being provided with evidence based information on the high air changes from the mechanical ventilation system.

8.1.2 Organisational factors

An Energy Policy was developed by the Trust and communicated to all staff in the hospital before the intervention to enforce the organisation's culture towards energy conservation as Siero et al. (1996) and Mulville et al. (2016) found it was more effective to focus on workplace culture and practices than the attitude of the staff involved in the intervention. Enforcing an organisational culture of energy conservation was used to help mitigate the barrier of (2) lack of expectation (Daly and Large 2016).

Djordjevic and Cotton (2011) identified potential barriers around communicating organisational sustainability policies and practices, which was seen during this study. Poor communication in relation to the Trust's Energy Policy was particularly evident in the control group, who, from analysis of the energy data for small power appeared to bring in additional space heater(s) at night during the intervention period (winter).

Use of space heaters is a common practice with nursing staff on the wards, albeit prohibited in the Trust's Energy Policy due the risk of fire. In contrast, the intervention group received evidence information during the behaviour change intervention about the benefits of a healthy environment, which enforced the messages in the Trust's Energy Policy to control temperatures in the wards within the CIBSE recommended level. Consequently, the intervention group did not appear to join the control group in the prohibited practice of bringing in additional space heater(s) despite reporting that they were cold during the heating season (1st November 2017 - 30th April 2018) in their staff comfort surveys and focus groups.

Another factor that was found to be essential to the success of the behaviour change intervention was senior and middle management support (Cox et al. 2012, Morgenstern, Raslan, et al. 2016). NHS England has a hierarchical structure, so the Trust Board sponsor provided the authority for the senior and middle management to support the study (Lo et al. 2012), which in turn provided the mandate for the ward staff to participate in the study and the confidence that they were active and influential within the programme to ensure success (Thompson et al. 2004) again helping to mitigate the barrier of (2) lack of expectation (Daly and Large 2016).

Another factor that was found to be essential to the success of the behaviour change intervention and to help mitigate the barrier of (3) habit and memory (Daly and Large 2016) was the appropriate level of resources (Ryan-Fogarty et al. 2016), particularly in relation to the time allocated to the facilitator and the Operation TLC champions to complete the required Operation TLC activities.

For the intervention facilitator, this included time for meeting stakeholders (senior manager, middle managers, champions, soft and hard facilities managers), running training sessions and attending feedback sessions, which was estimated to total circa 20 hours (3 hours for meetings, 6 hours for training, 5 hours for feedback sessions, 6 hours for feedback sessions) during the study (excluding time for data monitoring and analysis). For the Operation TLC champions, this included time to attend training sessions with the facilitator, and time to undertake Operation TLC activities, including distributing materials and promoting the Operation TLC actions with other staff in the intervention group, which was estimated to total circa 15 hours during the study.

Previous studies found that if workloads are high and/or resources are low then employees may not have time to become fully engage with or get involved in energy conservation interventions (McGain and Naylor 2014, Morgenstern, Raslan, et al. 2016), which was observed by the researcher during this study. During these times, some of the Operation TLC actions were not undertaken. Fortunately, these times were not common and for the majority of the time, the staff in the intervention group were observed by the researcher to be completing the Operation TLC actions during and after the behaviour change intervention.

Whilst this could have been as a direct result of the researcher being present and unwittingly prompting the staff to behave accordingly, on the whole the data findings do support the observations by the researcher that staff in the intervention group appeared to be completing the Operation TLC actions during the behaviour change intervention.

To overcome issues around workload and resources (Ryan-Fogarty et al. 2016) and to help mitigate the barrier of (3) habit and memory (Daly and Large 2016), refresher training and feedback sessions were incorporated into scheduled team briefs. During these sessions, the staff were observed to be particularly receptive to public praise for their active participation in the study and very interested in the data findings from the sensors, which they were observed sharing with other staff, patients and visitors in the intervention wards. The promotional pens and 'thank-you' heart chocolates were also popular with staff in the intervention group, although not as much as the feedback. These findings are in line with those identified by Handgraaf et al. (2013) who found social rewards that were given publically outperformed all others.

8.1.3 Contextual factors

Involving key stakeholders also avoided the contextual factor of a lack of control over the environment (Bull et al. 2014, Dunphy 2014, Ornaghi et al. 2018) helping to mitigated the barrier of (1) lack of knowledge about how the building and its systems work (2) lack of expectation about what actions the staff are allowed to do to control their environment and (4) issues around facilities maintenance (Daly and Large 2016).

This was particularly evident in the launch event and second workshop, which was attended by all the stakeholder. During these workshops the participants took the opportunity to introduce themselves to each other, talked about what they did, learn more about how the building and its systems work and speak to the hard and soft facilities providers about facilities maintenance and soft facilities operational practices and issues.

Feedback provided by the researcher and staff during the feedback sessions, staff focus groups and comfort surveys also helped to avoid the contextual factors of lack of control over the environment (Bull et al. 2014, Dunphy 2014, Ornaghi et al. 2018) and lack of control over the equipment (Topf 2005, Littleford 2013, Mulville et al. 2017) in order to mitigate the barrier of (2) lack of expectation about what actions the staff are allowed to do to control their environment.

Both the control and intervention groups during the pre and post-intervention focus groups reported the windows were draughty, which caused the patients to be cold. This theory was tested by putting air temperature sensors near the windows, which showed the cold sensation felt by the staff and patients was the result of the colder outside temperature at night radiating from the glass and aluminium frame of the windows rather than ill-fitting draughty windows.

However, a consequence of the feedback and shared knowledge is that the intervention group appear to have a heightened awareness of the ward environment and as a result appeared, more sensitive to it. This was evident in the findings from the staff comfort surveys and staff focus groups in the study periods during and after (winter/spring) the intervention, in which the intervention group reported feeling mainly cold during the winter and spring, which they acknowledged was different from previous years, whereas whilst the control group reported being cooler during this period they still talked about the hospital being hot during the day and night, and across the seasons.

Despite omitting the generic secondary action 'control heating gradually' from the Trust bespoke Operation TLC action list, the complimentary thermometers and evidence based information given to the staff in the intervention group, empowered them to regularly monitor the ward temperatures and only report issues of overheating / cold to the hard facilities provider when the temperatures fell outside the CIBSE recommended levels, rather than solely relying on subjective feelings of thermal comfort.

From the suite of tools and materials used to help (1) lack of knowledge and (2) lack of expectation about what actions the staff are allowed to do to control their environment and equipment, the complimentary thermometers were found to be the most popular with the participants and effective tool used in the study together with the stickers that indicated which equipment may / may not be switched off.

8.1.4 Summary

As discussed, whilst most of the barriers identified by Daly and Large (2016) that may prevent hospital staff from completing the required Operation TLC actions were mitigated during the behaviour change intervention, this study was still not able to fully overcome the barrier of (3) habit and memory. Albeit in relation to one participant who actively would not follow the secondary action of 'close windows when the heating is on', as they ardently believed it was essential to introduce fresh air to the ward despite being provided with evidence based information on the high air changes from the mechanical ventilation system.

Likewise, whilst most of the potential social, organisational and contextual factors identified as barriers during the literature review were mitigated during the behaviour change intervention, this study was not able to fully mitigate the barrier of workload and resources and the participants were observed not completing some Operation TLC actions in busy periods during the behaviour change intervention.

The study also showed that the nursing staff had an increased awareness of the environmental impacts on the wards as a result of the evidence based information used during the intervention, including the need to following the Trust's Energy Policy, which creates risks in terms of acceptability of the approach to the nursing staff participating in the intervention, who reported their wards were cold as a result of controlling temperatures within the CIBSE recommended levels (22-24^{o}C) during the heating season, which made them feel uncomfortable.

8.2 Energy findings

The descriptive analysis of energy used for lighting showed the intervention group used 5% (2.4 kWh per day) less electricity for lighting before and during the intervention but used 13% (7.4 kWh per day) less after the intervention, which equates to an 8% saving.

As the number of light fittings were identical across the study wards, possible reasons for the difference in the range of power demand values may be due to (1) light tube failures in the patient rooms participating in the study (2) lighting may have been switched on or off in non-patient areas of the study wards, such as offices and staff mess rooms etc. that are on the same lighting distribution board and (3) changed habits of the nursing staff in the intervention group switching lights off in the patient areas in response to the required actions of the behaviour change intervention.

The results showed that both study groups used more energy for lighting during the intervention than before the intervention, which as expected negatively correlates with the total hours of sunshine during these periods. Before the intervention (August, September, October) there was a total of 424 hours of sunshine and during the intervention (November, December, January) there was a total of 194.5 hours of sunshine (The Met Office 2018b).

The Met Office (2018a) reported a total of 330.6 hours of sunshine for the period after the intervention (February, March, April), which is consistent with the findings from the intervention group that less energy was used for lighting after the intervention than during the intervention. However, the control group used more energy for lighting after study period than it had in either of the two previous study periods, which is not consistent with the reported hours of sunshine by the Met Office. This may be due to heightened awareness of the impacts of light (natural and artificial) on the wards by staff in the intervention group but not in the control group.

The descriptive analysis of energy used for small power showed the intervention group used 11% (2.4 kWh per day) more electricity for lighting before the intervention, 22% (4.8 kWh per day) less during and 13% (2.4 kWh per day) less after the intervention, which equates to a 33% saving during and a 24% saving in electricity for small power after the intervention.

The descriptive analysis showed a distinct rise in power demand for small power in the control group for approximately four hours during the night time; starting around 22:00:00 and ending around 02:00:00. This appears to be due to the use of electrical equipment, such as space heater(s) in the control group that was not used in the intervention group.

Use of space heaters is a common practice with nursing staff on the wards albeit prohibited in the Trust's Energy Policy due the risk of fire on the wards. Feedback gathered from the staff comfort survey and staff focus groups back up this hypothesis during which staff in the control group consistently reported it was colder at night.

Other possible reasons for the difference in the range of power demand values may be (1) variation in patient health conditions effecting the utilisation of the medical equipment (2) small power equipment being switched on or off in non-patient areas of the study wards, such as offices and staff mess rooms etc. that are on the same small power distribution board and (3) changed habits of the nursing staff in the intervention group switching off equipment in the patient areas in response to the required actions of the behaviour change intervention.

In both domestic and non-domestic settings energy behaviour change was found to diminish when feedback stopped (Dwyer et al. 1993, Darby et al. 2016), which mirrors the findings from the intervention group for the energy for small power but not the findings from the energy for lighting, which further increased after the intervention. In relation to energy for lighting, the behaviour change took up to a month to take effect in the intervention group. The effect of the behaviour change (reduction in energy for lighting) then continued to increase for three months, peaking one month after the feedback stopped showing a delay in the effect. In relation to energy for small power, the effect of the behaviour change (reduction in energy for small power) took effect immediately and was sustained for four months, peaking one month after the feedback stopped.

It takes around sixty-six days for a behaviour to become a habit (Lally et al. 2010), which may explain why some behaviour change interventions have not been able to successfully deliver long term energy conservation (Fisher and Irvine 2016). In relation to energy for lighting, the effect of the behaviour change appeared to diminish over the following two months, although the reduction in energy for lighting was still higher in these months than in the study period before the intervention, which may suggest that this action has developed into a habit. In relation to energy for small power, the effect of the behaviour change intervention then diminished over the fifth month and had appeared to have stopped by the sixth month, which may suggest some action takes longer than sixty-six days to become a habit.

This study purposely stopped providing feedback to the participants after running the behaviour change for three months in order to monitor potential tail-off of the behaviours. In previous studies, it was identified that continued engagement was required to maintain energy conservation (Dwyer et al. 1993, Darby et al. 2016), consequently the nursing staff may have continued the behaviour change actions, in this case switch off lights and equipment, if they were provided with continued feedback for encouragement. However, it was also identified that engagement in feedback was found to diminish over time (Gulbinas and Taylor 2014), so new forms of feedback or encouragement should be sought, such as inter-ward competitions to counteract monotony.

Non-healthcare energy conservation interventions, primarily domestic, universities and offices reported energy savings of between 1-12% for heating and 1.5-20% for electricity (Abrahamse and Steg 2013, The Carbon Trust 2013, Mulville et al. 2014). The NHS SDU and GAP reported potential energy savings of 3% from energy behaviour change interventions in healthcare (NHS Sustainable Development Unit 2010, Daly and Large 2016), based on findings from running Operation TLC at St Bartholomew's NHS Trust.

Before the intervention, both the control and intervention groups used 72 kWh of total energy use per day for lighting and small power. Both during and after the intervention, the control group used 77 kWh of total electricity use per day for lighting and small power and the intervention group used 67 kWh per day, a difference of 10 kWh per day, shown in Figure 87.

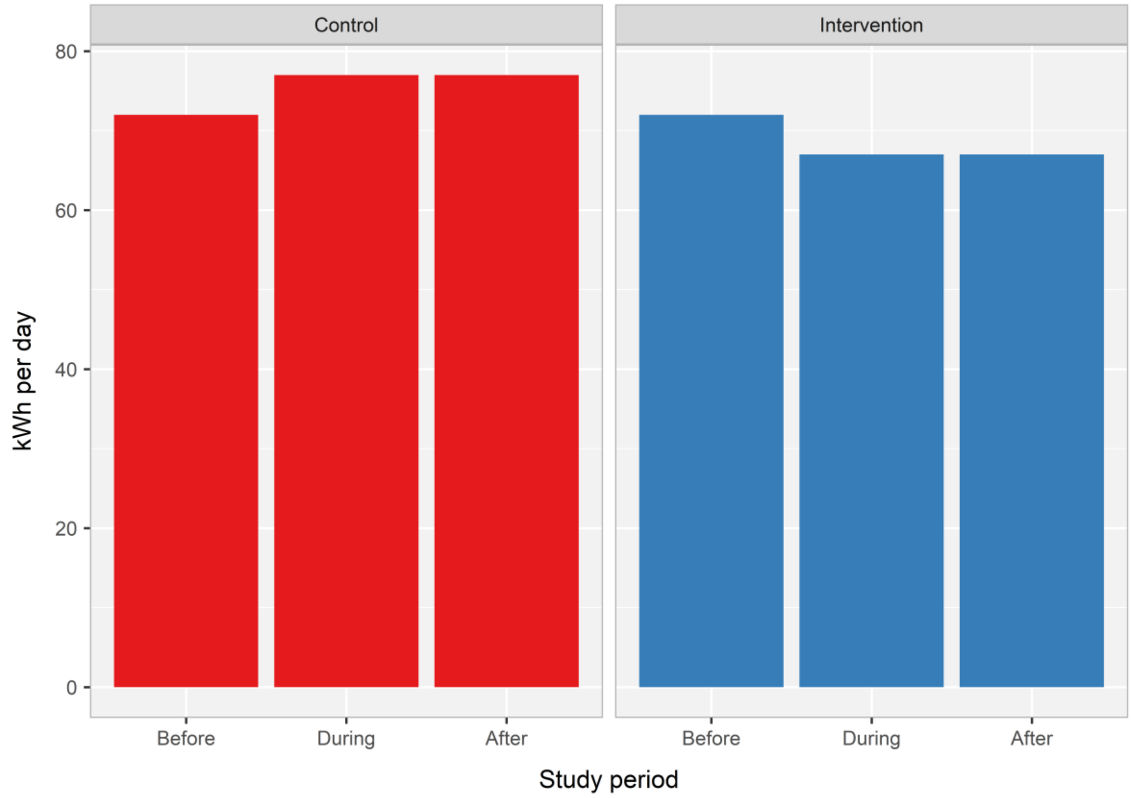

Figure 87. Total energy consumption per day (kWh/day) for lighting and small power, comparing the control and intervention study groups for the study periods before (1st September - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

Consequently, the descriptive analysis shows this study produced a total electricity (lighting and small power), and associated carbon dioxide emissions and financial saving of 13% in both the study periods during (1st November 2017 to 31st January 2018) and after (1st February 2018 to 30th April 2018) the behaviour change intervention, which supports the theory that *running an energy behaviour change, adapted from Operation TLC saves energy, and consequently carbon dioxide emissions and money*. For the two intervention wards participating in this study this equated to total saving of 620 kWh and 226 kgCO_2e[4] for the during and after study periods (6 months).

However, whilst the results of the statistical analysis to test the research questions and hypothesis relating to energy confirms there was a statistically significant difference between the medians of the control and the intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

[4] Calculated using UK Government emission conversion factors for greenhouse gas company reporting: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting [accessed 15/01/2019].

8.3 Environmental findings

8.3.1 Light

The descriptive analysis showed that the intervention group switched lights on for 11% less hours than the control group during the intervention and 8% less after the intervention, which fits the findings from the literature review that energy behaviour change was found to diminish when feedback stopped (Dwyer et al. 1993, Darby et al. 2016).

The result of the statistical analysis to test the research questions relating to light confirmed the findings from the descriptive analysis of the light sensors and supports the theory that *running an energy behaviour change, adapted from Operation TLC creates a healthy environment for patients and staff* by decreasing the use of artificial lighting and consequently increasing the use of natural light. However, as the light sensors did not distinguish between natural and artificial lighting the study was not able to establish a benchmarking to analyse the difference in light activity between the control and interventions groups before the intervention.

These savings equate to an average saving of one hour per ward per day in the intervention group compared to the control group in the study periods during and after the intervention, which is consistent with the anticipated results of the Operation TLC secondary action of 'introduce quiet time for an hour after lunch' during which lights are switched off or dimmed to facilitate patient rest and recovery.

Whilst the finding for the light data showed an 11% saving during the intervention the energy data for lighting did not show any savings during this period. An explanation for this may be that whilst the light data is specific to the patient rooms in the wards participating in the study, the electricity for lighting (kWh) also includes lighting in the other areas of the study wards, including corridors, offices and staff rooms, which may have been left on by staff as a result of limited sunshine (194.5 hours) during this period (The Met Office 2018a).

After the intervention the results from the light data and electricity for lighting (kWh) continue to show a positive reduction, and the amount for the light data (8% saving) is consistent when compared to the energy for lighting data (8% saving). Again, this may reflect the increase in hours of sunshine (330.6 hours) for this study period, which may have resulted in staff turning lights off in the other areas of the ward.

From feedback during the staff focus groups, the staff in both the control and intervention groups felt the lighting on the study wards was too bright when the artificial lights were on and too dark when the blinds were closed during the day time for adaption to summer over-heating. This confirmed there was scope to turn lights off in the wards, which was supported by the results from the quantitative data. During the focus groups, both the control and intervention groups reported the lights were difficult to control.

From the comfort surveys, the control and intervention group reported the highest percentage in the 'neither bright nor dim' score during and after the intervention study periods, which show that lighting was not a significant concern for staff on the wards. Implying the staff on the intervention ward turned lights off as a result of the behaviour change intervention in order to improve the environment for their patients.

8.3.2 Sound

The descriptive analysis showed that median noise levels in the intervention group were the same as the control group before and after the intervention and 1 decibels (dB) less than the control group during the intervention, which supports the theory that *running an energy behaviour change, adapted from Operation TLC creates a healthy environment for patients and staff* by reducing noise levels on the ward during the intervention period.

Whilst the results of the statistical analysis to test the research questions and hypothesis relating to noise levels confirms there was a statistically significant difference between the medians of the control and the intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

Possible reasons for the difference are (1) occupancy levels, particularly visitor occupancy as patient and nursing staff occupancy was identical across the study wards (2) differing health conditions of the patients, for example patients with dementia were observed frequently shouting and calling out during the study pilot and (3) changed habits of the nursing staff in the intervention group switching off equipment in response to the required actions of the behaviour change intervention.

The descriptive analysis also revealed that over the study period there were 40 incidents of noise levels exceeding 110dB, all of which occurred during the day time although there were 33 incidents of noise levels exceeding 100dB during the night time, which would have been significantly impacting as back ground noise levels are lower at night (median 51dB) than the day time (median 68dB). From the 24-hour pilot study peak noise incidents occurred as a result of alarms, metal bins, noise from nurses' station at handover times and patients, usually those with dementia, shouting and calling out. It is likely a combination of these noise events occurring would be required to reach such high noise levels.

These findings were confirmed by the results of the 'noise' question in the staff comfort survey, which showed that staff in the intervention group had more scores in the quiet range than staff in the control group. However, during the intervention the intervention group had scores in the 'very noisy' and 'noisy' choices, whilst the staff in the control group did not. This may be due to the staff in the intervention group having a heightened awareness of the importance of controlling noise levels in the ward to create a healthy environment for their patients as a result of the behaviour change intervention.

The descriptive analysis also shows a clear dip in decibel levels during the quiet time period (13:30:00 - 14:30:00) in the intervention group but not in the control group, presented in Figure 57, which supports the theory that *running an energy behaviour change, adapted from Operation TLC creates a healthy environment for patients and staff* by introducing quiet time, during which lights were switched off, noise levels were reduced and patient rest was increased.

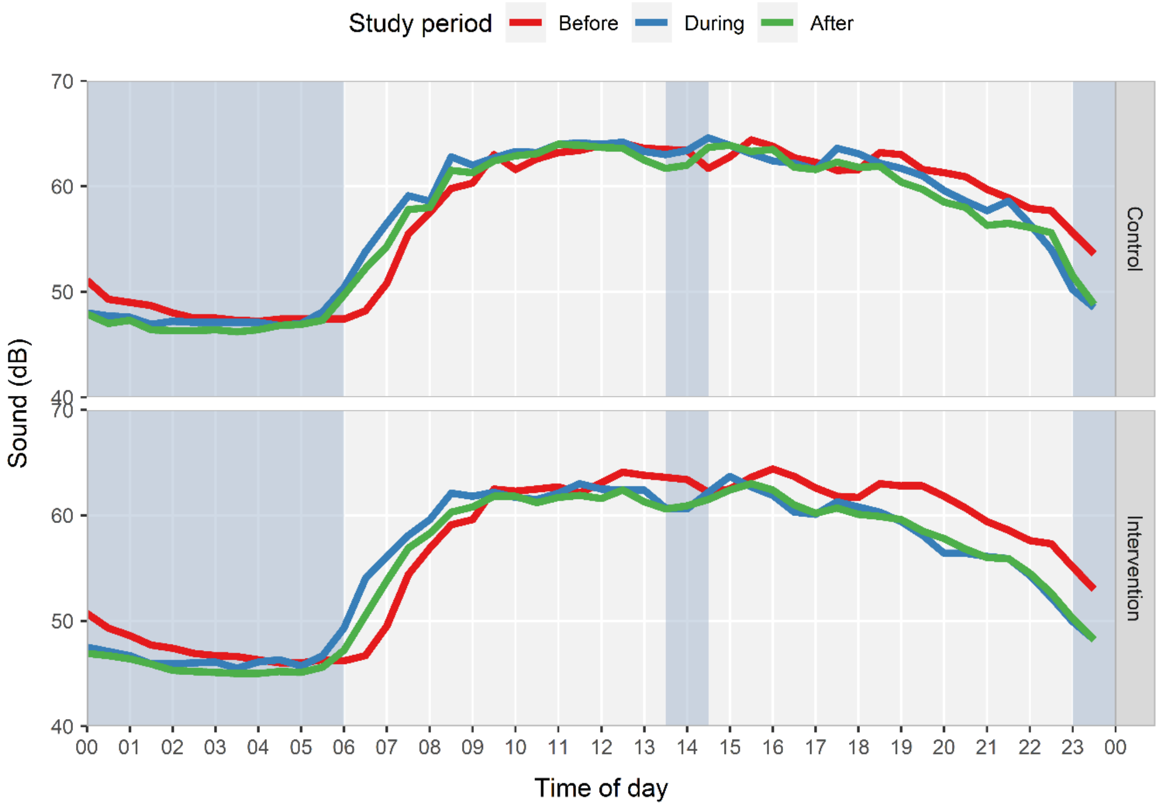

Figure 57. Average median minutely daily sound (dB) levels showing 'quiet time' period (13:30:00-14:30:00) and 'night time switch off' (23:00:00), comparing the control and intervention study groups for the study periods before (1st August - 31st October 2017), during (1st November 2017 - 31st January 2018) and after (1st February - 30th April 2018) the behaviour change intervention

For general and single wards in UK hospitals the published standards for acceptable noise levels is 30dB (CIBSE 2015, Department of Health 2007), background noise levels typical measured 45-68dB and peak noise levels typically measuring above 85dB (Ulrich et al. 2004). Results from the descriptive analysis found median noise levels in the study wards ranged between 50-52dB during the night time and 68-69dB during the day time for the study groups across the whole study period (1st August 2017 - 30th April 2018) and peak noise levels measured above 85dB with maximum noise levels of 120dB in the control group and 118dB in the intervention group.

This confirmed feedback from staff during the focus groups, who reported the study wards were noisy during the day. During these focus groups the participants thought people, particularly the staff were a major contributor to noise levels on the wards, which was confirmed during the study pilot that found a significant relationship ($r_s = 0.14$, $p = 1.972e-07$) between sound data (dB) and observed occupancy levels during the day time.

8.3.3 Air temperature and thermal comfort

The descriptive analysis for air temperature showed the intervention group had similar albeit lower median temperatures to the control group before the intervention (average 0.2^{o}C difference), which lowered further (median 0.6^{o}C difference and maximum 0.9^{o}C difference) during the intervention and then tailed off (0.4^{o}C to difference) after the intervention, which supports the theory that *running an energy behaviour change, adapted from Operation TLC creates a healthy environment for patients and staff* by controlling temperature. This result is consistent with previous findings from energy behaviour change in non-domestic settings that savings diminished when feedback stopped (Dwyer et al. 1993, Darby et al. 2016).

Whilst the results of the statistical analysis to test the research questions and hypothesis relating to air temperature confirms there was a statistically significant difference between the medians of the control and the intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

The pilot study established that the nursing staff in the study wards have very little control over their environment and as the heating and ventilation systems were identical across the study wards, possible reasons for the difference in the air temperature values may be due to (1) differing window activity and (2) use of standalone heating and cooling equipment, primarily fans although space heaters have been brought into the wards by nursing staff albeit prohibited as they may pose a fire risk.

Before the intervention both groups reported in the staff comfort surveys and during the focus groups that the study wards were hot, which was expected due to the hospital building comprising of (1) high thermal mass (2) mechanical ventilation with high number of air changes and (3) no air conditioning or other forms of mechanical cooling making the building prone to summer overheating.

After the intervention, staff in the intervention group reported it was cold whilst staff in the control group reported a mixed response with some feeling the ward was still hot during this period, which may reflect a heightened awareness of the intervention group to control temperature within the CIBSE recommended levels 22-24°C verses past expectation of conditions (usually the hospital is always hot) by some of the staff in the control ward.

The recommended acceptable Predicted Percentage of Dissatisfied (PPD) range for indoor thermal comfort is less than 20% dissatisfaction (British Standards Institute 2005, American Society of Heating Refrigeration and Air-Conditioning Engineers 2017, Cannistraro and Bernardo 2017). The wet bulb thermometer tests found the PPD was slightly higher in the intervention group than the control group before the intervention (20% and 19% respectively) and after the intervention (14% and 13% respectively).

Despite remaining either on or below the PPD recommended level (20%) before and after the intervention, both groups reported being in the uncomfortable range of scores in the staff comfort surveys throughout the study.

Before the intervention, both study groups reported being mainly 'uncomfortable' in the staff comfort surveys. During and after the intervention, the control group reported being mainly 'slightly uncomfortable', which is in line with an improvement in PPD scores (moving from 19% to 13%). However, the intervention group reported a higher percentage in the 'very uncomfortable' choice during these periods, which is not in line with the PPD scores which also showed an improvement (moving from 20% to 14%). This may reflect (1) a heightened awareness of the intervention group to the environment as a result of the behaviour change intervention and (2) the limitations of the PMV-PPD model, which has proven not to be a good fit for non-air conditioned buildings (Beizaee and Firth 2011), such as the hospital where the study was run.

8.3.4 Relative humidity

The descriptive analysis showed median relative humidity in the intervention group was lower albeit small before (0.7%), during (1.6%) and after (1.5%) the intervention, therefore, these findings show that the intervention had no significant impact on relative humidity.

This is confirmed by the results of the statistical analysis to test the research questions and hypothesis relating to relative humidity which show that whilst there was a statistically significant difference between the medians of the control and the intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

As the building has a high thermal mass and mechanical ventilation system with high air changes but does not have air conditioning, the difference in relative humidity values are likely to have occurred due to (1) difference in window opening activity between the control and intervention groups and (2) difference in the efficiency of the ventilation systems.

During and after the behaviour change intervention, both the control and intervention groups spent a high percentage of time (80% & 82% for the control and 73% & 76% for the intervention groups respectively) below the CIBSE recommended relative humidity levels (40-70%). The hospital building comprises of mechanical ventilation with high number of air changes with no air conditioning or other forms of mechanical cooling supplemented by opening windows, which are restricted to a 10% opening angle. As a result, the atmosphere inside the building feels drier than atmospheric humidity, although the building is located in the south of England which has a fully humid (f) climate in accordance with the Köppen classification ((Kottek et al. 2006).

However, the quantitative findings are not consistent with the qualitative findings from the staff comfort surveys in which the staff reported the highest percentages (69% & 60% for the control and 63% & 70% for the intervention groups respectively) in the 'neither humid nor dry' choice for the same (during and after) study periods.

8.3.5 Carbon dioxide

The descriptive analysis showed median CO_2 in the intervention group was lower albeit small before (29 ppm), during (31 ppm) and after (30 ppm) the intervention, therefore, these findings show that the intervention had no significant impact on CO_2.

This is confirmed by the results of the statistical analysis to test the research questions and hypothesis relating to CO_2 which show that whilst there was a statistically significant difference between the medians of the control and the intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

As the ventilation systems on the wards are identical and subject to the same pre-planned maintenance regime the difference in CO_2 levels may have occurred due to the (1) difference in the efficiency of the ventilation systems and (2) difference in window opening activity between the control and intervention groups.

Throughout the study, both study groups spent the majority of time (99%) within BS EN 16798-1 high range (IEQ_I) for indoor environmental quality. However, the quantitative findings are not consistent with the qualitative findings from the staff comfort surveys in the 'air quality' question. Before the intervention, the control group reported the highest percentage (53%) in the 'slightly bad' score and the intervention group reported the highest percentage (33%) in the 'bad' score. However, the 'bad' score is consistent with feedback from staff during the pre-intervention staff focus group for Intervention B ward who reported the ward as having poor air quality.

During and after the staff reported the highest percentages (51% & 68% for the intervention group and 76% & 45% for the control group respectively) in the 'neither bad nor good' scores, which is consistent with the quantitative findings. However, previous studies (Bedford and Warner 1939, Angus 1968) reported that occupants associated poor air quality with a build-up of disagreeable heat moisture and odour rather than CO_2, which may explain the reason for these inconsistencies.

8.3.6 Window movements

The descriptive analysis showed that before the intervention, the intervention group had 53% more window movement events than the control group, 27% less during the intervention and 3% less after the intervention, which supports the theory that *running an energy behaviour change, adapted from Operation TLC saves greenhouse gas emissions whilst creating a healthy environment for patients and staff* by closing windows when the heating is on enabling the heating system to effectively control temperatures and minimise energy wastage. These results are consistent with the literature review revealed that in non-domestic settings energy behaviour change was found to diminish when feedback stopped (Dwyer et al. 1993, Darby et al. 2016).

Whilst the results of the statistical analysis to test the research questions and hypothesis relating to window movement events confirms there was a statistically significant difference between the control and the intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

As number of windows were identical across the study wards, possible reasons for the difference in the frequency of window movement events may be (1) seasonal variation (2) differing health conditions and medication of the patient affecting their ability to thermal regulate (Havenith 2001) and (3) established belief and practice, for example in the intervention group one participant felt that it was essential to introduce fresh air to the ward despite being provided with evidence based information on the high air changes from the mechanical ventilation system.

In the staff focus groups after the intervention, the staff in the control and intervention groups both reported that the windows were draughty and that patients had complained they were cold near the windows, which is consistent with the findings from the 'temperature' question in staff comfort surveys for the intervention group who reported a significantly higher percentage in the 'cold' score during and after the intervention. Whilst the control group continued to report more scores (52%) in the hotter range during these study periods, they also reported a high percentage of scores (38%) on the cool range.

Both the control and intervention groups reported they would like to be able to open the windows wider, particularly during the summer, which is consistent with the findings from the 'temperature' and 'overall comfort' questions in staff comfort surveys in both the control and intervention study groups before the intervention who reported a higher percentage in the 'hot' and 'uncomfortable' choices respectively.

However, this study used a count of window movement events to compare window activity in the study groups throughout the study, which does not definitively prove if the movement event was associated with opening or closing the window. Consequently, less window movement events do not necessarily mean the windows spent less time open.

8.4 Staff and patient experience findings

8.4.1 Trust primary management information

The result of the statistical analysis to test the research hypothesis relating to staff satisfaction confirm the findings from the descriptive analysis of the Trust management information data, and does not support the theory that *running an energy behaviour change, adapted from Operation TLC improves staff satisfaction* by reducing staff sickness and staff turnover.

The descriptive analysis showed the intervention group had higher staff sickness before, during and after the intervention when compared to the control group. Not only this, but staff sickness levels actually increased during and after the intervention in both the control and interventions group.

The descriptive analysis also showed that intervention group had higher staff turnover before, during and after the intervention when compared to the control group. Although, it also showed that staff turnover was lower in the intervention group in the study periods during and after the intervention, when compared to the period before the intervention. Whereas it was conversely higher in the control group during these periods when compared to the period before the intervention.

However, these findings may be the consequence of other factors occurring concurrently with Operation TLC, such as the personal factors, organisational factors, seasonality or other factors. Not only this but when the mean percentage of staff sickness and staff turnover for the study periods before, during and after the intervention were compared to the same management information for a two-year period (1st January 2016 - 31st December 2018) that incorporates the study period (1st August 2017 - 30th April 2018), shown in Table 88, it appears to support the previous findings.

Table 88. Comparison of Trust management information showing mean percentage of staff sickness and staff turnover for the study periods before, during and after the behaviour change intervention, and over a two-year period incorporating the study period

Period	Study group	Mean % of staff sickness	Mean % of staff turnover
2016-2018	**Control**	5	11
2016-2018	**Intervention**	6	20
Before	**Control**	2	8
Before	**Intervention**	3	25
During	**Control**	4	14
During	**Intervention**	6	23
After	**Control**	5	16
After	**Intervention**	8	18

Consequently, it may be concluded that running a behaviour change intervention, based on Operation TLC did not increase staff satisfaction in the categories of improved staff sickness and staff turnover.

Whilst the result of the statistical analysis to test the research hypothesis relating to patient wellbeing does not support the theory that *running an energy behaviour change, adapted from Operation TLC improves patient wellbeing* by improving patient recovery through reduced patient length of stay (days) in hospital for patients returning home.

The descriptive analysis showed that in the intervention group the mean length of stay for patients returning home reduced by 1% during the intervention and then by a further 2% after the intervention, whilst in the control group mean length of stay for patients returning home increased by 2% during the intervention and then reduced by 5% after the intervention.

However, this result must be taken with extreme caution as the finding may be the consequence of other factors occurring concurrently with the behaviour change intervention, such as the patients' medical conditions or their prescribed medication or other factors.

Not only this, but when the mean patients length of stay (days) for the study periods before, during and after the intervention were compared to the average mean patients length of stay (days) for a two year period (1st January 2016 - 31st December 2018) that incorporates the study period (1st August 2017 - 30th April 2018), shown in Figure 88, it appears that the mean two year period had the same percentage of difference (44%) between the control and intervention groups as the study period during the intervention.

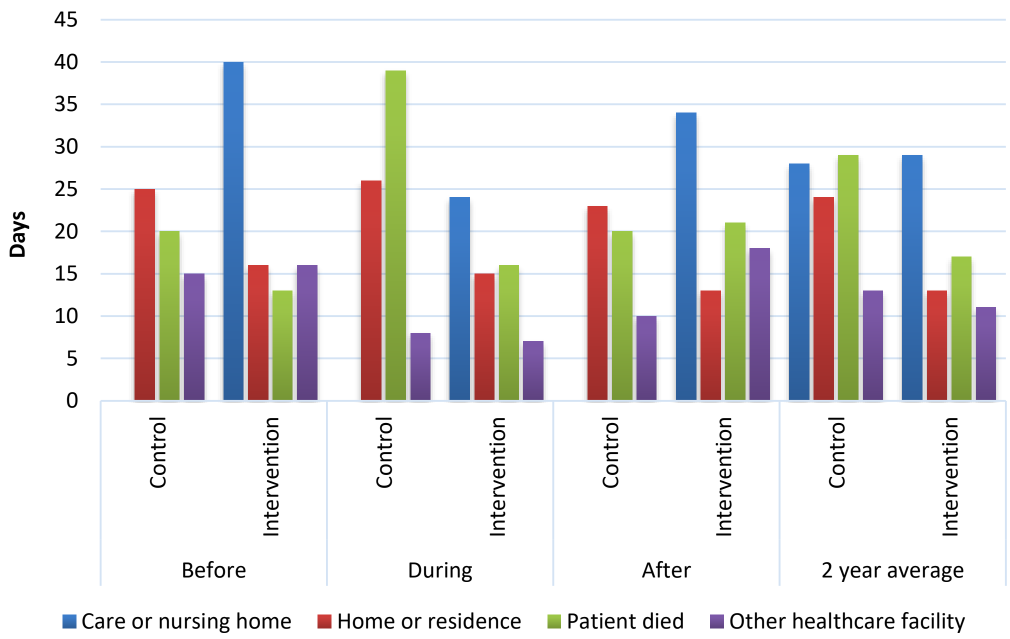

Figure 88. Comparison of Trust management information showing mean patient length of stay (days) for the study periods before, during and after the behaviour change intervention, and over a two-year period incorporating the study period

Consequently, it must be concluded that running a behaviour change intervention, adapted from Operation TLC does not improve patient wellbeing in the category of improved patient recovery.

8.4.2 Patient bed movements

Before the intervention, intervention group had 22% more patient bed movement events than the control group. During the intervention the intervention group had 17% less patient bed movement events than the control group and after intervention the intervention group had 32% less patient bed movement events than the control group, which supports the theory that *running an energy behaviour change, adapted from Operation TLC improves patient wellbeing* by increasing patient rest. These results are not consistent the findings that in non-domestic settings energy behaviour change was found to diminish when feedback stopped (Dwyer et al. 1993, Darby et al. 2016) as patient bed movements events continued to reduce after the intervention.

Whilst the results of the statistical analysis to test the research questions and hypothesis relating to patient bed movement events confirms there was a statistically significant difference between the control and the intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

As number of patients were identical across the study wards, possible reasons for the difference in the frequency of bed movement events may be (1) differing health conditions of the patient, for example, from the pilot study it was established that patients with dementia move frequently in their beds as a result of their condition (2) number of direct contacts, for example, from the pilot study it was established that patient bed movements correlated with occupancy levels, particularly with direct interactions (patient examinations, talking to nurses and visitors) and (3) the environmental conditions in the ward, particularly noise and thermal comfort.

Not only this but these results must also be taken with extreme caution as the finding may be the consequence of other factors occurring concurrently with Operation TLC, such as the patients' medical conditions or their prescribed medication or other factors. Not only this, but it took time for staff in the study groups to fully adopt the action of moving patients and not the beds, which was not the policy before the study. Consequently, some of the movement activity before the intervention may be as the result of the beds being moved rather that the patient moving in the bed.

8.5 Limitations

Whilst the barriers of implementing the behavioural change were discussed in the section 8.10 this section discusses some of the broader limitations identified during this study.

8.5.1 Sample used

The greatest limitation to the external validity of this study was the small sample size as this study only comprising of three in-patient acute-care wards in one community hospital accommodating elderly (aged over 65 years[5]), often vulnerable patients some with dementia and other mental health conditions (on average 27.5%[1]). However, two of the most current challenges for the NHS is the growth of mental health illness in society (The King's Fund 2015) and an ageing population (Appleby 2013), so the study-wards represent a growing patient demographic for the NHS.

Whilst NHS England has 287 community hospitals (HSCIC 2016b) these are made up of a whole range of building types, sizes and ages, for example the Trust involved in the study is responsible for eight community hospitals ranging from the study hospital (10 year old PFI, 3 wards, 36 patient) to one built of stone in 1921 comprising three wards with 53 patients. Not only this but NHS England community hospitals only account for approximately 3% of NHS England's total energy budget (HSCIC 2016a), which is a small consumption size in comparison to the NHS England acute hospitals.

However, despite the NHS community hospitals being varied the actions associated with the behaviour change intervention, namely **T**urn off equipment and unwanted noise, **L**ights out and **C**ontrol temperature are applicable to any hospital building and patient type through adaption of the secondary actions. What may not be validated is the level of benefits these other types of community hospital buildings will realise if they emulate this behaviour change intervention.

Whilst the sample size of the study limited the external validity of this study, the large sample size of the data gathered from sensors provides assurance of the internal validity of the quantitative variables as a large sample size increases the confidence in the estimate, decreases uncertainty and provides greater power to detect differences (Kaplan et al. 2014). However, marginally significant effects observed in large sample sizes typically mean that the effect of the study is quite modest (Kaplan et al. 2014).

Another possible limitation of the study is the potential for pseudoreplication in the sample, which leads to the exaggeration of the statistical significance of a set of measurements resulting from treating the data as independent observations when they are in fact interdependent (Davies and Gray 2015).

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[5] Figures obtained from Trust's Tableau management information reporting system (Tableau 2003), accessed on 01/08/2018

The consequence of pseudoreplication is that it increases the chance of achieving statistical significance resulting in a false result (Davies and Gray 2015), which may account for the some of the statistical inferential analyses showing a significant difference before the intervention when the descriptive analysis does not.

Whilst control and intervention groups have independent nursing staff, including supervisors and managers, the actions of the nursing staff are confounded by other influences such as (1) past experience (2) social / group norms (3) patient's preference and (4) other potentially unknown confounding aspects that impact on the study. To avoid pseudoreplication any dependent data samples were averaged and the findings were investigated in relation to other aspects during the study analysis, such as time of day (Millar and Anderson 2004).

8.5.2 Quantitative and qualitative data collection methods used

The study pilot highlighted that an accelerator based approach does have limitations when measuring patient bed movements amongst some patient groups, which creates limitations when setting the thresholding level set on the accelerometer for analysis. For example, patients with dementia frequently move in bed as a consequence of their health condition rather than necessarily the effects of the environmental conditions.

This study used a count of window movement events to compare window activity in the study groups across the study period. However, the criteria used does not identify whether the activity is associated with the window being open or closed. Consequently, it was not possible to fully verify if fewer window activity resulted in the desired action, namely closing the windows when the heating system is on.

The light sensors used for the study did not distinguish between natural and artificial light, making this approach only valid for winter months as it may over-predict the 'lights on' values during months with increased hours of sunshine. As a result, the data for the period before the intervention was disregarded from the study, which limited the ability to complete a full examination between the study periods before and after the intervention, and consequently (1) conclude whether the behaviour and the factors influencing it changed in the expected way and (2) evaluate to what extent these changes are due to the intervention, and not to some naturally occurring event (Steg 2008) for this environmental variable.

During the study, over 2,000,000 values were gathered from the sound sensors therefore, to facilitate the processing and analysis of the sound data, the raw data was aggregated to minutely mean and maximum values during the pre-processing activity. Whilst this reduced the number of observations from 200 million to 1,832,795 into a create a processible dataset, it may lead to smoothing of the datasets reducing the influence of high values in the dataset (Fisher 1925).

During the study staff were asked to voluntarily complete anonymous weekly comfort surveys, however, the response rates for the staff comfort surveys (1) before = 39% (2) during = 33% and (3) after = 37% were lower than the average response rate (59.2%) for professional employees in an organisation reported in an academic study (Baruch 1999), which limits the effectiveness of the findings.

Another limitation of the staff comfort surveys is the potential for bias and pseudoreplication, which occurs when individual observations are heavily dependent on others (Millar and Anderson 2004). Staff were frequently observed completing the comfort surveys at the nurses' station at the same time as their colleagues and whilst it appeared the nursing staff were filling them out individually, they were completing them at the same time of day and under the same environmental conditions.

8.6 Further research

8.6.1 Energy data

Whilst, the total electricity (lighting and small power) savings (13%) from this study fall in the range of previously published energy savings in non-healthcare organisations. This study comprised a small sample size, therefore, further research is recommended to investigate whether the electricity savings realised during this study are replicated by repeating the study in other community hospitals and in other categories of healthcare environments, such as acute-care hospitals and mental health facilities.

It takes around sixty-six days for a behaviour to become a habit (Lally et al. 2010), which may explain why some behaviour change interventions have not been able to successfully deliver long term energy conservation (Fisher and Irvine 2016). In relation to energy for small power, the effect of the behaviour change intervention then diminished over the fifth month and had appeared to have stopped by the sixth month, which may suggest some action takes longer than sixty-six days to become a habit. Therefore, further research is recommended to investigate this.

8.6.2 Environmental data

8.6.2.1 Light

The light sensors used did not measure lux levels, which meant it was difficult to verify the findings from the comfort surveys. Consequently, further research is recommended to identify a more effective way to monitor artificial light activity and measure lux levels, particularly if the study is repeated in other healthcare environments.

8.6.2.2 Sound

During the study, over 2,000,000 values were gathered from the sound sensors, which resulted in random sampling and extensive processing being used for the descriptive and statistical analyses. Consequently, further research is recommended to enable a full investigation of this particular variable. The sound sensors used for the study were mains powered and data was lost when the study wards were subject to power losses. Consequently, it recommended that an uninterrupted power supply (UPS) be used for monitoring equipment that uses mains power but does not have suitable back up batteries.

8.6.2.3 Temperature and thermal comfort

During the study, over 1,000,000 temperature values together with 463 staff surveys were gathered. Whilst this study examined the overall effects of behaviour change in the hospital environment, there is scope to undertake a more detailed investigation of how observed temperatures related to quantitative air temperature data gathered during this study. This includes investigating how the findings relate to other aspects not investigated during this study analysis, such as room types or time of day to name a few.

8.6.2.4 Relative humidity

During the study, over 1,000,000 relative humidity values together with 463 staff surveys were gathered. Whilst this study examined the overall effects of behaviour change on the hospital environment, there is scope to undertake a more detailed investigation of how observed humidity related to quantitative relative humidity data gathered during this study. This includes investigating how the findings relate to other aspects not investigated during this study analysis, such as room types or time of day to name a few.

In the study periods during and after the behaviour change intervention, both the control and intervention groups spent a high percentage of time (80% & 82% for the control and 73% & 76% for the intervention groups respectively) below the CIBSE recommended relative humidity levels (40%-70%).

However, the quantitative findings were not consistent with the qualitative findings from the comfort surveys in which the staff reported the highest scores (69% & 60% for the control and 63% & 70% for the intervention groups respectively) in the 'Neither humid nor dry' category for the same (during and after) study periods. Therefore, further research is recommended into the relative humidity levels on the ward to enable a full investigation into this difference in findings and the reason for the high percentage of findings below the CIBSE recommended levels.

8.6.2.5 Carbon dioxide

Whilst the quantitative data showed that the study groups spent the highest percentage of time (99%) within BS EN 16798-1 IEQ_I high range for indoor air quality, the quantitative findings from the comfort survey category 'air quality' did not reflect this, particularly in the study period before the intervention.

Before the behaviour change intervention, the control group reported the highest percentage (53%) in the 'slightly bad' score and the intervention group reported the highest percentage (33%) in the 'bad' score. Therefore, further research is recommended into the CO_2 data in relation to the occupants' observations of air quality on the wards.

8.6.2.6 Window movements

This study used a count of window movement events to compare window activity in the study groups across the study period. However, this does not identify whether the activity is associated with the window being open or closed; therefore, further research is recommended to enable a full investigation of this variable.

8.6.3 Staff and patient experience

8.6.3.1 Patient bed movements

As the findings from this study may be the consequence of other factors occurring concurrently with Operation TLC, such as the patients' medical conditions or their prescribed medication or other factors, it is recommended to check whether these findings are replicated by repeating the study in other community hospitals.

As it took some time for the staff in the study groups to fully adopt the action of moving patients and not the beds it is recommended that any required process / activity changes associate with a behaviour change intervention are introduced at least two months, and preferably three months prior to the start of the monitoring period for the study.

8.6.4 Other health benefits

Whilst this study did measure some of the health benefits from running the energy behaviour change intervention, such as patient rest and recovery, it is recommended that future research attempts to identify, quantify and directly measure the other potential health benefits associated with the identified environmental factors when running a behaviour change intervention, based on GAP's Operation TLC in a health care environment.

8.6.5 Behaviour change intervention

8.6.5.1 Information and tools

For this study, evidence-based information about how the behaviour change actions will improve the environment for the wellbeing of patients and satisfaction of the staff was presented to the participants in training sessions and posters displayed in the participating wards. Whilst this method of information provision appeared to be successful at the beginning of the intervention, the staff did not appear to look at the posters after the initial training, although patients and visitor were seen reading the posters throughout the during and after study periods.

Workload of the staff and the abundance of other information notices and posters throughout the wards appears to have limited the effectiveness of this tool. Consequently, future research is recommended to investigate more innovative ways of providing information to the participants, other than posters and monitoring their effectiveness.

8.6.5.2 Feedback and engagement

This study purposely stopped providing feedback to the participants after running the behaviour change, however, the literature review identified that continued engagement was required to maintain energy conservation (Dwyer et al. 1993, Darby et al. 2016) so the nursing staff may have continued the behaviour change actions if they were provided with continued feedback for encouragement. Consequently, future research is recommended to investigate whether the behaviour change actions are continued with continued feedback, and if so for how long if feedback is continued for longer.

However, it was also identified that engagement in feedback was found to diminish over time (Gulbinas and Taylor 2014), so new forms of feedback or encouragement should be sought in future research, such as inter-ward competitions to counteract monotony.

8.7 Summary of the discussion

A summary of the findings from the study is presented below:

8.7.1 Energy findings

Electricity	• The behaviour change intervention produced a 13% reduction in electricity (lighting & small power) consumption during and after the intervention, when compared with the control group. • Whilst there was a statistical significant difference between the control and intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

8.7.2 Environmental findings

Light	• The behaviour change intervention produced an 11% reduction in 'lights on' hours during the intervention and a 8% reduction after the intervention, when compared to the control group.
Sound	• The behaviour change intervention produced a 1dB reduction in median sound values during the intervention, when compared with the control group. • Whilst there was a statistical significant difference between the control and intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.
Air temperature & thermal comfort	• The intervention group reduced median air temperature by 0.6°C during the intervention and 0.4°C after the intervention, compared to the control group. • Whilst there was a statistical significant difference between the control and intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

Relative humidity	• The findings show that the intervention had no significant impact on relative humidity.
Carbon dioxide	• The findings that the intervention had no significant impact on carbon dioxide.
Window movement	• The behaviour change intervention produced a 27% reduction in window movements during the intervention and a 3% reduction after the intervention, when compared with the control group. • Whilst there was a statistical significant difference between the control and intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

8.7.3 Staff and patient experience findings

Trust data	• The findings show that the intervention had no significant impact in terms of the change in staff sickness or staff turnover between the control and intervention groups over the study periods. • The findings show that the intervention had no significant impacts in terms of the change in patient length of stay in hospital between the control and intervention groups over the study periods.
Patient bed movements	• The behaviour change intervention produced a 17% reduction in bed movements during the intervention and a 32% reduction after the intervention, when compared with the control group. • Whilst there was a statistical significant difference between the control and intervention groups, as the difference occurred across all three periods there is no statistical evidence that the difference occurred as a consequence of the behaviour change intervention.

Chapter 9 Conclusions

This study used qualitative and quantitative data collection methods to measure the potential sustainability (economic, environmental, social) benefits for patients, staff and the organisation of running an energy behaviour change intervention, adapted from Operation TLC in older persons' acute-care wards in a NHS community hospital with the aim of academically verifying the theory that:

"Running a behaviour change intervention in a hospital saves energy whilst creating a healthy environment that improves patient wellbeing and staff satisfaction"

This study also examines research gaps identified during the literature review, so consequently has the following objectives:

1. To run a behaviour change intervention in a hospital and measure how much energy and carbon dioxide equivalent (CO_2e) it saves.
2. To link the energy behaviour intervention to the respective hospital building, processes and interfaces with the occupants.
3. To identify, quantify and critically discuss the applicability and limitations of running an energy behaviour change intervention in a hospital.

   To identify, measure and analyse the sustainability (economic, environmental, social) benefits of running an energy behaviour change intervention in a hospital.

In conclusion, this study showed that running a behaviour change intervention, adapted from Operation TLC in a NHS community hospital providing older-persons acute-care produced the following results:

1. Electricity savings of 13%, together with the associated greenhouse gas emission and financial savings, although there was no statistical evidence that this occurred as a result of the behaviour change intervention.

2. The behaviour change intervention was directly linked to a NHS Community hospital providing older-persons acute-care, which accounts for 37% of all NHS England hospitals (HSCIC 2016b). The behaviour change intervention, modelled in Figure 13, was designed to appeal directly to clinical staff. Therefore, the behaviour change intervention used evidence-based information to emphasize the health benefits to staff and patients of implementing Operation TLC, together with rewards, feedback and goal setting to incentivise staff to participate. During the study senior and middle management support and other stakeholder involvement, particularly hard and soft facilities teams, was identified as an essential behaviour change factors together with sufficient resources for the participants, particularly the intervention facilitator and ward champions.

3. Some of the barriers that this study encountered included (1) habit and memory and (2) workload & resources. Some of the limitations identified included (1) small sample size and (2) potential for pseudoreplication in the sample.

4. Environmental savings included reduction in artificial light (11%), reduction in median noise levels (1dB), reduction in median air temperature (0.6°C) and reduction in window activity (27%) in the intervention group when compared to the control group during the intervention period. Social savings included reduction in sleep disturbances and (22%) in the intervention group when compared to the control group during the intervention period, shown in Figure 89. Although there is no statistical evidence that these benefits occurred as a result of the behaviour change intervention.

This nurse led behaviour change intervention also created the quieter periods required for better patient outcomes, which continued for at least a month after the intervention before gradually tailing off but not stopping during the monitoring period. Although it took up to a month to implement quieter periods showing a delay in the effect. Switching off small power equipment took effect immediately and continued for a month after the intervention, before tailing off over the next month and completely stopping in the following month.

The study also showed that the nursing staff in the intervention group had a heightened awareness of the environmental impacts on the wards as a result of the evidence based information used during the intervention, particularly in relation to noise and temperature, which creates risks in terms of acceptability of the approach to the nursing staff participating in the intervention, who reported their wards were cold as a result of controlling temperatures to remain within the CIBSE recommended levels (22-24^{o}C) during the heating season.

The model shown in Figure 89, summarises the implementation costs and the sustainability (economic, environmental and social) benefits identified from the descriptive analysis of running the energy behaviour change intervention in a NHS Community hospital providing older-persons acute-care.

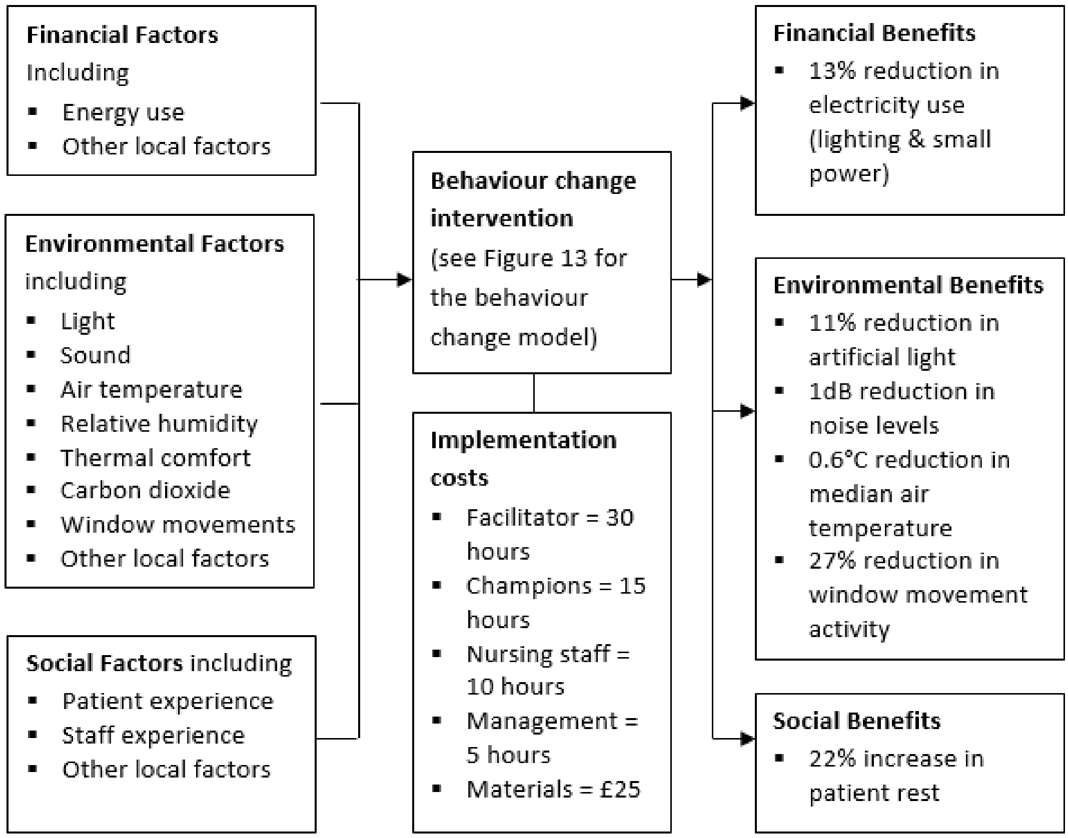


Figure 89. Model of the sustainability factors affected by the energy behaviour change intervention used in an NHS Community Hospital and the realised sustainability benefits

To summarise, the contribution to existing knowledge resulting from this study is threefold. Substantively, this study has identified implementation costs and the sustainability benefits (economic, environmental and social) of running the energy behaviour change intervention in a NHS community hospital. Theoretically, this study identified the sustainability (economic, environmental and social) factors in the ward environment affected by the energy behaviour change intervention. Methodologically, this study proposed a new model for running a behaviour change intervention in hospitals.

Appendix A Summary of behaviour change models and theories adapted from Darnton (2008)

Behaviour Models & Theories	Economic Assumptions	Behavioural Economics	Role of Information	Values, Beliefs and Attitudes	Norms and Identity	Agency, Efficiency and Control	Habit and routine	Role of Emotions	External factors	Self-Regulation	Societal factors
Expected Utility Theory	✓										
Principles of Hyperbolic Discounting, Framing Inertia											
Simon's Bounded Rationality (1955)		✓									
Tversky and Kahneman's Judgement Hueristic (1974)		✓									
Kahneman and Tversky's Prospect Theory (1979)		✓									
Stanovich and West's System 1 / System 2 Cognition (2000)		✓									
(Information) Deficit Models			✓								
Awareness Interest Decision Action (AIDA)			✓								
The Value Action Gap (e.g. Blake 1999)			✓								
(Adjusted) Expectancy Value Theory				✓							
Fishbein and Ajzen's Theory of Reasoned Action (TRA) (1975)				✓							

Behaviour Models & Theories	**Economic Assumptions**	**Behavioural Economics**	**Role of Information**	**Values, Beliefs and Attitudes**	**Norms and Identity**	**Agency, Efficiency and Control**	**Habit and routine**	**Role of Emotions**	**External factors**	**Self-Regulation**	**Societal factors**
Rosenstock's Health Belief Model (1974)				✓							
Roger's Protection Motivation Theory (1977)				✓							
Stern et al's Schematic Causal Model of Environmental Concern (1995)				✓							
Stern et al's Values Beliefs Norms (VBN) Theory (1999)				✓							
Petty and Cacioppo's Elaboration Likelihood Model of Persuasion (ELM) (1986)				✓							
Fazio's MODE Model (1986)				✓							
Schwartz's Norm Activation Theory (1977)					✓						
Sykes and Maza's Norm Neutralization Theory (1957)					✓						
Cialidini's Focus Theory of Normative Conduct (1990)					✓						
Rimal et al's Theory of Normative Social Behaviour (2005)					✓						
Turner and Tajfel's Social Identity Theory (1979)					✓						
Turner's Self Categorisation Theory (1987)					✓						

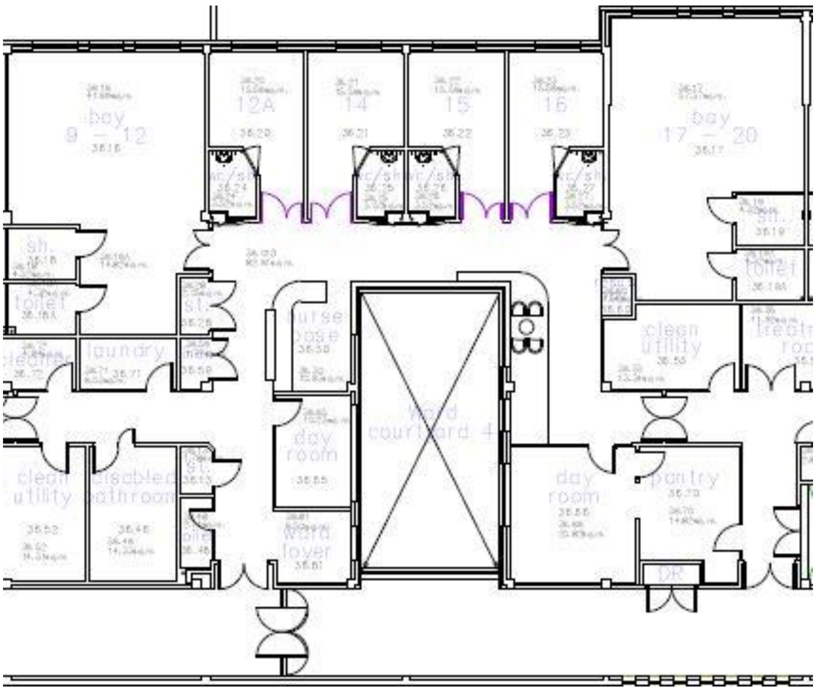
Behaviour Models & Theories	Economic Assumptions	Behavioural Economics	Role of Information	Values, Beliefs and Attitudes	Norms and Identity	Agency, Efficiency and Control	Habit and routine	Role of Emotions	External factors	Self-Regulation	Societal factors
Ajzen's Theory of Planned Behaviour (TPB) (1986)						✓					
Bandura's Theory of Self Efficacy (1977)						✓					
Hovland's Theory of Fear Appeals (1957)						✓					
Kolmuss and Agyeman's Model of Pro-Environmental Behaviour (2002)						✓					
Triandis' Theory of Interpersonal Behaviour (TIB) (1977)							✓				
Gibbins and Gerrard's Prototype / Willingness Model (2003)							✓				
Slovic's Affect Heuristic (2002)								✓			
Loewenstein et al's Risk As Feelings Model (2001)								✓			
Spaagaren and Van Vliet's Theory of Consumption as Social Practices (2000)									✓		
Giddens' Theory of Structuration (1984)									✓		
Carver and Scheier's Control Theory (1982)										✓	
Bandura's Social Cognitive Theory of Self-Regulation (1991)										✓	

Behaviour Models & Theories	**Economic Assumptions**	**Behavioural Economics**	**Role of Information**	**Values, Beliefs and Attitudes**	**Norms and Identity**	**Agency, Efficiency and Control**	**Habit and routine**	**Role of Emotions**	**External factors**	**Self-Regulation**	**Societal factors**
Viek et al's Needs Opportunities Abilities Model (1997)											✓
Dahlgren and Whitehead's Main Determinants of Health Model (1991)											✓

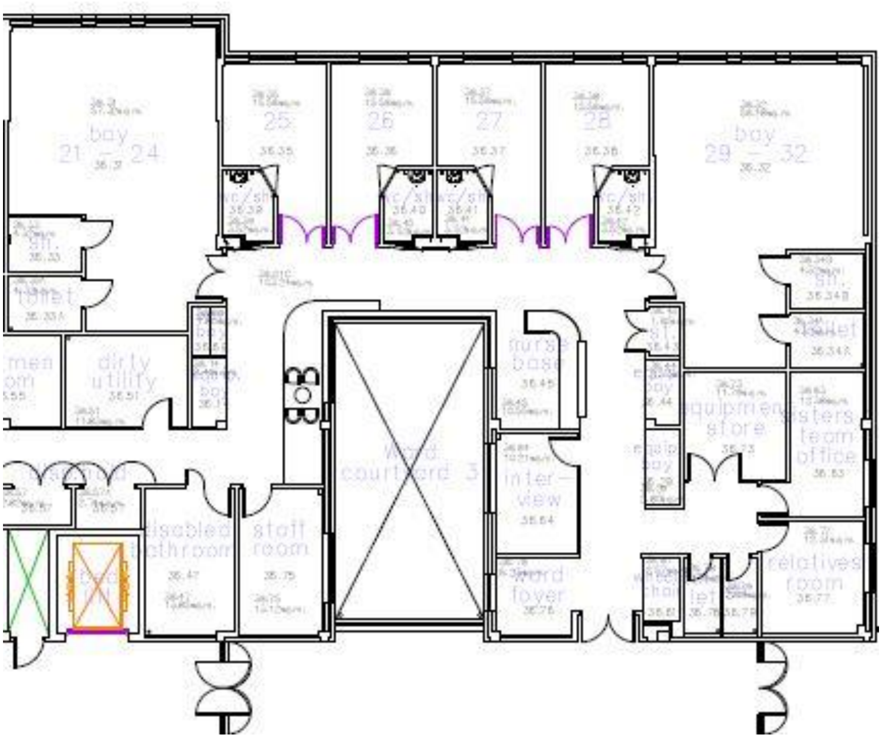
Appendix B Ward layouts

Control Ward

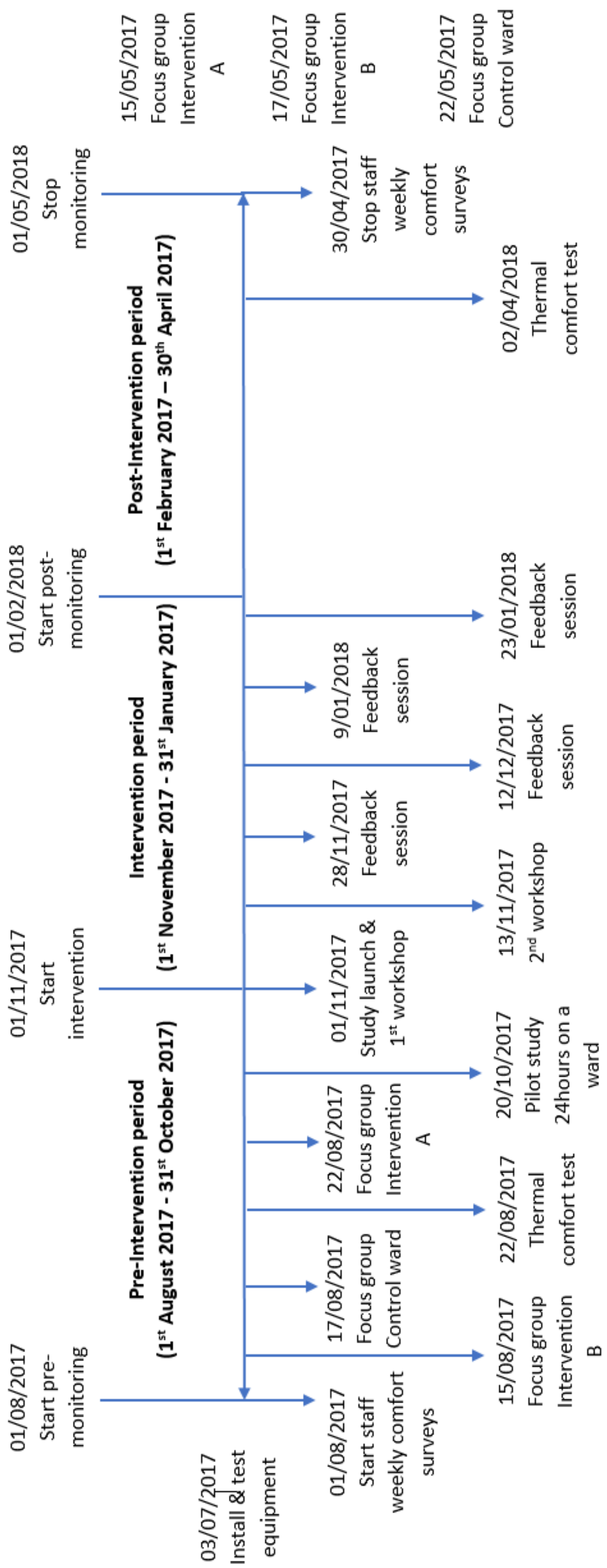
Intervention A Ward



Intervention B Ward



Appendix C Timeline of key project activities



Appendix D Hospital energy policy

1. Introduction

This document contains the Energy Policy for XXXXX Hospital. It sets out the Partners approach to energy management and energy efficiency on site, and commitment to continually improve energy performance.

The Partners comprises of the PFI Owner, the Hard Facilities Provider, the Soft Facilities Provider, the NHS Tenant and the NHS service providers.

The Partners recognise the impact that climate change is having on the health & care system and are committed to reduce the carbon footprint associated with the activities and services delivered at XXXXX Hospital.

2. Scope

This Policy is intended for use by all staff, temporary & agency workers and contractors working on site.

3. Definitions

a) **Energy:** refers to grid & on-site generated electricity and natural gas.
b) **Energy performance:** refers to the amount of energy actually consumed (or estimated to be necessary) to meet the different needs associated with the standard use of the building, including but not limited to heating/cooling, lighting and provision of hot water.
c) **Energy efficiency:** refers to the minimum / optimum amount of energy required to enable delivery of the activities and services on site.
d) **Climate change:** refers to recent changes in climate that have been observed since the early 1900s which are of a consequence of the rise in greenhouse gas emissions created by human activities.
e) **Carbon footprint:** refers to the amount of carbon dioxide released into the atmosphere as a result of the activities and services on site.

4. Duties / Responsibilities

a) **PFI Owner:** has overall responsibility for ensuring security and consistency of the energy supply to site. PFI Owner is also responsible for working with the other Partners to improve energy efficiency and reduce energy consumption on site in line with UK Government targets.

b) **Hard Facilities Provider:** has day to day responsibility for managing the site's energy supply and maintaining all associated energy infrastructure and plant, including but not limited to boilers, air conditioning equipment, ventilation units etc. The hard facilities provider is also responsible for working with the other Partners to improve energy efficiency and reduce energy consumption on site in line with UK Government targets.

c) **NHS Tenant:** is responsible for managing the site PFI contract and ensuring high energy performance on site. NHS Tenant is also responsible for working with the other Partners to improve energy efficiency and reduce energy consumption on site in line with UK Government targets.

d) **NHS Service Providers, temporary & agency workers and contractors on site:** are responsible for implementing this policy and any specific procedures associated with this policy in their local environment. All NHS staff, temporary workers and on-site contractors are also responsible for working with the other Partners to improve energy efficiency and reduce energy consumption on site in line with UK Government targets.

5. Policy Contents

Policy objective: The objective of the energy policy for XXXXX Hospital is to ensure the following:

a) That the building contributes to the overall NHS target of meeting the UK Government's Climate Change Act target to reduce energy consumption by 34% by 2020 (from 1990 baseline).

b) That the building contributes to the overall NHS carbon reduction target of achieving a 28% reduction of primary energy consumption by 2020 (from 2013 baseline) in line with the Sustainable Development Unit target for the health & care system.

c) That the building achieves the Department of Health set target of 35 – 55GJ/100 cubic metres energy performance for all new developments and major refurbishments.

d) That the building achieves CIBSE standard for thermal comfort in hospital of an internal temperature of 21ºC - 24ºC.

e) That the utility costs to operate the building are strictly managed without prejudice to the Partners.

f) That the building energy performance is regularly monitored and managed in order to comply with UK Government targets and reporting requirements relating energy consumption and carbon emissions.
g) To raise awareness amongst all staff (including temporary and agency) working in the hospital and those visiting the hospital (including contractors) of their duty to contribute to the targets set out above.

Energy Management: the following shall occur:

a) Regular monitoring of the building's energy consumption, and associated KPIs & mandatory reporting requirements such as ERIC will be carried out by the Hard Facilities Provider and reported regularly to the Partners during contract meetings.
b) Electricity and natural gas supplies shall be metered and meter readings will be collected regularly in order maintain records of consumption and to monitor the levels of consumption. Monthly reports will be provided to detail the overall buildings energy consumption and consumption per zone highlighting any significant deviances and/or anomalies.
c) The Hard Facilities Provider will provide the other Partners with monthly reports detailing the buildings total energy consumption highlighting any significant deviances and anomalies. The Partners will review, assess and explore the significant deviances and anomalies during contract management meetings.
d) The Partners will review, assess and explore any anomalies with energy billing and/or any revenue cost implications etc. in accordance with the PFI contract.
e) On average a drop in room temperature of 1°C saves 8% of the annual heating consumption. The Partners will investigate energy efficiencies and initiatives to reduce energy consumption during contract management meetings. Potential energy improvements will be fully costed and developed into a business case prior to implementation. Any costs associated with energy improvements will be apportioned in accordance with the contract and based on realised benefits.

Energy Conservation & Efficiency: all staff, including temporary & agency workers and contractors on site are responsible for energy conservation and improved efficiency. Consequently, all staff need to be familiar with their local environment. Good housekeeping practice should form part of the staffs' everyday routine and it is expected that all staff will have consideration for the following:

a) **Lighting:**

- Make sure that lighting levels are not greater than necessary.
- Switch off lighting when it is no longer required.
- Switch off lighting in empty and unused rooms.

b) **Equipment:**

- Switch off IT equipment when not required or in use and at the end of the day, this includes but is not limited to: photocopiers, printers, fax machines, computers (display screens & hard drives), shredding machines, chargers (mobile phone, cameras etc.).
- Wherever possible, switch off clinical equipment when it is not required or is fully charged.
- Switch off air conditioning equipment during non-working hours and when not required by the users of the area it is serving.

c) **Heating:**

- Ensure heating temperatures are not excessive for the local environment.
- Reduce heating temperatures during non-working hours.
- Close windows when the heating is on.
- In areas that are provided with air conditioning, settings are set appropriately for the environment it is serving.

All staff, including temporary staff and contractors are responsible for reporting any deviances in environmental conditions to the Helpdesk as soon as possible.

Operational Management: In addition to the above the Soft Facilities Provider and Hard Facilities Provider, including their contractors and sub-contractors should ensure the following:

a) Windows are kept clean (ensuring efficiency of light sources)
b) Lighting is kept clean (ensuring efficiency of light sources)
c) Ensure lighting is replaced with high efficiency lamps (preferably LED).
d) Any redecoration is carried out using light colours and light coloured furnishings.
e) Optimise the use of directional shades and diffusers.

f) Routine checking of all areas ensuring that temperature, ventilation, lighting and hot water temperatures are maintained to within the tolerances specified with the use parameters.

g) Regular maintenance of all heating and cooling equipment is carried out in accordance with manufacturer's recommendations to ensure that maximum operating efficiencies are maintained.

h) Recalibrate controls ensuring correct settings are maintained.

i) Check location of thermostats are correct and appropriate.

j) Ensure minimum required hot water temperatures are supplied to all non-critical areas.

k) Limit showers to a flow rate of 0.2 litres/sec where possible.

l) Ensure any dripping taps are attended to in accordance with estates service schedule 14.

m) Ensure all ventilation ductwork is free from leakage and excessive vibration.

The Hard Facilities Provider will manage the site's building management system (BMS) and thermal controls (thermostatic radiator values, air cooling/heating systems etc.) to deliver an internal temperature of between 22 - 24^{o}C in the heating season and 23 - 25^{o}C in the non-heating season in line with CIBSE thermal comfort standard for hospitals to ensure the optimum healing environment.

The only except will be those areas within the PFI contract with specific thermal requirements. The internal temperatures in these areas will be managed in line with the contacted requirements.

Regular internal temperature readings will be taken to monitor the thermal comfort of local environments.

Portable electric fan heaters and private electric heaters are not permitted on site. There may be requirements, due to mechanical failure when portable (temporary) heating is required within areas. This measure will only be taken in extreme circumstances when a failure event has occurred and subsequent actions are required to rectify the event. The replacement (temporary) heating will be removed as soon as the mechanical problem has been rectified and the heating system is working normally.

6. Training Requirements

Housekeeping best practice detailed above will form part of in house training and staff familiarisation of the hospital.

All staff on site, including temporary and contractors are required to become familiar with this policy and the use of heating, ventilation and water supply controls where necessary with regard to energy conservation.

All newly recruited staff, including temporary and contractors are required to undertake familiarisation with this policy and the use of heating, ventilation and water supply controls with regard to energy conservation as part of their induction.

All staff, including temporary and contractors are responsible to ensure that their actions when using heating, ventilation and water supply controls will not negatively affect energy consumption.

7. Monitoring Compliance

The Partners are responsible for ensuring the effective implementation and regular review of this policy in all aspects of resource management and decision-making.

Any changes to this policy will be agreed by all Partners at the next available contract management meeting and communicated to staff on site at the earliest opportunity.

8. Policy Review

This Policy should be reviewed every 3 years, unless significant change or organisational learning indicates otherwise.

9. References

Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare.

Appendix E Workshop 1 presentation

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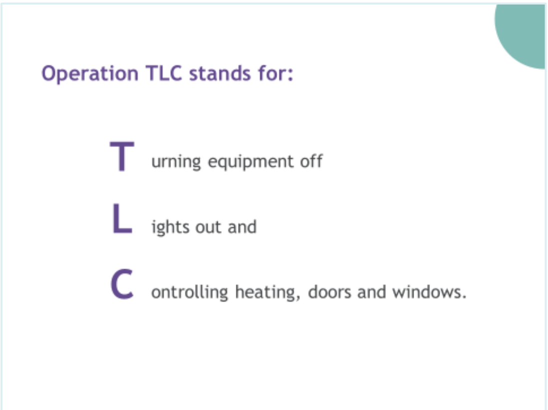

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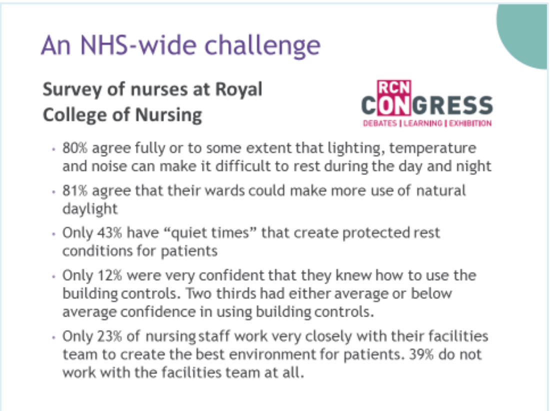

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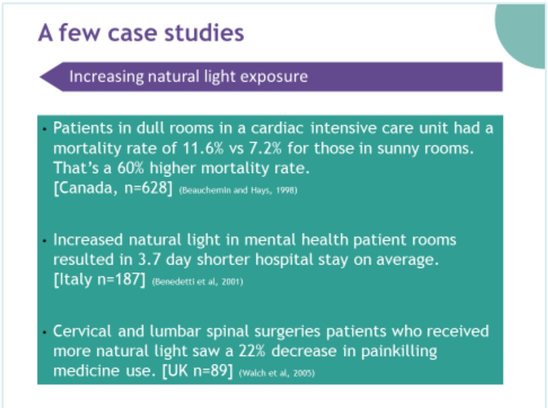

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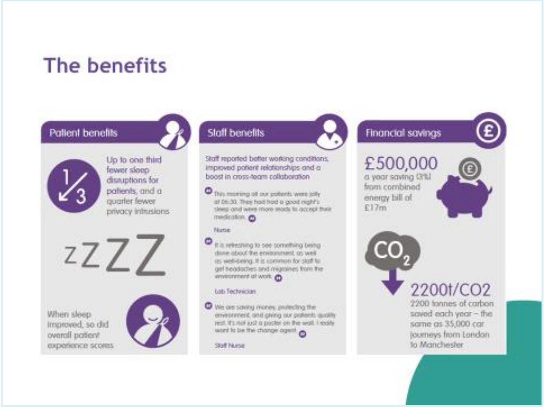

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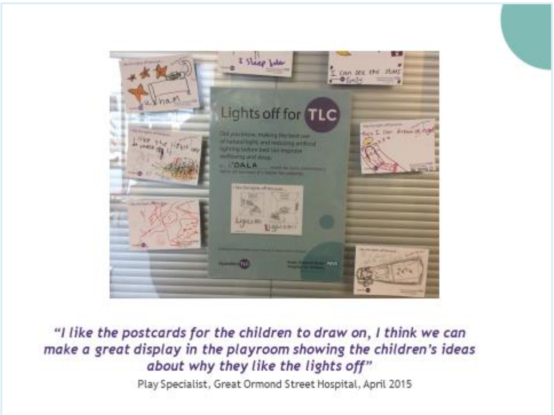

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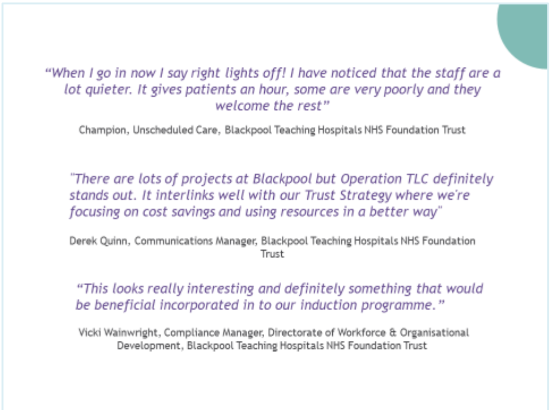

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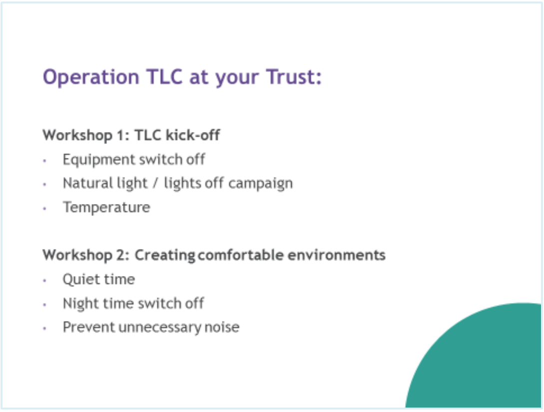

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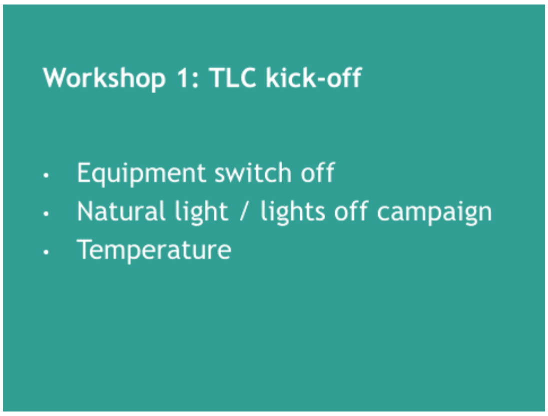

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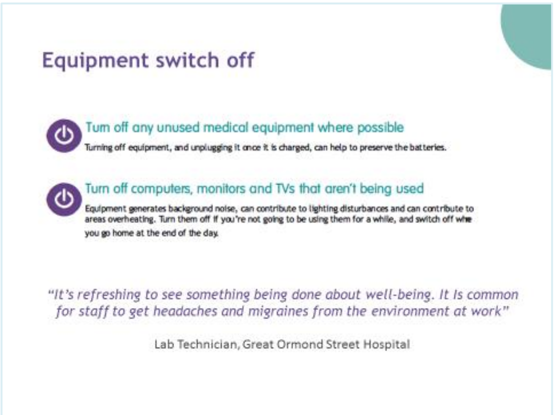

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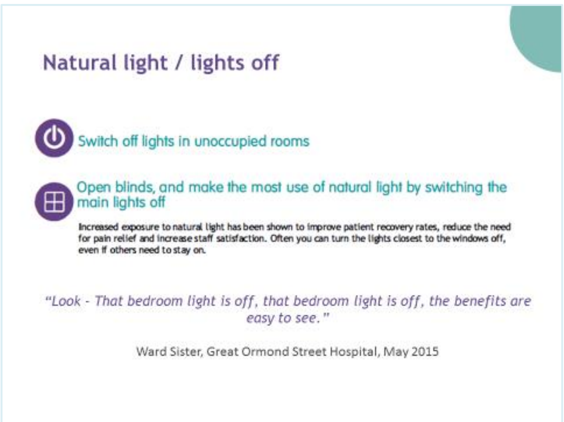

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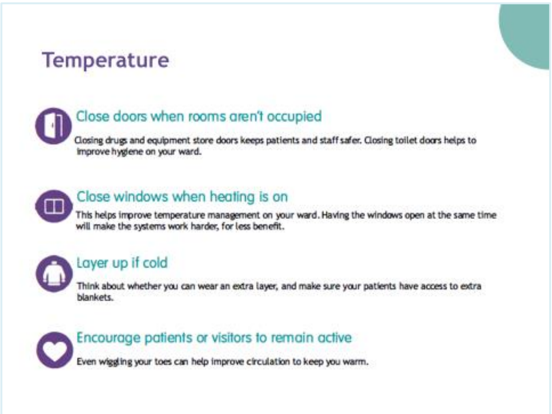

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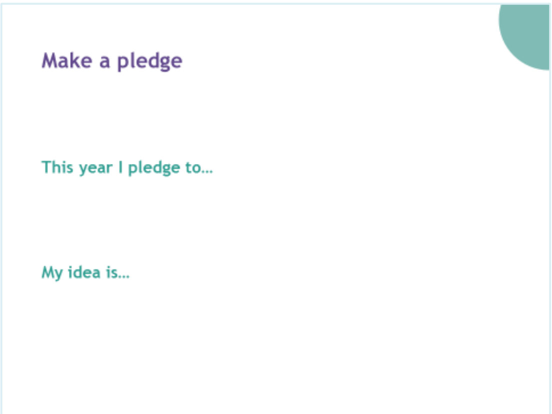

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Appendix F Workshop 2 presentation

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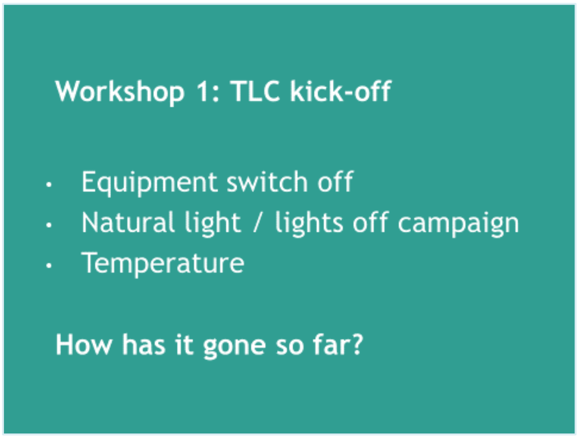

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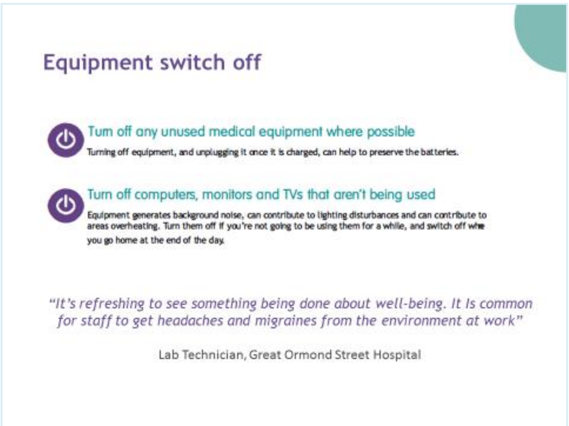

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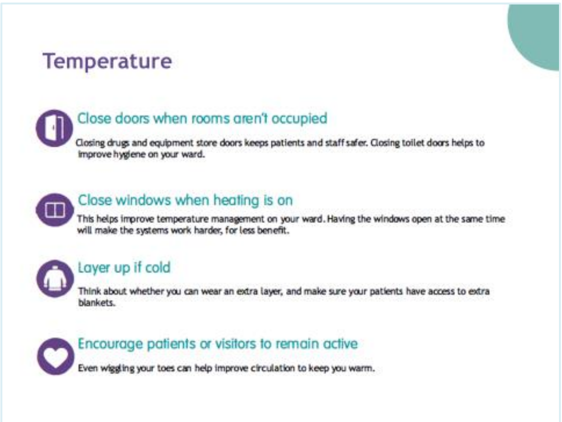

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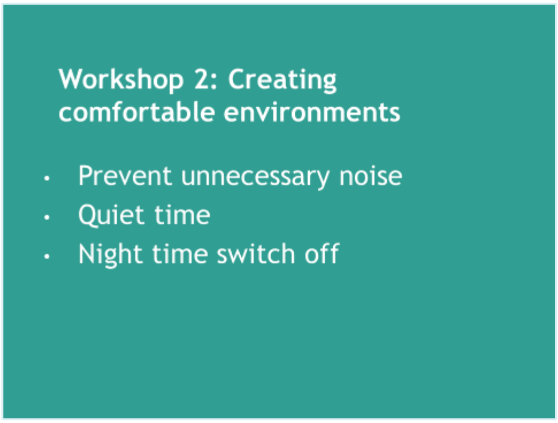

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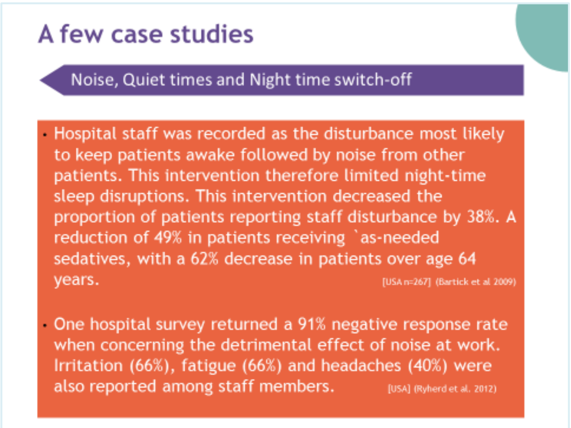

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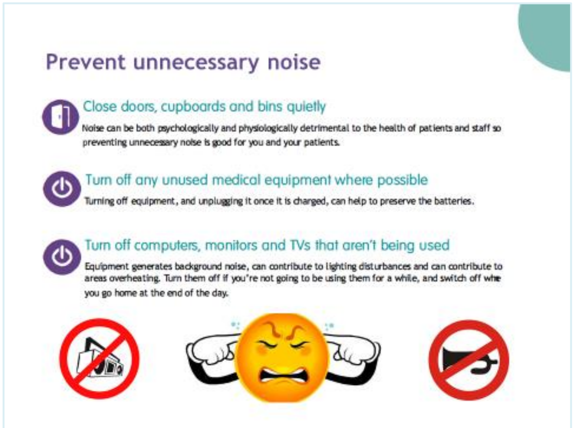

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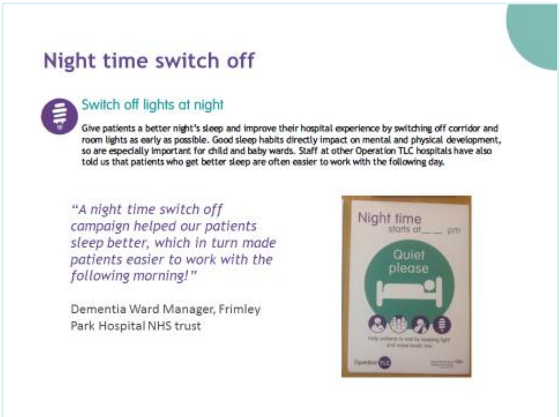

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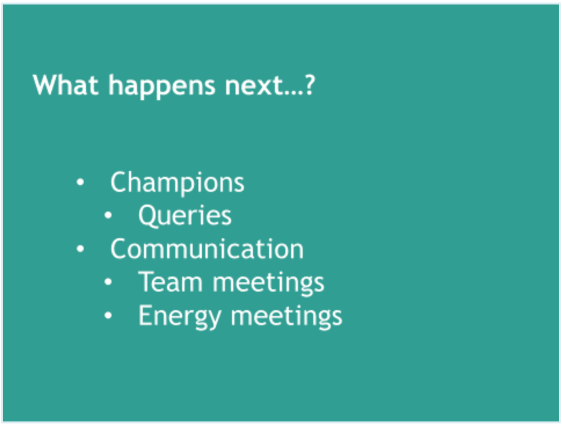

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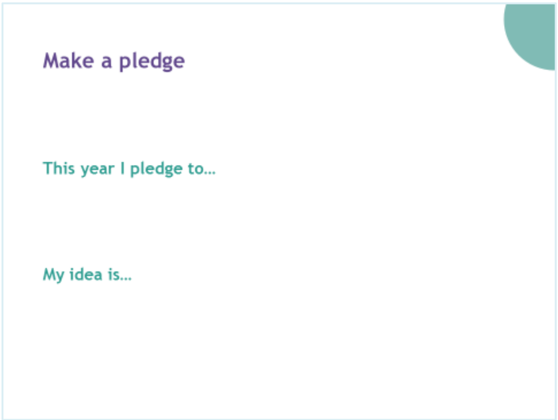

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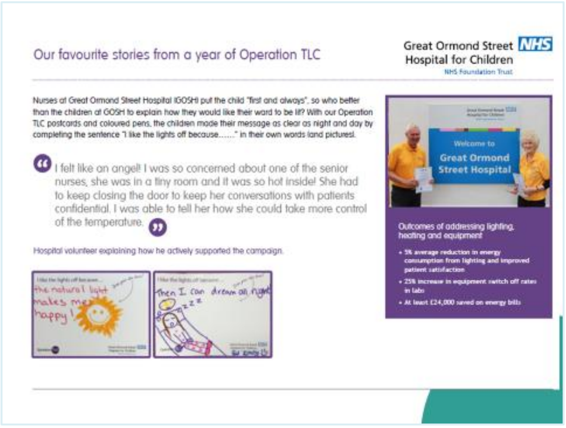

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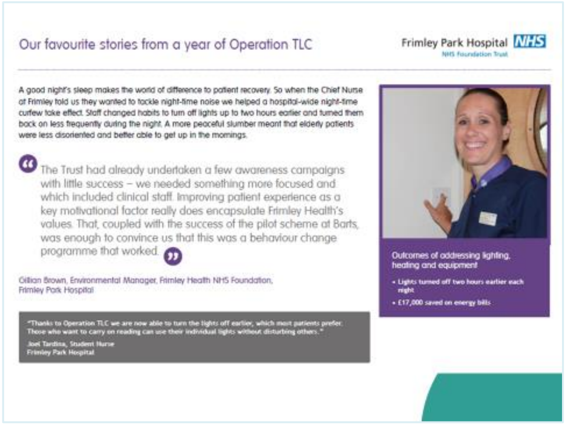

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Appendix G Staff comfort survey

This questionnaire is being conducted as part of a PhD research project aimed at improving the hospital environment for patients whilst saving energy. The answers you provide will help us understand the ward's environment and how effective Operation TLC is, which will then help us to improve. This questionnaire is anonymous and your answers will be confidential. By completing the questionnaire, you are consenting for the answers given to be used as part of an academic study. The questionnaire has been developed based on Stoops, J.L. (2001) and Global Action Plan's Operation TLC staff survey, using ASHRAE thermal sensation scale.

Please answer all the questions below by circling the description that best fits how you feel about the ward environment.

DATE COMPLETED: **TIME COMPLETED:** **WARD:**

TEMPERATURE

How do you feel at present? Please circle the description that best fits:

Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot

LIGHTING

How do you feel about the lighting level at present? Please circle the description that best fits:

Very bright	Bright	Slightly bright	Neither bright nor dim	Slightly dim	Dim	Very dim

NOISE

How do you feel about the background noise level at present? Please circle the description that best fits:

Very noisy	Noisy	Slightly noisy	Neither noisy nor quiet	Slightly quiet	Quiet	Very quiet

AIR QUALITY

How would you describe the quality of the air at present? Please circle the description that best fits:

Very bad	Bad	Slightly bad	Neither bad nor good	Slightly good	Good	Very good

AIR MOVEMENT

How do you feel about the air movement at present? Please circle the description that best fits:

Very high	High	Slightly high	Neither high nor low	Slightly low	Low	Very low

HUMIDITY

How do you feel about the humidity (dampness) of the air at present? Please circle the description that best fits:

Very humid	Humid	Slightly humid	Neither humid nor dry	Slightly dry	Dry	Very dry

OVERALL COMFORT

How would you rate your overall comfort (considering all the above factors)?

Please circle the description that best fits:

Very comfortable	Moderately comfortable	Slightly comfortable	Neither comfortable nor uncomfortable	Slightly uncomfortable	Uncomfortable	Very Uncomfortable

Do you have any other comments about your environment? If so, please put your comments in the box below:

Appendix H Staff focus groups

Key: Staff = a member of the nursing staff, including ward manager, sisters, nurses, health care support workers or a member of the ward admin staff)

A. Pre-intervention focus groups

Control Ward, 17th August 2017

1. What experience do you have of Operation TLC?
All staff: None

2. How do you find the present temperature in the ward?
a) During the day?
Staff 1: Warm.
Staff 2: Very hot.
Staff 3: You can tell the change in temperature as you come in from down stairs.
Staff 1: Minimal airflow.
Staff 2: No air flow.
Staff 4: Like a convection oven.

b) At night?
Staff 1: No air flow, but less humid and a lot calmer. More comfortable until the morning about 6 you can feel it pick up again. You can feel the difference; all the lights are off so helps cool it down, plus blinds are shut.
Staff 2: It is cooler at night time. Bearable.

3. How does it differ between seasons?
a) Winter & summer?
Staff 1: To be honest not a lot, during the day when the heating is on your stifling sometimes. If you have to shower a patient, you're dying in there to be honest; no window and have to have the door shut. You would think because its winter it would be better, it's not, because the heating's on. No happy medium.
Staff 4: And because the seasons, are not true seasons in May we had two weeks of glorious weather, and now it's our summer and it's not brilliant but it is still hot on the ward and humid.
Staff 2: It is humid and hot.
Staff 4: We can have a hot day in winter and the heating is still on and then you're in for a really bad day.
Staff 3: It would be nice to have a Rep to control the heating on site. I know a lot of hospital are not controlled on site, so they could turn our radiators down or wherever the heating is controlled. If you have a patient with a temperature the atmosphere around them is warm anyway, you have a job to bring their temperature down. The ward is so warm even with a fan; it is so hard to get their temperature down when the whole ward is so warm.

b) Autumn & spring?
Staff 3: A little more bearable.
Staff 1: When does the heating kick in? Because we had some really good weather in October, and then you're suffering because the heating's on and can't be switched down. You ask for the heating to be turned down and they say no.
Staff 4: When a patient is warm, they are down to the minimum with just a nighty on, in the winter you can put a dressing gown on them if they are a bit chilly, or a blanket. Actually I don't think they ever get that chilly, only at night time when you get to like 3 o'clock they can have an extra blanket.
Staff 2: It can be colder by the windows.
Staff 3: You can get patients complain that if they are by the windows it can be a bit draughty.
Staff 1: The NHS are counting pennies, when we have the heating on and windows open, think how much money is wasted. Opening windows is not economical.
Staff 2: What you also need to remember with this modern hospital is that an awful lot of it is glass; it's like a green house, even on a mild day with just a little bit of sun it heats up because of all the windows.
Staff 3: If you go out into a stairwell, it gets so hot. It gets so hot, they then open the door and all the heat then comes out on this level, so it gets hot all along the corridor.
Staff 4: I am asthmatic and I feel it on my chest. Almost like I am gasping, on a normal day I am not but when the weather changes and it gets hot, I am gasping.
Staff 1: The patients complain about the heat, asking if they can just have a sheet on. Being a rehab ward some of them refuse to get dressed and ask for just a nighty because it's so hot. Just down to heat.
Staff 2: I am at the menopausal age so if I am having a hot flush I am dripping with sweat especially in the shower room, which has no ventilation.
Staff 3: You come out as wet as the patient because you have to wear the plastic apron, plastic glove, just like a boil in the bag basically.
Staff 1: it is like going into a sauna with clothes on.

4. How do you find the present lighting in the ward?
a) During the day?
Staff 3: I think you need to have it on otherwise it would be quite dark.
Staff 2: We tried having it off on those hot days but for the patients it was too dark.
Staff 1: They are in bed and can't see very well any way, some of them. We turn the lights off trying to make it cooler.
Staff 4: It is quite dark; it's too bright with the lights on, although we do have the dimmer.
Staff 1: It's down to the patients as they need to see, we get a lot of patients that are fall risks, so we need decent lighting in order to see things. It is not through wanting the lights on; giving our choice we would probably have them off because of the heat they generate. But because of the patients we need them on.

b) At night?
Staff 2: The nurses station is left on dim but the rest are switched off.
Staff 3: Unless a patient asks, sometimes a side lamp by the bed. Particularly if I am worried about someone I will. Some prefer it off and I will respect that. Some like it on for reassurance.
Staff 1: It's all about the position of the lights on the main ward they are on the ceiling in the side rooms they are on the wall.

5. How do you find the noise levels in the ward?

a) During the day?

Staff 4: It's noisy at the moment as we have got the fans on, they can be really noisy.

Staff 2: During the day has got quitter now Jackie has put those signs on the window sills, so now people can't sit on the sills along the corridor, a lot of people just chat and chat and chat.

Staff 3: They come in and everything seems to echo when they are talking, some people just chat and it echoes and you can hear everything they are saying. Now they are not allowed to sit there, they do what they have got to do and move on. They have not got chance to sit and chat.

Staff 1: You've got more movement, the canteen staff bringing the trollies, rattily things with cutlery.

Staff 3: You need oil on them trollies, WD40.

b) At night?

Staff 4: We try to keep it to a minimum. Only two staff on anyway.

Staff 3: Not so many people moving around. The commode and the bins, in the daytime you don't notice them because they are drowned out by everything else but at night…

Staff 1: You can't get away from no noise, snoring. If you walk around there is going to be noises. It's not a library.

Staff 2: The buzzers are loud, no difference between day and night, like a door bell. One night the buzzer got stuck on, it had shorted and was reverberating around the whole ward; we had to wait for someone to repair it.

6. Do you feel the physical environment has any impact on patient environment in terms of wellbeing, recovery and patient's experience?

Staff 1: Late at night we have problems with that, people in the bays. In the bay's some patients have not been getting a good night's sleep, because another patient has got confused, shouted, talking but we've got nowhere else to put them. You notice the next day, those patients are absolutely knackered and don't want to do anything other than rest on their beds because they have not had a good night's sleep.

Staff 2: After everything we have talked about I think heat is the main issue, we monitor their fluid intake but when it's warmer you have to keep on top of it more, a lot more.

Staff 3: You have to keep on top of the fluids or else their blood pressure will drop. So when it's warm you have to encourage them more, but some of them do not want to drink.

Staff 2: It gets quite emotional

Staff 1: Yes, when it's hot, they sleep; when they are sleeping they are not drinking. When they are not drinking it's like a vicious circle they get infection like urinal infections and blood pressure problems. It could be detrimental to their stay in hospital, and could prolong it.

Staff 4: In hot weather lethargy is a real problem because they get zonked out.

Staff 1: Also because of the nature of being in hospital, it's a boring place anyway, if they of an age where they are not able to read or entertain themselves. The TVs are quite high over the beds. If you got someone in bed 4 and their eye sight is shocking, we cannot move the TV closer. Mr So-and-so may not want to watch that, and then it causes problems. Yet again another noise, potential problem, some want to watch TV all the time, soaps or whatever, others just want quite.

Staff 3: I come from Bournemouth, and each patient has their own TV even on the wards. 4 hours free, if they are above a certain age they get it free.

Staff 1: In Southampton General you get TV in the morning until lunchtime, they watch Holiday's in the Sun or Jeremy Kyle.

Staff 2: In the side room the TV is quite high, so they have to like strain.
Staff 1: No communal area, where they can sit together on this ward.
Staff 4: We have had a few ladies lately who all chatted, but have had to shout across the ward. They maybe more likely to sit together. When Strictly starts again they will all be watching, they congregate around by the telly.
Staff 3: You're at home elderly and isolated, you come into hospital and your elderly and isolated, it must be quite hard to make friends as an elderly person. The social side of hospital is as important as the medical side. It's mostly elderly people that get lonely, depressed. If they can have a chat with somebody, just a few minutes. We have had some people who are very friendly with each other, taking each other's numbers, they chat share the paper.
Staff 2: There is a chap who comes around and chats, but it's not that regular. A lot of them are lonely. It's quite true.
Staff 1: On the other end of the spectrum there are those who just want quiet. We had a chap in one of the bays who was next to someone who had the TV on loud all the time and use to shout "Shut Up" so that the other end of the spectrum. It is a balance. If you had somewhere you could put the loud one and leave the quite one.

7. What would you like to change about the environment in your ward?
Staff 1: A communal area.
Staff 3: With a TV and some tables so they can have a chin wag.
Staff 2: New TV's with ear phones, so they can all watch different programmes. Internet connection.
Staff 4: I remember when I started here I thought isn't it warm, I started in December. I said it's very warm up here, they told me wait until the summer, do you remember? I now know exactly what they were on about "the summer".
All staff: Ventilation in the showers.
Staff 3: Could they put something on the ward where we can control the temperature? When we have done everything we can like close windows, issue blankets maybe then we could turn the heating up, and if it's hot we can turn it down. Saves someone 20 miles away setting it at random.
Staff 2: I tell you what; they have not been doing it very well.
Staff 1: I think they think because it's October, bump it up. It may well be October but when the sun come out it really gets quite warm. It can be 18-19 degrees in October; they still put it on whatever.
Staff 3: Can we have air conditioning on the ward? Better infection control even just at desk area, in the summer everyone was going into the treatment room for a break as it has air con. In the offices downstairs they have air con, we running around up and down in plastic aprons and gloves.

Intervention A Ward, 23rd August 2017

1. What experience do you have of Operation TLC?
All staff: None.

2. How do you find the present temperature in the ward?

a) During the day?

Staff 1, Staff 4: Hot.

Staff 2: Too hot.

Staff 3: I'm melting now.

Staff 2: You walk in and it's like oh with the heat. As soon as you come out of the lift it hits you.

Staff 1: As soon as you get to the stairwell it hits you. At the top of the stairs it hits you harder. One of the patients said it's like a sauna up there and he is always cold.

a) At night?

Staff 4: You think it would be cooler at night, I think it's hotter.

Staff 2: They get cold, so we close the windows, all the fans are off. No air movement.

Staff 1: It was stifling up here on Monday night.

Staff 2: it's hot now. I can feel it on my back; it ruins my hair [laughs].

3. How does it differ between seasons?

Staff 4: It's not as hot.

Staff 1: it's hotter up here because the heating's on. April/May time the heating is still on. It's stifling up here.

Staff 1: It is still hot up here as we get all the heat from down stairs. On this top floor wherever you are it is too hot.

Staff 2: Why they never put air-con in or even extractor fans in the bathrooms? You come out of the shower room needing a shower; in fact, you look like you have had a shower. It's like that day or night any time of the year. Maybe a little cooler in the winter, but not a lot, and then the heating kicks in. The heating on high because of the patients we have got and then they wonder why the bugs don't go. We breed them.

Staff 1: We are allowed to have scrubs, above a certain temperature, but we have to buy them ourselves. Twenty pound a pop.

Staff 2: It doesn't have to be scrubs, if we had this uniform but in a different material it may help the issue. In the summer we could have ¾ length.

4. How do you find the present lighting in the ward?

a) During the day?

Staff 2: Bright. It makes it hotter.

Staff 1: it has to be bright so you can see the patients and paperwork. When it's bright we have to put the blinds down, when its dark we have the lights on it's a vicious circle.

Staff 4: The crash trolley area has no light; you can't see a thing. There should be a little light there.

Staff 3: We need to have something there as long as it's not too bright.

b) At night?

Staff 4: it's all or nothing. You can have the lights off and then the light on the nurse's station is too bright. Even the bedside lights for some people they are too bright, or you have none on and you are walking around with a torch. I got shouted at with my little torch "put that light out now" from a patient.

Staff 2: If you have medication to do and you have no lights on you have to fumble around with your pen torch, which you have to hold with your teeth. It's a nightmare.

Staff 1: They should be more individual to each patient. Like if one patient is reading and another wants to doze. The lamps also get so hot.
Staff 3: That then generates heat around the ward when they are on they're that hot. If you look at the lamp down, you can see where they are burning.
Staff 1: Problems with lighting not working. It gets reported and not fixed, when you get thunder storms and you get power cuts all the lights turn on. Every light turns on you have to go around turning them all off.
Staff 2: Bay 12, if you try to dim them it goes brighter.
Staff 3: The ceiling light are out and then suddenly they will come on. Three times that light came on.

5. How do you find the noise levels in the ward?
a) During the day?
Staff 2: Weekends not so bad. Not so many staff members as during the week; hideous. They all gather around the nurse's station. [all agree]

b) At night?
Staff 1: Only when the buzzers break and you have to phone maintenance. And they are going all night.
Staff 3: Patients have problem with the buzzers going off.
Staff 4: You get one settled and the buzzer goes off not even on this side but the other side, it's loud and annoying.
Staff 2: It's more highlighted at night. You can hear things because it's night time and really quiet. The slightest noise goes everywhere.

6. Do you feel the physical environment has any impact on patient environment in terms of
a) Wellbeing? Recovery?
Staff 1: Yes, when it's hot and loud. There's an impact if they are not drinking enough or eating. Dementia patients don't realise it's hot they wrap themselves up in blankets and overheating themselves. And the bed linen is that thick.
Staff 2: The windows open silly. They should open from the top to get a bit of breeze in. You're not getting any breeze in.

b) Patient's experience?
Staff 2: We get hot and sweaty and we moan about being hot and sweaty, it drives me crazy. Sometimes when I'm showering someone I have to leave the room to dry my face of the sweat as pouring down me. I was being asked questions the other day and I'm sitting there with a paper towel, it's disgusting. I think when everyone hot we're down, you try to stay perky. You want to get a drink or have a wee but you can't because you have two patients.

7. What would you like to change about the environment in your ward?
All staff: Air con.
Staff 2: You said if it over a certain temperature, you are allowed to wear scrubs. Is it 35?
Staff 4: No it's less than that. It's too hot, I don't know what it is today, but I'm sweltering now. They are not taking into consideration the rounds we are doing. It's absolutely ridiculous. The Trust is not going to provide us with scrubs; I can't afford to buy them. I don't see why they can't look at changing the whole of the uniform we have got for everybody. I know it would have a

huge financial impact, but if you bought a new uniform that was thinner, you would alleviate the fact that people are too hot and would be buying scrubs that they can't wear.
Staff 3: The heat it impacts my cough and I can't breathe, especially when you are in an area where the air is not moving.
Staff 1: We are not lying about how hot it gets, honest.
Staff 2: New windows, opening at the top.
Staff 3: Extractor fan in the bathroom, you have to have it in houses.
Staff 2: Can we have a look at why we have to wear tights? It's too hot for trousers.
Staff 4: The policy says.
Staff 1: I tried one day and it killed me without tights. Infection control, that's why we can't have air con, infection control. Have you seen our fans they are disgusting; they don't get a regular clean. It's ok for managers to have air-con.
Staff 3: The patients that are a bit more coherent come in from downstairs and say it's hot up here.
Staff 1: If air-con can spread legionella that should be looked at. I know it's the cost element as well. If they had put it in, in the first place when they built the hospital, you would not be having to do your research on why we are all so hot. It would not be an issue. It was a brand new hospital built from scratch. They have air-con in certain places, but not in the places they need it.
Staff 2: It is common sense, that the top floor would get all the heat, we have a lockable treatment room and the medication is supposed to be stored under 25 degrees. This has not got air-con. We had to move all the saline bags, no air-con.
Staff 4: It gets even hotter, because the kitchen is right next to it. Have you asked the kitchen staff?
Staff 1: Maybe looking at the start and finish times in the summer, at the moment you have the early staff finishing at 3.30 and the late staff starting at 1.00 so you have so many bodies on the ward, just stagger the amount of people, it would also affect noise levels.
All staff: Air flow is the main thing.

Intervention B Ward, 20th July 2017

1. What experience do you have of Operation TLC?
All staff: None.

2. How do you find the present temperature in the ward?
a) During the day?
Staff 1: I think its air quality that makes me struggle. It's a marked difference in temperatures as you come up to the top floor where we are based. It's almost stifling to a point it slows down your work and makes it difficult to concentrate. We have got water available but you are not always in a position to drink enough, so you can end up with a head ache and lethargic.
Staff 2: Providing personal care in the side rooms, I find myself starting to sweat, feeling light headed and dizzy. I have had one big episode where I have been hanging on to the wall, sort of thing. Washing patients in the side room near the open windows, I was feeling light headed and extremely uncomfortable.
Staff 1: The side rooms are really, really hot at the moment. At least you have got air movement through the bays. If you have a door closed on the rooms, there is not ventilation other than a window which opens about 5 inches.
Staff 3: Its bad in the bathroom, it's really hot. It's not the physical for me, I can work in the heat it's the psychological especially for the dementia patients. I have had to walk away several times;

situation build up when they are not usually a problem. It is the heat that give the feeling of closeness. The heat makes you more intolerant.
Staff 5: The comfort is so bad you just have to go and sort yourself out. It's a really test.
Staff 4: It doesn't help intolerance. I also find when it is that hot the amount of documentation errors. I notice immediately but I was writing up a different patient in another person's name, purely because someone has been talking about them next to me and I start writing this person's name – that never happens usually.
Staff 5: The temperatures in the men and female wards are different. People nay is a good few more degrees hotter. And if you're wearing protective clothing I end up suffocating. I feel like I cannot breathe. My attention span is different and I find myself more irritable than usual. You cannot break away, its unprofessional drinking from bottles of water.
Staff 2: It's like a physiological thing, you have got people coming on to the ward and walking through the ward saying how hot it is, they then go off the ward. The team morale is affected. When we had that hot 2 weeks it was terrible.
Staff 1: I dread coming to work, 8 hours in this sweating my backside off. [All agree]

b) At night?
All staff: Still hot.
Staff 5: In the ward during the day and in the night it's the same. It's the same.
Staff 3: I came on the other morning and the shirt of the person on the night shift was coated in sweat.
Staff 4: We know it is because we check the temperature. We were hoping it would fall but it didn't; it stayed the same.
Staff 2: We start at 9, go put my stuff on, it's too hot. The patients don't all feel it under their blankets, you can't have fans on because some patients get cold and you put the patients first. You can't hear anything at night and you have nothing to look at; you notice the heat more.
Staff 4: Not so many distractions at night.
Staff 1: I actually find it harder on nights. Changeover of staff or if you're on a shorter shift during the day you can have a break and maybe go outside or go to somewhere with air conditioning and cool down. On nights when you're here for 12- 13 hours.
Staff 5: Our shirts are the best demonstration, they're saturated and all we've done is wash patients.
Staff 3: First thing in the small medicine room it's already 24 degrees. The room doesn't have air conditioning but it has a fridge in for the medicines, which is giving off more heat and this can cause you to make errors. You can't concentrate which is bad because you're working out the medicines. But the room next to it, the dressing room has air conditioning and we never use it in this room.
Staff 1: We also need to lock this room, controlled drug room, which makes it hotter. It can get to 30-40 degrees in here.

3. How does it differ between seasons?
a) Winter & summer?
Staff 2, Staff 3: It doesn't really differ.
Staff 5: It's about the air quality. There's something about when you walk onto these wards it's very dry. People are lethargic. [All agree]
Staff 1: We had staff member who had to be moved by occupational health because she couldn't bear it up here with her respiratory problems. [Staff 3 agrees]

Staff 4, Staff 1: It is cooler. The temperature is lower but it's still hotter than anywhere else.
Staff 3: The heating system is so poor. It makes it extremely hot up here so we having to open windows. [All agree]
Staff 2: The heating system is pumping out heat and we've having to open windows, which is a waste of money.
Staff 1: We have to have the fans going all the time; winter and summer, morning or evening. It's not good [all agree]; it's noisy and costs more money.
Staff 2: During the 2 weeks we had the heatwave. Half of my patients had kidney issues and were terribly dehydrated. And then they come in here and it's seriously harming their care.
Staff 4: We ask them to drink and they complain the waters hot.
Staff 3: Our patients are always cold, but even they were saying how hot it was during this time.

b) Autumn & spring?
Staff 1: Hot for the staff when the heating kicks in. They come on and it's boiling hot but by 2 o'clock its freezing cold.
Staff 5: And you have to wear a plastic tabard on top of our uniform.
Staff 3: Or very thick uniforms.
Staff 2, Staff 1: There is much more difference in the temperature. When the heating starts its baking until early hours and then it's freezing.
Staff 3: The heating system doesn't take into account the changing outside temperature.
Staff 1: The patients get cold and we put on blankets but if the majority are cold we call up XXXX and get them to turn the heating up.
Staff 2: But then it gets too hot. There's no control. [All agree]
Staff 5: The amount of washing you have to do because everything's hot and sweaty.

4. How do you find the present lighting in the ward?
a) During the day?
All staff: All right.
Staff 2: You don't really need the lights on.
Staff 3: You can dim the lights. They're quite customisable.
Staff 5: The lights not an issue because you got a lot of windows here.
Staff 1, Staff 4: We switch off the lights.
Staff 3: But we have to have the blinds closed to keep the temperatures down which makes it darker.

b) At night?
Staff 3: The lights at the nurse's station stay on.
Staff 4: The lights are off in the rooms and we've got the lamps above the beds if we need to treat someone but they're too bright and often broken.
Staff 2: I had an ill patient the other night and the lamp wasn't working so I had to put on the whole bay.
Staff 5: There's no regular maintenance. We have to report it when then doesn't work.
Staff 2: The problem is that everyone struggles to work them. [All laugh]
Staff 1: There are three interconnected lights and you have to get them all in the right position to work.
Interviewer: Wow that does sound complicated [all agree and laugh]

5. How do you find the noise levels in the ward?

a) During the day?

Staff 3: Noise is worse at night.
Staff 2: Morning its ok then lots of staff come onto the ward, then its quieter later.
Staff 1: The wards were made dementia friendly, which is lovely but they've run out of money and didn't replace the bins, which crash down and are really noisy. This is a really issue to our patients with dementia. [all agree]
Staff 4: I'd say the main issue at the moment is the fans; they cause the allot noise. I constantly have a headache.
Staff 5: You don't notice how deafening the fans are until you leave the ward and there's nothing. [All agree]

b) At night?

Staff 3: No issues with noise at night.
Staff 1: I think it's so quiet you really notice any noise that does happen. [All agree]
Staff 5: We know everyone's sound individually, so we know when we hear a sound who it probably is. We're all intensely listening so we can't afford to have the fans on.

6. Do you feel the physical environment has any impact on patient environment in terms of Wellbeing?

All staff: Yes.
Staff 2: That is my main issue with the dehydration issues. It looks like their drunk.
Staff 3: Yes, definitely when we have the hot weather.
Staff 4: Yes, significant. We change the patients and they're clothing is coated in sweat which makes them feel cold but in fact they're baking.
Staff 2: It's the equivalent of waking up in cold sweat.
Staff 1: Patients with COPD really struggle with hot air.

a) Recovery?

All staff: Yes. They won't recover so quickly.
Staff 2: IF they're dehydrated they are more likely to get infections.
Staff 4: They pick up infections more when they're weak and vulnerable from the heat.
Staff 3: Germs spread in the heat.

b) Patient's experience?

Staff 3: If they are uncomfortable then they'll feel worse about their stay.
Staff 4: Some of patients get annoyed because they see others with fans and they don't have one, which upsets.
Staff 2: When they feel hot they get irritable and so they have a bad experience.
Staff 1: Definitely the number of calls increase when the weather is hot. They are angrier and more uncomfortable.

7. What would you like to change about the environment in your ward?

Staff 2, Staff 3: Air conditioning.
Staff 1: We would like the ability to control our temperature. We have issues out of hours, if there is sudden drop or increase in temperature we have to call out an engineer, which is much more expensive.

Staff 5: Better windows that we can open. Or tinting or something to control the heat in the summer and cold in the early hours.
Staff 4: It's like a greenhouse.
Staff 3: Staff uniforms. They so thick and uncomfortable in the heat.
Staff 1: Noise, definitely the bins.
Staff 3: Yes, the bins are a big one. The cupboards also, we have to put a towel over the linen cupboard at night because it slams every time you close it and the patients wake up.
Staff 4: The telephones at night are so loud, so at the night and weekends we don't have a switchboard so all the call come to the wards.
Staff 5: The buzzers. Everywhere else I've worked the buzzers and alarms have a night mode. I was shocked when we can't.
Staff 2: We have a function on the panel but it's not always working. I've tried to set it a few time but it's not working.
Staff 3: The majority of our patients have dementia so we have to eliminate as much noise as possible.
Staff 5: We get aggregated in the heat so we'd like lighter uniforms.
Staff 2: We can buy scrubs. I can't to reiterate enough the uniform problem.
Staff 3: Plus, the apron and the gloves. At least we can wear a dress; the men can't.

B. Post-intervention focus groups

Control Ward, 1st June 2018

1. What was your experience of participating in Operation TLC?
Not applicable. Control ward.

2. How do you find the present temperature in the ward?
a) During the day?
Staff 1: Hot. [all laugh]
Staff 2: Too hot.
Staff 3: You feel it as soon as you come out of the lift.
Staff 4: If we didn't have the fans on it would be unbearable.
Staff 5: It takes a little bit off it but imagine being in the shower with a patient and coming out into it; its oppressive.

b) At night?
Staff 2: It's cooler so it is more bearable.
Staff 3: It is bearable.
Staff 2: I haven't found an issue with heat at night.
Staff 3: Patients complain that they are cold by the window.
Staff 2: Yes, patients ask for blankets at night.

3. How does it differ between seasons?
Staff 1: It's never cold.
Staff 5, Staff 4: Even in the winter it's hot.
Staff 3: The seasons aren't seasons. When we get hot days in the winter and the heating's on it's unbearable.

Staff 2: Fit feels like the heating is not keeping up with the changes in the seasons.
Staff 3: Seasons don't fall as they used too. The radiators should have seasonal setting like at home so it cuts off when the temperature is at the correct setting already.
Staff 1: The fire alarms were going in the stairwell the other day because the temperatures had got over 50^{o}C.
Staff 4: You really notice the difference from the ground floor to the second floor. As you go up the building it gets much hotter. It's lovely downstairs.
Interviewer: So on the whole you don't think there is a significant difference between seasons on the ward.
All staff: Yes, it's always hot.
Staff 3: The patients may say different.
Staff 2: Yes, patients say they are cold and ask for blankets even when it's hot on the wards.

4. How do you find the present lighting in the ward?
a) During the day?
Staff 2: Can't see well.
Staff 4: It's low.
Staff 1: Some nurses don't turn the lighting on, which is not adequate.
Staff 3: It's low; quite oppressive.
Staff 5: To stop the ward getting hot we close the blinds, then you've got some of the nurses turning the lights off and it gets even gloomier.
Staff 3: We have the sun first thing in the morning so by lunchtime it's shining straight into our ward so we close the blinds.

b) At night?
Staff 2: Lighting in side rooms is not great and you have to put the light on above the bed.
Staff 3: The light in these lamps is rubbish and they get hot.
Staff 2: It's not great; they have a yellow light. They're hot so you don't leave them above the patient's head. [all laugh]
Staff 1: The lighting and temperature control is really crap. [all agree]

5. How do you find the noise levels in the ward?
a) During the day?
Staff 5: Lots of bells and it is noisy but we've got accustomed to it.
Staff 1: Yes, you really notice when it's quiet.
Staff 3: Got background noise on-top of background noise; fans, radios, tv etc.
Staff 2: Yes, you've got some patients that can't handle having their headphones on so they have the headphones around their neck and the radio on full.
Staff 3: And some have their TVs on so loud.
Staff 4: Then you've got the wheelie bin squeaking.
Staff 2: And patients calling out.
Staff 3: And the nurses. Some staff are so loud and some are quiet.
Staff 1: Some people's ideas of noisy is not another person's idea of noisy.
Staff 3: It is noisy but we've just got used to the noise.

b) During the night?
Staff 2: Nights are calm. You do get some anxious patients calling out. But on the whole it's quiet.

6. Do you feel the physical environment has any impact on patient environment in terms of their wellbeing, recovery and experience?

Staff 1: Yes, we have a lot of patients that ask why they're being punished. It's because they are on their own in a side room but it's not intentional. They get a sense of isolation.

Staff 3: As human beings not many like to be on our own.

Staff 2: A lot of patients with chest problems struggle with their breathing. We can't open the windows so we can't an air flow and it's hot.

Staff 5: I've has respiratory problems myself and I really struggle in the ward.

Staff 2: We really struggling with patients in the bathrooms; it's too humid and hot so we both struggle. We even had patients feint in the shower.

Staff 1, Staff 3: There is no ventilation.

Staff 5: It's like a sauna.

Staff 3: They're naked, which is ok for them but we're fully clothed with thick uniform, plastic apron, gloves and no air flow; and sweating. [all agree]

Staff 1: The other problem with the temperature is that we use a lot of blankets and they are really heavy, which puts pressure on their legs and feet and may cause sores.

Staff 3: We don't use blanket cradles anymore, which would stop this.

7. What would you like to change about the environment in your ward?

Staff 4: I'd like a nice window that you could actually open.

Staff 3: Air conditioning.

Staff 1: At least we have a water machine now.

Staff 2: Heat is the biggest thing effecting us.

Staff 5: It makes you more tied.

Staff 2: Makes you dread coming to work.

Intervention A Ward, 17th May 2018

1. What was your experience of participating in Operation TLC?

Staff 1, Staff 5: Enlightening

Staff 2: Yes, I think one of the biggest thing was to remember all the sensors. Moving beds about without people thinking before they did it. But it was good.

Staff 3: Something I thought when the monitors were saying it was warm I was freezing cold. But yes it was enlightening.

Staff 4: For the last ten years, ever since I've been working here I just dread the summers. I'd be dripping with sweat and I'd think I don't want to be here. Then in the winter we find the opposite; it's really cold.

Interviewer: how did you find the actions?

Staff 2: Yes, ok

Staff 3: What like shutting the windows [all laugh]. Well I wouldn't open the windows anyway, I'm such a cold person. I go behind people and close them if they're opened.

Staff 4: I found it a bit difficult keeping all the lights low. You go into the wards and it's quite dark. But I understand it's a good thing because it's keeping the place cool.

Staff 2: With quiet time, sometimes we didn't quite remember to do it and with some of the patients, they were just behaving normally and didn't sit quietly and rest.

Staff 1: Yes, it's difficult as they don't do it at home; rest at that time of day.

Staff 3: We used to do it years and years ago but now doing it here I can't recall there was too much change in the patients' behaviour even when we put the lights down low an explain this is the quiet time.
Staff 1: We've got a lot of patients with dementia and I don't think many of them realised what time of day it was anyway. [all agree]
Staff 5: I think in hospital the patients are bored to death anyway and have a little snooze when the want to. [all agree]

2. How do you find the present temperature in the ward?
a) During the day?
Staff 1, Staff 2, Staff 4, Staff 5: hot.
Staff 3: Well then again it's hot outside so it's going to be. But the other week I was freezing cold. I was so cold by the time I got home. It's a nightmare.
Staff 2: You are a cold person.
Staff 3: Yes. I find it comfortable today whereas others find it hot.
Staff 1, Staff 4, Staff 2: hot and sweaty.
Staff 5: I found it hotter yesterday; then I was hot and sticky. Today it not quite so bad.
Staff 4: The corridor and stairwells get extremely hot or cold, which really affect the staff and patients. [all agree]
Staff 2: Yes, there lots of windows. They don't open or if they do it's not noticeable.
Staff 3: Yes, they do open but not very much to make a difference.

b) At night?
Staff 5: I don't do night shifts.
Interviewer: Do any of you do nights?
All staff: No.

3. How does it differ between seasons?
Staff 5: I've only been here since January. I found it cold.
Staff 1: Yes, I wear a cardigan.
Staff 4: I didn't think we were allowed to wear a cardigan on the ward.
Interviewer: Yes, just to clarify as there is some confusion. The policy states you must be bear above the elbow when physically handling patients, so you can wear a cardigan or jumper when you are on the ward and are not physically touching a patient.
Staff 2: Been a bit different as it has been quite cold during the winter.
Staff 3: Yes, it's been cold this year. Is it because of the glass? I know glass creates cold in winter and heat in summer. [all agree]
Staff 5: It's difficult because there's lots of difference; some feel hot some feel it cold.

4. How do you find the present lighting in the ward?
Staff 3: I like them on in the morning. I don't like the light off in the bays. The rooms are long and the back of the bay is always dark, so I always turn the lights on in the bays.
Staff 1: It's good that we can dim the lights.
Staff 5: Yes, a lot of the patients are elderly and at 20.00hrs they're ready to go to bed. Dimming the lights, it makes it more comfortable for them.
Staff 2: I agree you come in the morning, particularly in the winter and its dark and I like to be able to see what I'm doing.

Staff 3: Yes, it’s grey enough as it is, without being dark in the ward.
Staff 2: In the summer it doesn’t bother me because its bright anyway.
Staff 3: Don’t you find it’s dark at the end of the day even in the summer? [all agree]
Staff 4: I’ve come on a couple of shifts at 13:00 and the lights are off its quite dark. With our patients at their age they aren’t able to see well, particularly when the lights are off.

5. How do you find the noise levels in the ward?
a) During the day?
Staff 1: It’s noise when the nurses get together. [all agree]
Staff 5: Doctors rounds are louds.
Staff 3: It’s all or nothing [all agree]. There’s dozens of them and you can’t hear yourself think, or like today its quiet and you think where are they all? [all laugh]
Staff 2: Yes, it’s been quite today.
Staff 2: Yes, it’s quieter on the weekend when there are no doctors and OTs on the wards.
Staff 1: Yes, there are much fewer people on the weekends.
Staff 4: Purely down to the numbers that come onto the ward.
Interviewer: So you think its people that cause the most of the noise on the wards?
All staff: Yes.
Staff 5: The bin trolleys are noise. The wheels’ squeak.
Staff 1: Yes, the one today was very bad.
Staff 4: The big laundry trolleys in the morning are also noisy.
Staff 3: The laundry trolley is down to the person who puts the laundry in. He keeps it just about far enough for us not to complain. It’s not the trolley, we had the young man from downstairs do it and we didn’t even know he was there; he was so good. But this one who always does it has been told about it before, instead of opening the door he used to smash the trolley into the doors.
Staff 2: The meal trolleys can be bad. Not the trolleys themselves but the housekeepers.
Interviewer: So apart from the bin trolley that squeaks, you think it’s the people’s actions creating the noise not the trolleys?
All staff: Yes.
Staff 2: Yes, most of the meal trolley are very quiet but there’s one who pushes the trolley around and makes such a noise. Crash, bang, wallop. Everything is moving, the crockery is rattling. Don’t know how you make a non-noisy trolley make so much noise. [all laugh]
Staff 1: Yes, this person doesn’t change her tone of voice; she always shouts. She doesn’t change her tone to the patients; she’s so loud to everyone.
Staff 5: Yes, she’s always too loud and if the patient doesn’t answer quickly enough they don’t get anything.
Staff 2: Sometimes the black and yellow waste bins in the rooms are too noisy if you release the pedal too quick.
Staff 4: Some people are noisy and some people are not. It’s the way we are.

6. Do you feel the physical environment has any impact on patient environment in terms of their
a) Wellbeing? Recovery?
All staff: Yes.
Staff 3: Yes, but the environment here is rather nice, therefore our patients are always satisfied; they love the atmosphere.

Staff 1: Yes, we have a patient here whose has come back in and they say they love it here and wouldn't want to go anywhere else.
Staff 5: Patients like it because we can look after them well. The environment is particularly lovely and it's the right size for us to look after them well.
Interviewer: how about the environment in relation to temperature, light, noise and those kinds of elements?
All staff: Yes.
Staff 2: Yes, if they are comfortable then they are happy and if they are happy then they get better quicker.
Staff 3: Yes, when they're happy we all happy. All these things rub off on each other. And if staff are not happy then this effects on the patients.

b) Experience?
Staff 1, Staff 2, Staff 3, Staff 4: Yes.
Staff 5: Yes, but I don't think they think about it.
Staff 4: They would be more likely to complain about their care if they had a bad experience.
Staff: 2: Yes, we have a sprinkling of frequent fliers who don't mind coming back. [all laugh and agree]

7. What would you like to change about the environment in your ward?
Staff 1: Make it a bit cooler.
Staff 3: No I wouldn't do that. Being selfish, I'd make it more comfortable for me. [all laugh]. For me it needs to be warm I hate being cold. Everything ceases up and I can't think.
Staff 5: I prefer being cold.
Staff 2: We're all like that. We want to make it comfortable for ourselves. That's what makes it difficult. I like to be just comfortable. I don't like to be hot.
Staff 4: Yes, if you get cold you can put something on.
Staff 3: But if you're hot you can do something about it. At home if I get hot I take my shoes off and put my feet on the tiled floor.
Staff 1: You can't do this here though. [all laugh]

Intervention B Ward, 15th May 2018

1. What was your experience of participating in Operation TLC?
Staff 1: Bit of an inconvenience
Staff 2: Really?
Staff 1: Yes, it was a bit of an inconvenience at times but on the whole it was ok.
Staff 3: It was more about remembering the bed monitors.
Staff 3: In the beginning it was a bit harder but as got easier now to remember.
Staff 5: The window signs concern the patients. They see the sticker and think they can't open the windows open at all.
Interviewer: Just to clarify the windows only have to be closed when the heating is on. Not at this time of year when the heating is off. Feel free to remove the stickers if it's confusing for the patients just put them back on when the heating is switched on later in the year.
Staff 5: The problem is that the British weather doesn't work as a season anymore. It can get very warm in the winter still and COPD patients COPD benefit from having the windows open.

Interviewer: Yes, obviously when we first started the initiative we made it clear that if the actions impacted on specific medical conditions then obviously you do what you need to do in terms of the patients' medical requirements.
Interviewer: So on the whole it was a bit of an inconvenience but not too bad when you got into the swing of things.
All staff: Yes.

2. How do you find the present temperature in the ward?
a) During the day?
Staff 2: Generally, I find it all right.
Staff 1, Staff 3, Staff 4: Not today. It's hot today.
Staff 5: It's getting hotter.
Staff 4: It gets very hot in the side rooms but we can shut the blinds. The computers make it hotter.

b) At night?
Staff 1: When we had cold weather, it was cold on nights.
Staff 2: Yes, but we can wrap up if it gets cold.
Staff 1: Yes.
Staff 3: It gets cold at night. There are loads of drafts, particularly from the windows.

3. How does it differ between seasons?
Staff 4: I found it very cold in the winter. I don't normally feel cold on this ward but I did this year.
Staff 1, Staff 2, Staff 3, Staff 5: No difference; hot.
Staff 2: It's unbearable in the bathrooms all year and the uniforms are so thick.
Staff 3: Yes, we're hot anyway washing the patients and then we're dripping in sweat with the thick uniform with the plastic aprons and gloves on.

4. How do you find the present lighting in the ward?
a) During the day?
Staff 3: Too bright.
Staff 5: People put it on too much.
Staff 2: I find it difficult to use.
Staff 5: I find it really effects my eyes. I don't switch them off because others switch them on.
Staff 1: There's too much light. We have the lights on the ceiling, the lights in the wall and it's too much.

b) During the night?
Staff 3: Fine.
Staff 1: They don't go off before 21.00 hrs at night and if you turn them off you're told off because the patients can't see.
Staff 2: I had trouble seeing the other night when it was on dim and if you put the lamp on above the bed it's too bright for the patient and they complain.
Staff 5: They should be energy saving bulbs. They get very hot.

5. How do you find the noise levels in the ward?
a) During the day?
Staff 1: Between 13.00-15.30 horrendous.
Staff 4: I think it's noisier in the afternoon than in the morning.
Staff 2: There's too many staff on.
Staff 3: And then the visitors come in and it's even noisier.
Staff 5: Yes, and then you get the doctors coming around.
Interviewer: So you think its people that create the noise on the ward?
All staff: Yes.
Staff 5: It's the same on a Monday morning. It's really loud because the doctors are on their rounds; and they come in on mass because they bring the consultants and their juniors with them. Then you add in the nurses.

b) During the night?
Staff 2: It's fine.
Staff 5: We're still too noisy at hand over 20.30hr.
Staff 3: It's only the patients crying out that causes noise at night.

6. Do you feel the physical environment has any impact on patient environment in terms of their
a) Wellbeing? Recovery?
Staff 1: A lot of patients are complaining they're cold at night.
Staff 5: A lot are elderly and have circulation problems.
Staff 1: The patients that are close to the windows say how cold it is at night.
Staff 2: The blankets are thin but they're really heavy so you can't put too many on.
Staff 3: The temperature effects them a lot. Warm temperature spreads the germs. Patients that have left because they've been healed come back in 12 hours later because they've picked up a bug in here. We've had quite a few of these recently.

b) Experience?
Staff 2: No they loved it here. [all agree]
Staff 5: Yes 'Hotel XXXX'. [all laugh]
Staff 1: 24hr bed and breakfast. They love it.
Staff 3: They're quite happy with the environment apart from being cold.
Staff 5: I don't think the environment bothers them.
Staff 1: If we don't give them enough time and attention it bothers them.

7. What would you like to change about the environment in your ward?
Staff 3: Fix the draughty windows.
Staff 4: We should be able to open the windows in the staff rooms more.
Staff 2: Air conditioning and better lighting.
Staff 5: The lighting. Better dimmers. I go home and my eyes hurt.
Staff 1: The lights over the patients' bed. These are completely wrong. The light is far too bright and a horrible yellow colour. They're too hot.
Staff 2: Yes, they're dangerous. They get far too hot.
Staff 1: They really complicated to switch on/off.
Staff 3: The noise from the bins and the cupboard door. The heavy door causes loud bangs.

Appendix I Pre-processing of the light data

1. Familiarisation with the Light Data

a) Daily lighting profile

Figure 1 shows the outputs for four select days in order to examine light profiles within the winter and summer seasons.

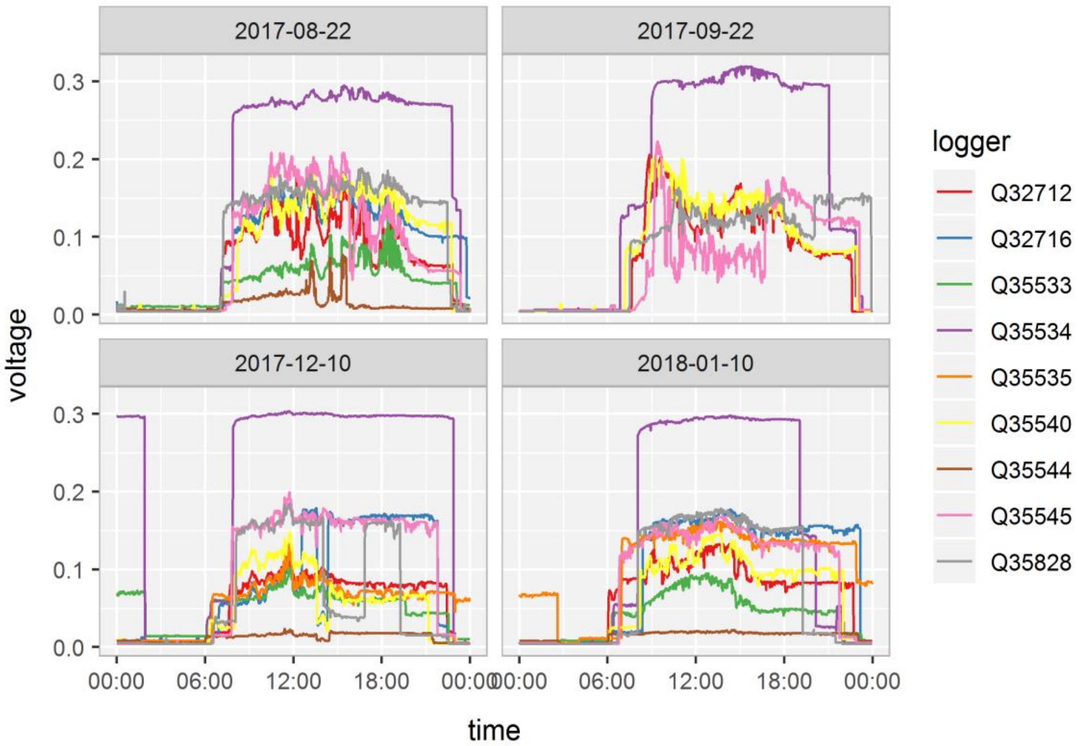

Figure 1: A comparison of light sensors across four days

2. Normalising lighting

Figure 2 shows the 'winter evening' (6-8pm during January) mean light value for each sensor, in order to identify the difference between the ON values for each depending on its sensitivity. A winter evening was chosen as there is no natural light and therefore the sensors should only record the artificial lighting in the wards.

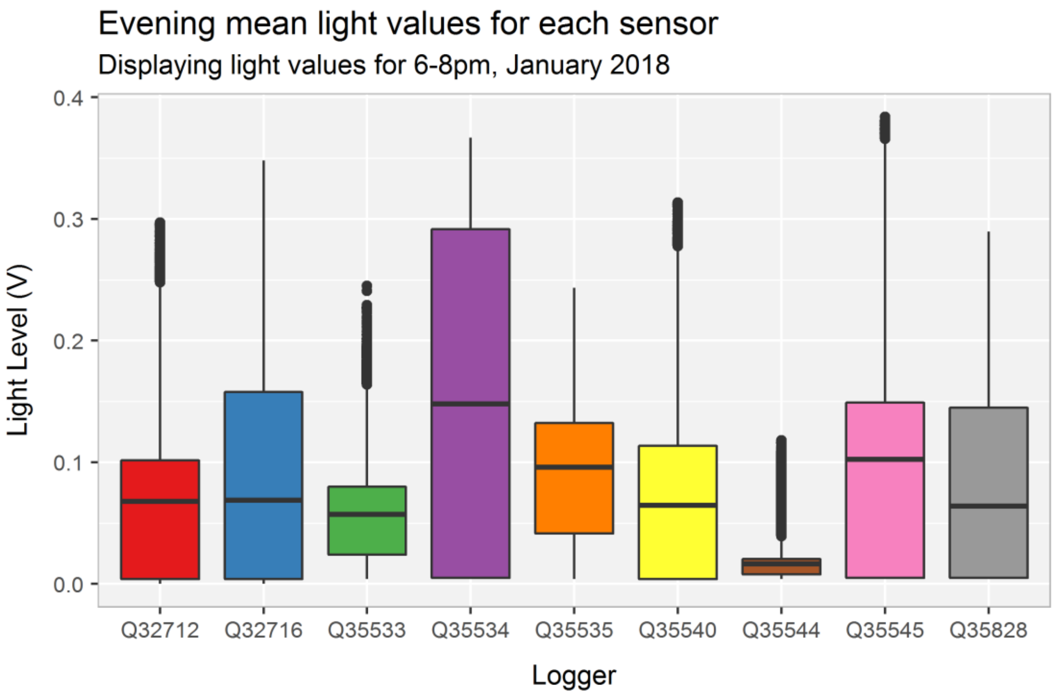

Figure 2: Mean light voltage level for each sensor

3. Organising the Light Data

Having calculated the average night time value, the light recordings are normalised for each sensors using a value of 1 corresponding to the mean evening value calculated above. Based on this normalised value, the following bands are defined:

a) Winter:

In months where the artificial lighting is dominant (i.e. the winter months), the following bands are used within the analysis:

- 0 to 0.25: the light is off
- 0.25 to 1.0: the light is dimmed
- 1.0 to 1.5: the light is on
- 1.5 to Inf: the light is on, plus natural daylight.

b) Summer:

In months where natural lighting is dominant (i.e. the summer months), there is difficulty in differentiating between ambient and artificial values but the following band is used within the analysis:

- 0 to 0.1: the light is off

4. Categorising the Light Data

a) Normalised daily lighting profile (using mean evening ON values)

Figure 3 shows the daily normalised outputs for the previous four select days using the mean evening ON values.

Figure 3 A comparison of normalized light sensors across four days.

The results from Figure 3 highlight that the cut-off value for evening lighting appears to vary. For example, the sensor in room 36.16 has a higher value on 10th January than the 22nd August. As a result, it was determined that the normalisation should occur across a broader time period. This was selected to be weekly.

b) Normalised weekly lighting profile (using mean winter evening ON values)

Figure 4 shows the weekly normalized outputs for the previous four select days using mean evening ON values.

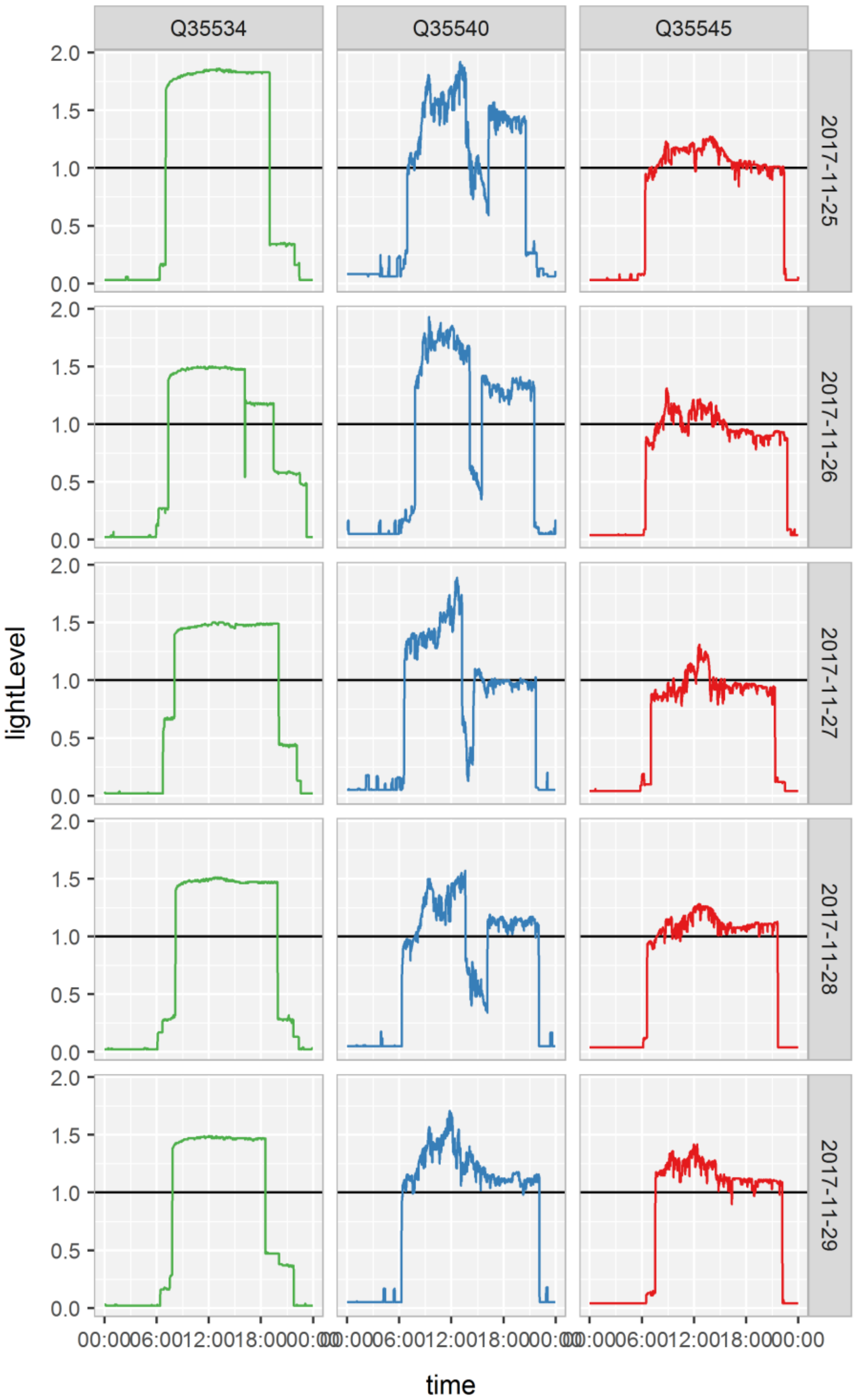

Figure 4: A comparison of three light sensors between the dates of 25th November and 29th November 2017

Figure 4 shows that the daytime value is caused by artificial lighting, as the value is constant across the day with minimal variation (something which wouldn't occur from natural light). The graph also shows inconsistency between days, with the lights being turned on and off at different times. Based on this normalised value, the summer band is disregarded and the winter band is revised as follows:

***Winter Only**:

In months where the artificial lighting is dominant (i.e. the winter months), the following bands are used within the analysis:

- 0 to 0.25: the light is off
- 0.25 to 0.6: the light is dimmed
- 0.6 to 1.25: the light is on
- 1.25 to Inf: the light is on, plus natural daylight.

c) Normalised daily lighting profile (using mean morning lights ON values)

Figure 5 shows the lights ON value determined from the mean value between the hours of 10 and 12 during winter using the new banding criteria. This approach is only valid for winter months and will under predict the light levels of summer months. However, as the intervention was run during the winter months this should approach be suitable for analyzing the light data.

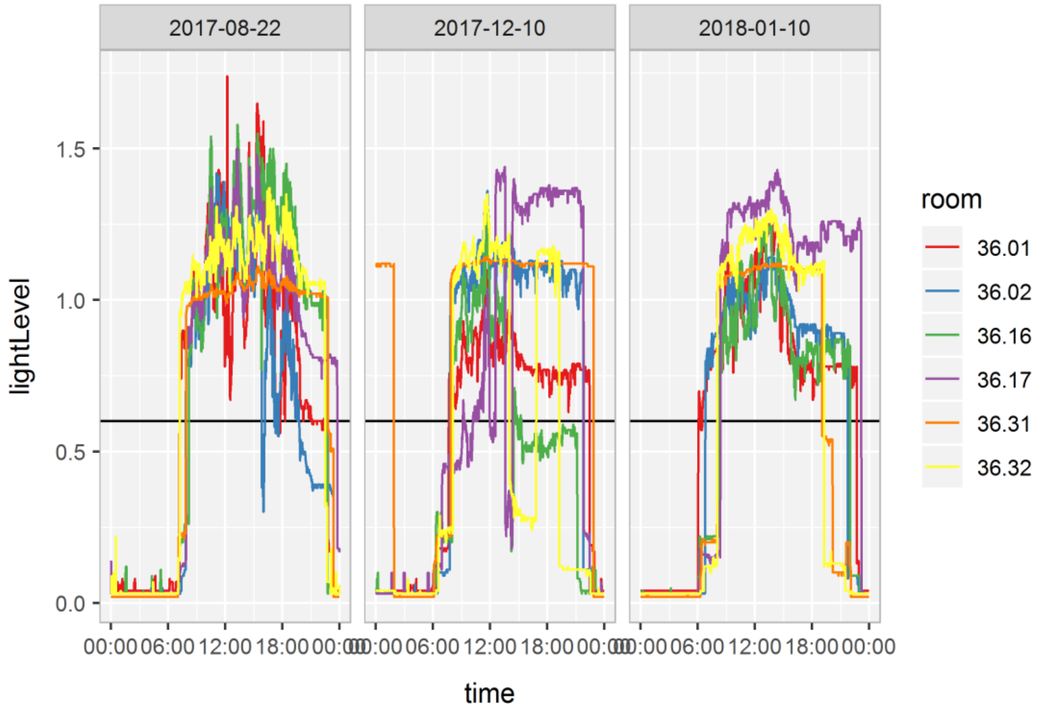

Figure 5: Lights normalized by daily mean value

Figure 6 shows an example room (Rm 36.01) using the daily normalised lighting profile (mean morning ON values). The graph shows that this methodology performing reasonably well for the winter months.

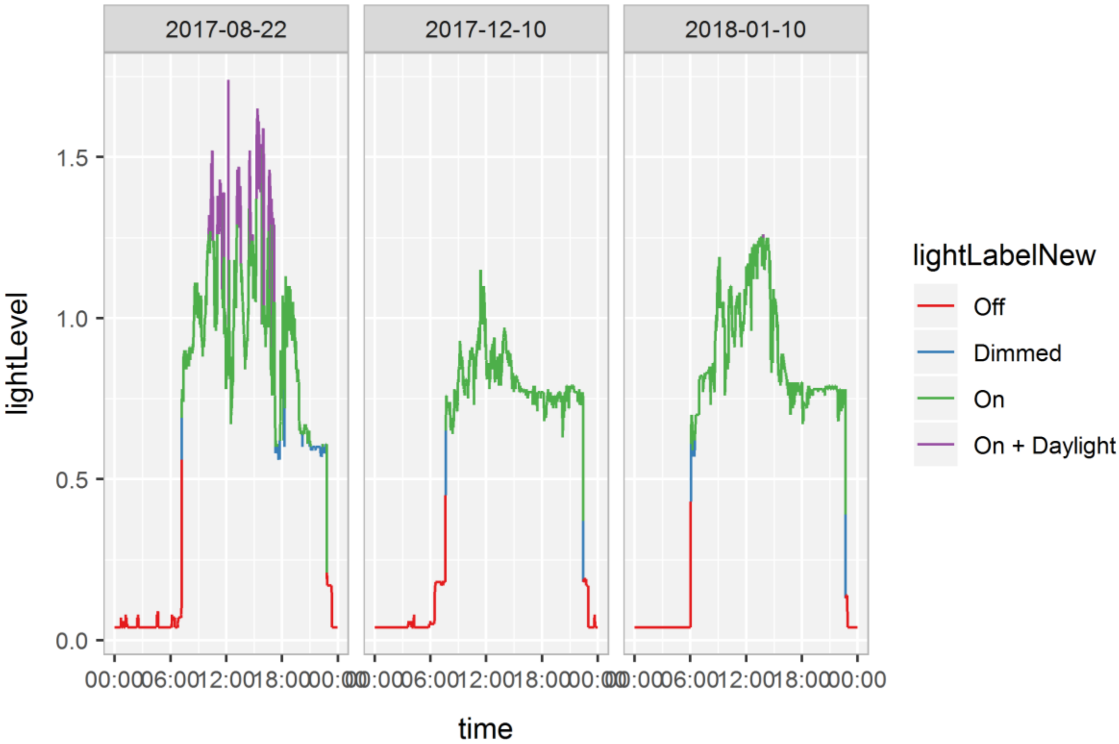

Figure 6: Example data of normalized data

Appendix J Pre-processing of the window movement data

As the sensors remain in the same position on the window, the sum of the acceleration forces (XYZ) will indicate a movement and the intensity of the movement will can be used to determine changes in the window position.

Therefore, the first step of the processing established a baseline for each sensor as follows:

1. Calculate the sum of the acceleration forces using the equation:

   $$Accel = SQRT\ (Y_{value}\hat{}2 + X_{value}\hat{}2 + Z_{value}\hat{}2)$$

2. Calculate the daily mean value for each sensor, which represents the value of gravity for each sensor, which should be around 9.81 but it varies slightly with elevation for each sensor, using the following equation:

   Accel_gravity = mean daily value for the sensor

3. Establish the daily baseline for each sensor using the following equation:

   Accel_baseline = Accel - Accel_gravity

The second step of the processing developed the criteria or a ‘small movement’, which represented the window being ajar or closed (moving to or from a 5% angle) and a ‘significant movement’, which represents the window being fully opened or closed (moving to or from a 10% angle) based on the intensity of the movement. This included the following steps:

4. Consolidate movement values to one sample per second to avoid timestamp duplication. As the movement sensors collect up to 12 samples per section, the maximum motion value for each second was kept.

5. Remove background noise for each sensor using an interactive motion dashboard. This produced the following criteria:

   Accel_noise = Accel_baseline ± 0.1

6. Develop criteria from small movement using an interactive motion dashboard and observations taken by the researcher. This produced the following criteria:

   Small_movement = Accel_noise ± 0.5

7. Develop criteria from significant movement using an interactive motion dashboard and observations taken by the researcher. This produced the following criteria:

   Significant_movement = Accel_noise ± 1.0

Appendix K Pre-processing of the bed movement data

As the sensors remain in the same position on the bed, the sum of the acceleration forces (XYZ) will indicate a movement and the intensity of the movement will can be used to determine patient bed movements.

Therefore, the first step of the processing established a baseline for each sensor as follows:

1. Calculate the sum of the acceleration forces using the equation:

   $$Accel = SQRT\,(Y_{value}\text{^}2 + X_{value}\text{^}2 + Z_{value}\text{^}2)$$

2. Calculate the daily mean value for each sensor, which represents the value of gravity for each sensor, which should be around 9.81 but it varies slightly with elevation for each sensor, using the following equation:

   Accel_gravity = mean daily value for the sensor

3. Establish the daily baseline for each sensor using the following equation:

   Accel_baseline = Accel - Accel_gravity

The second step of the processing developed the criteria for a 'significant movement', which represents a visible patient movement the following: patient examinations, bed sitting up / laying down in the bed, getting on / off the bed and turning in the bed in line with the observed 'bed events' identified by the researcher during the study pilot, shown in Table x. This included the following steps:

4. Consolidate movement values to one sample per second to avoid timestamp duplication. As the movement sensors collect up to 12 samples per section, the maximum motion value for each second was kept.

5. Remove the background noise for each sensor using an interactive motion dashboard. This produced the following criteria:

   Accel_baseline = Accel_baseline ± 0.1

6. Develop criteria from significant movement using an interactive motion dashboard and observations taken by the researcher. This produced the following criteria:

   Significant_movement = Accel_noise ± 0.3

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