A Global Study

Designing for Gender Equality

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The Chartered Institution of Building Services Engineers

Ken Dale Travel Bursary Award

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EXECUTIVE SUMMARY

Thermal comfort of occupants in buildings has drawn considerable interest in research for many years with studies exploring the topic across various building types. This research funded by The Chartered Institution of Building Services Engineers (CIBSE) through The Ken Dale Travel Bursary Award aims to assess disparities in male and female thermal comfort levels in commercial offices.

This paper documents the author's findings across 9 case study offices in London, San Francisco, Rio de Janeiro and Doha. As part of an initial online survey distributed to all occupants, 193 participants responded by answering a series of questions based on a typical working day, including – city location; gender (sex) type; description on their thermal comfort; the time at which this most likely occurred; desk location in the office; clothing and activity levels; as well as preferred adjustment measures to meet their personal comfort needs. Data collated from the survey revealed that most male occupants across all case studies considered their office to be either 'Neutral', Slightly warm' or 'Warm' based on wearing a long-sleeve or short-sleeve shirt and a pair of trousers. This differed to most female occupants who considered their office to be either 'Slightly cool', 'Cool' or 'Cold' based on wearing smart casual clothing under the same conditions. Observatory sessions followed in each case study office with notes taken on occupancy behavioural patterns to inform the research further and align commonalities and potential differences in datasets. Feedback from the sessions highlight an imbalance on thermal comfort levels achieved between male and female occupants, as the latter demonstrated across most case study offices, that indoor temperatures were more favourable to their male co-workers.

The study goes on to draw conclusions on the research question '*are buildings designed with a gender bias?*' and provides recommendations for consideration both in the designing of commercial office spaces and further research through academia or industry.

ACKNOWLEDGEMENTS

The privilege of sharing this study with you all through CIBSE and The Ken Dale Travel Bursary has been an amazing experience and would not have been possible without the much-appreciated contributions from a host of individuals and companies. My journey through the application process, being granted with funding and researching through London, San Francisco, Rio de Janeiro and Doha has been a ‘once in a lifetime’ experience. I would personally like to thank:

- The Chartered Institution of Building Services Engineers (CIBSE) for The Ken Dale Travel Bursary Award
- HDR I Hurley Palmer Flatt for offering support & encouragement as my employers through the process
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ABOUT THE AUTHOR

Ifeanyi Raphael Amajuoyi is an Energy and Sustainability Consultant at HDR I Hurley Palmer Flatt having studied at Loughborough University with undergraduate and postgraduate degrees in *Architectural Engineering and Design Management* (2013) and *Low Carbon Building Design and Modelling* (2015), respectively. His experience in the built environment centres on developing energy strategies for cityscape defining residential, commercial and mixed-use developments working alongside leading architects and design teams. As winner of the ‘CIBSE ASHRAE Graduate of the Year’ award in 2017, his presentation on ‘*Is engineering an art and should building services professionals be more creative in the way they approach projects?*’ gifted him the opportunity of attending the ASHRAE Winter Conference in Chicago in January 2018. He is a qualified Domestic On Construction Energy Assessor (DOCEA) with over 350+ residential Energy Performance Certificates lodged in his portfolio.

PREFACE

The title, 'A Global Study: Designing for Gender Equality' was chosen from a selection of suitable options for this research due to its ambiguous nature and from what I have identified as being an inquisitive choice of wording. That said, the vision for this research paper is to hold the attention of all who come into contact with it, irrespective of their academic or professional background as I believe the storyline and research question '*are buildings designed with a gender bias?*' bears strong relevance to all as we occupy buildings as part of our everyday lives.

The backstory of this research idea came early last year (2019) after reading an article titled, '*The deadly truths about a world built for men – from stab vests to car crashes'* published by The Guardian (Criado-Perez, 2019) in February 2019. The article, which I think is an amazing read and available online, highlights several items which suggest our world is subconsciously (or not) designed favouring the human male above every other species. Interesting examples put forward in the article include, crash-test dummies in the automotive industry, which have, until recently, been based on the 'average' man thus, neglecting a significant proportion of the global gender balance. Similar examples are given in the production of stab-proof vests and other personal protective equipment (PPE), which the author states have been designed predominately with the male user in mind and therefore, provides little to no comfort for female wearers given considerable differences in body type. However, of relevance to this research are the figures provided to show comparable instances of a gender imbalance in the built environment, where design temperatures developed in the 1960s for offices have been based on the metabolic rate of the 'average' man. Research, to be discussed in greater detail through the course of this paper, has since shown that the metabolic rate of a female is considerably lower than that of the equivalent male doing the same activity, which in turn potentially overestimates the female metabolic rate in offices by as much as 35%.

Female colleagues in my office are a testament to the findings of such research, where most can be seen wearing additional layers of clothing to compensate for the relative difference in thermal comfort achieved between themselves and their male co-workers (like myself!). This research funded by the Chartered Institution of Building Services Engineers (CIBSE) Ken Dale Travel Bursary Award (2019) has given me the opportunity to study this further to understand whether a similar bias in thermal comfort is experienced in commercial offices across various cities around the world, when factoring in key differences in weather and climatic conditions, occupancy gender-mix demographic as well as, social influences including ethnic backgrounds and office dress culture.

This has been an amazing opportunity by combining research and travel to some of the most amazing cities in the world and would not have been possible without the funding and support from CIBSE and my colleagues. The choice of wording in this paper is intentionally simplistic to avoid overcomplicating the findings of this study and allows readers from all walks of life to understand its content. In instances where the inclusion of a technical term is crucial to the scenario, I have done my best to explain what they mean to make for ease of reading.

A special thank you and appreciation to everyone who has been a part of this journey with me and helped in one way or another – this is a toast to our collective achievement.

1. INTRODUCTION

Our subjective nature as humans essentially means we are all different. Aside from the clear distinctions in our appearance, we respond differently and show variations in emotion in any given instance. If I provide a scenario of an imaginary room as an example and asked 10 people to occupy this room, all varying in sex (male and female), age (toddlers to older members of society), body type (slender and muscular), and decided to leave a window open, it goes without saying that some will feel a colder sensation in comparison to others – considering we place this imaginary room in London and assess their thermal comfort levels in mid-January.

This study acknowledges that a considerable amount of research has been conducted in the built environment on thermal comfort of occupants in buildings and does not wish to regurgitate what is already established. The focus of this paper leans towards the contrast in thermal comfort achieved between male and female occupants in a typical conditioned commercial office, which suggests female workers are more likely to feel less thermally satisfied (i.e. colder) when compared to their male colleagues. An exploration of the findings from relevant papers on similar topics will guide this study on potential research areas that are yet to be developed and hopefully assist with answering the research question:

…are buildings designed with a gender bias?

Observations from my daily experience during working hours often notes that my female colleagues find the office temperature a little (or more) too low for comfort. This is evident in many cases, where they are left compensating for this thermal imbalance through adaptive measures including wearing additional layers of clothing, the use of localised electric heating fans and in some instances, making use of hot water bottles. This phenomenon bears significant contrast to me and other male colleagues, who in the same fashion, tend to find the office a little (or more) too warm for comfort. Authors Kingma, B. and Lichtenbelt, W. in their paper, *'Energy consumption in buildings and female thermal demand'* highlight the lapse in the modern office design, which is based on an assumed occupancy of the 'average' male metabolic rate (the rate at which we burn energy). This overestimation of the female metabolic rate, by as much as 35% on average, results in office indoor air temperatures being slightly slower than required to ensure female thermal comfort.

As such, this research looks to explore this observation further through the Chartered Institution of Building Services Engineers (CIBSE) Ken Dale Travel Bursary. The funding offers young professionals in the developmental stages of their career the opportunity to spend three to four weeks outside their own country researching aspects in line with their professional background, which will be of benefit to the institution, their employer, clients and the profession. As part of this research, case study offices were visited in London, San Francisco, Rio de Janeiro and Doha (see Figure 1) to explore thermal perception differences between males and females.

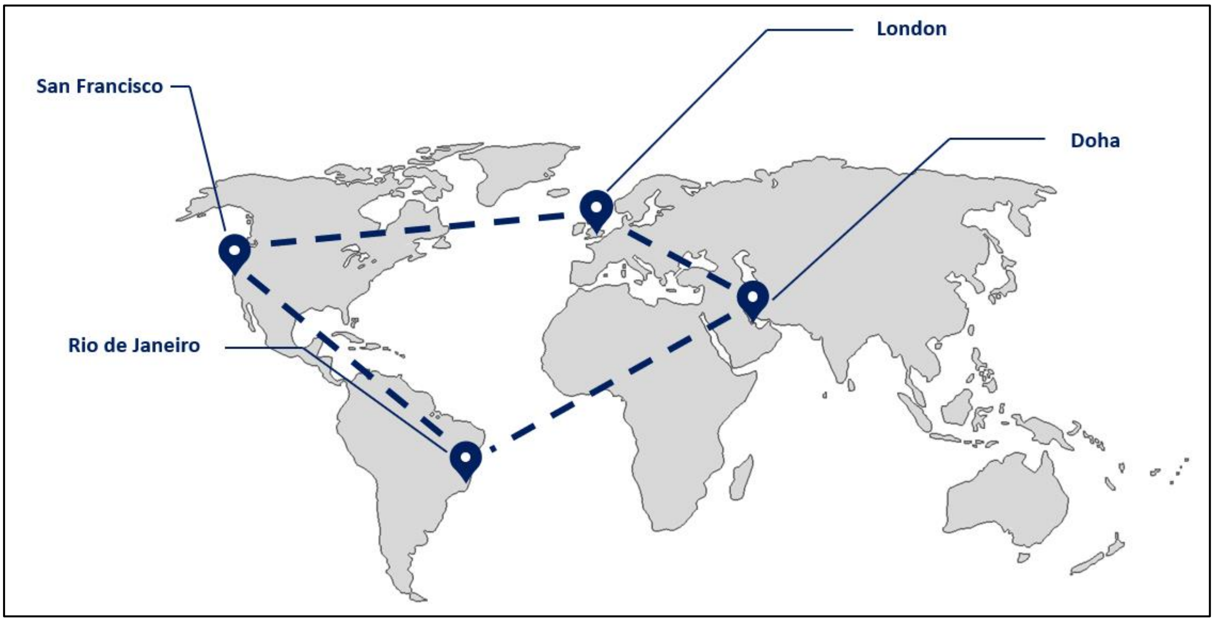

Figure 1 Cities visited as part of the 'A Global Study: Designing for Gender Equality' CIBSE/Ken Dale funded research

All participating case study offices in London, San Francisco, Rio de Janeiro and Doha were asked to distribute a thermal comfort survey to staff. This sought to gather information on city location, sex, comfort levels based on the established ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers) Standard 55, description of clothing worn and preferred methods of adjusting their comfort levels throughout the working day. Observatory sessions followed in each case study office, where notes were taken to report typical behavioural patterns of workers with a focus on differences to male and female thermal comfort levels.

The research goes on to analyse the data from the thermal comfort survey and observatory session in each case study office for comparison against case study offices in other cities. Evaluation of the data is explored with the research question in mind to understand if such a bias exists, and if so, remedial measures to be discussed and addressed further in future research through academia or industry.

2. LITERATURE REVIEW

2.1. Thermal comfort

Thermal comfort perceptions by occupants in buildings has been a long-standing research topic drawing considerable attention through published literature. These include papers such as '*Adaptive thermal comfort and sustainable thermal standards*' (Nicol and Humphreys, 2002), '*A review into thermal comfort in buildings*' (Teleghani, Tenpierik, Kurvers and van den Dobbelsteen, 2013), and '*Thermal comfort for free-running buildings*' (Baker and Standeven, 1996). The subjectivity surrounding human behaviour and expectations on comfort have been echoed across several papers reviewed and provide a suitable platform to discuss whether an all-round thermal comfort utopia for occupants simultaneously in buildings can be achieved.

The paper '*Thermal comfort and building energy consumption implications – A review*' (Yang, Yan and Lam, 2014) is one of many that highlight the importance of occupancy thermal comfort in buildings. Their reference to a literature survey of indoor environmental conditions found 'thermal comfort' of highest-ranking importance when compared with other parameters including, visual and acoustic comfort and indoor air quality. Similarly, '*Adaptive thermal comfort – principles and practice*' (Nicol, Humphreys and Roaf, 2012) mention the provision of a 'thermally safe haven' for occupants in a building, as one of the most important attributes after ensuring it is structurally viable. In recent years, studies have explored a range of parameters that influence our perception of thermal comfort in buildings. These vary from overall building use, the provision of conditioned indoor spaces as well as opportunities for interaction with the outdoor environment through openable windows. This is evident in the research paper titled, '*Mixed mode buildings: A double standard in occupants' comfort expectations*' (Deuble and de Dear, 2012). In this example, a sample of 60 occupants in mixed-mode offices (i.e. offices which provide an opportunity for natural ventilation through openable windows when outdoor conditions make this practical and the ability to switch to mechanical air-conditioned systems when required) in a sub-tropical climate. Findings from surveyed participants showed average thermal comfort levels were improved when offices were in natural ventilation mode compared to when windows were closed, and mechanical air-conditioning units switched on. '*Occupant comfort in UK offices – How adaptive comfort theories might influence future low energy office refurbishment strategies*' (Barlow and Fiala, 2007) presents the significance of analytical data to inform on optimising the office design and providing a more conducive working environment for occupants. They concede to improved methods of research, where occupants of buildings are studied to better understand thermal perceptions over the sole use of simulation design tools for the same purpose.

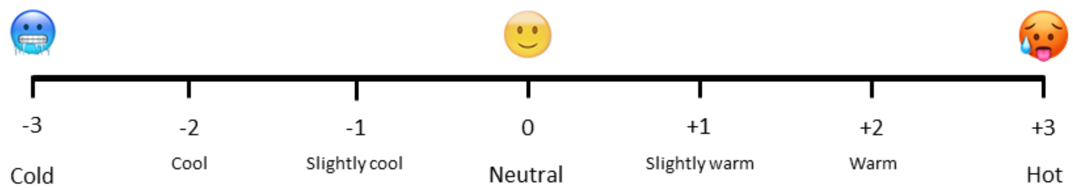

Figure 2. Fanger's 7-point scale in assessing the Predicted Mean Vote where -3 translates to being cold and +3 translates to being hot

The discussion on thermal comfort in buildings requires acknowledgement of the contributions of researcher, Povl Ole Fanger who spent many years on active research of occupants in buildings. The Predicted Mean Vote (PMV) and Percentage of People Dissatisfied (PPD), both created by Fanger, have become widely applied indices in assessing occupancy thermal comfort around the world based on his findings from steady state calculations in a climate chamber. The PMV prediction is based on a 7-point thermal sensation scale (see Figure 2) and is used to assess the mean value of votes of a group of occupants. This is seen in '*Evaluation of adaptive thermal comfort models in moderate climates and their impact on energy use in office buildings'* (Sourbron and Helsen, 2011), where the study explored potential areas of reducing energy use for heating and cooling whilst understanding the implications on thermal comfort of occupants. The same approach of using the PMV index is adopted in '*Evaluating thermal comfort in mixed-mode buildings: A field study in a subtropical climate*' (Luo et al., 2015). However, they amongst others including, (Yang, Yan and Lam, 2014); (Barlow and Fiala, 2007) and (Nicol, Humphreys and Roaf, 2012) highlight the limited application of such indices as being restricted to only the exact conditions they were created on. For example, these studies identified that the PMV/PPD did not accurately reflect the number of people who were not satisfied in their case study buildings where natural ventilation strategies were implemented nor did they account for variations in occupancy clothing or activity levels, where spaces were used to accommodate numerous activities taking place.

The paper '*Trends in thermal comfort research*' (Building Research Establishment, 1994) identifies that discrepancies in reporting of such indices became apparent as far back as the 1980s, some 10 – 15 years after they were developed. The paper goes on to discuss clear differences were observed when studies compared predicted physiological data through the PMV/PPD indices to actual occupancy thermal comfort studies that monitored behavioural patterns and reported feedback. A more recent paper titled, '*Forty years of Fanger's model of thermal comfort: comfort for all?*' (van Hoof, 2008) details limiting factors of such indices – developed in the 1960s and may be outdated as they were based on college-aged students and do not necessarily account for "all types of people, in any kind of building, in every climate zone".

The focus of this research paper is based on this discrepancy to further understand and explore the implications of applying these indices when designing modern commercial office spaces. Recent studies such as, '*Energy consumption in buildings and female thermal demand*' (Kingma and van Marken Lichtenbelt, 2015) discuss what may be a lapse in the empirical data used, where one of the primary variables – metabolic rate – is based on the 'average' male. They go on further to suggest that such design, therefore, risks overestimating the female metabolic rate by as much as 35%. This is supported with applied data in '*Metabolic equivalent: One size does not fit all*' (Byrne et al., 2005), where the metabolic rate of male participants exceeded female metabolic rates in a series of calculated surveys. A final note for this section of the report is taken from '*Are women feeling colder than men in air conditioning buildings?*' (REVHA Journal, 2015), where the author (Bjarne Olesen) counters the above theory in the office design stating "The reason that women often prefer higher ambient temperatures than men may be partly explained by the lighter clothing normally worn by women".

3. THE STUDY

3.1. Introducing the study

The concept of this research topic, 'A Global Study: Designing for Gender Equality' considers advancements of the modern commercial office by exploring the paradigm shift in gender-balance of a typical office today, compared to when thermal comfort indices such as the PMV/PPD were created.

This study ultimately looks to answer the research question 'a*re buildings designed with a gender bias?*' through the exploration of case study offices with the aim of analysing gender-comfort relationships when factoring in variables including:

- Location
- Weather and climate
- Cultural influences
- Adaptation of clothing
- Occupant demographic (proportion of males and females, etc.) and
- Internal layout and strategies for conditioning (heating/cooling) and ventilation

In line with the research objectives, 9 commercial offices were used as case studies across London (England), San Francisco (USA), Rio de Janeiro (Brazil) and Doha (Qatar) to assess occupancy thermal comfort levels. Male and female participants were assessed to discern the existence of thermal comfort disparities between both sexes whilst noting any other contributing factors. All case study offices were independent of the study and selected based on their ability to provide a thorough analysis by considering office size and number of employees to assess. The selection of offices was not specified based on core business areas, as such case studies varied from AEC firms (Architecture, Engineering and Construction) to real estate developers to financial institutions. The research had intentions of including a co-working space as a case study considering the recent rise in demand for such working environments. However, regrettably all co-working space providers contacted were unable to approve the study within the relatively short timeframe given to make this possible.

The assessments of case studies were conducted across two phases:

3.1.1. Thermal comfort survey

An 8-question online survey was circulated to a main contact(s) in each case study for further distribution to all willing participants within the office (refer to Appendix – A for the survey questions). The questions were provided in English with supporting translations in Portuguese for all Rio de Janeiro participants. The main purpose of the survey was to understand gender-specific thermal perception levels of participants from offices in each city, which will provide the basis for analysis of results and identification of common trends, if any.

3.1.2. Observatory session

Observatory sessions were organised with each case study office to inform on typical behavioural patterns of occupants. These were based on their response to various indoor conditions including air temperature, relative humidity levels, etc. whilst factoring heating, cooling and ventilation strategies. The sessions typically lasted between 1 – 3 hours and involved feedback through discussions from male and female occupants based on their thermal comfort levels. Transcripts (notes) were recorded during each visit and contents analysed to inform the study.

In line with ethical principles and the involvement of human participants, individual results from the thermal comfort survey have been kept anonymous with responses from each case study collated and placed in a larger pool of completed surveys from each city. As such, neither the author nor colleagues supporting with the data collection process can interpret where specific completed surveys have come from. This is on par with the aim of the study which focuses more on general male and female thermal perceptions and whether a bias in thermal comfort exists rather than thermal comfort feedback from occupants of a specific institution. The reporting of names of participating companies has also been kept anonymous for this purpose.

4. CASE STUDY ANALYSIS

4.1. Research destinations

The choice in destinations for this research were selected based on several variables including;

- Weather and climatic conditions
- Influence of local culture in the workplace
- Typical clothing levels of occupants in the region
- Office building types and;
- Anticipated gender-mix in a typical office environment

These variables were expected to assist in providing an acceptable platform for case study comparisons in the research and allow for further discussion in the analysis of results.

4.2. Survey

A total of 193 survey responses were collected from 3 weeks of travelling across 9 case study offices.

Table 1. Location of research case study offices

City	Country	Number of case study offices	Survey responses
London	England	2	72
San Francisco	America	3	80
Rio de Janeiro	Brazil	2	13
Doha	Qatar	2	28

San Francisco reported the highest number of participant responses followed shortly by London. It is worth mentioning that case study offices visited in these cities were notably larger in size with an increased number of office occupants compared to the smaller sized offices visited in Rio de Janeiro and Doha.

4.2.1. Gender-response rate

From the 193 responses, 107 were males, 83 females, 1 reported as being ‘Non-binary’, 1 preferred not to say and a further 1 preferred to self-describe as ‘Binary negative’.

The split in male-to-female response rate reflected observations in the average gender balance of most case study offices visited, which appeared to have a slightly higher number of male occupants compared to females.

4.2.2. Thermal comfort

All survey participants were asked to report on how best they would describe their thermal comfort in the office on a typical day. A selection of options was given in accordance with ASHRAE Standard 55 (Cold, Cool, Slightly cool, Neutral, Slightly warm, Warm and Hot).

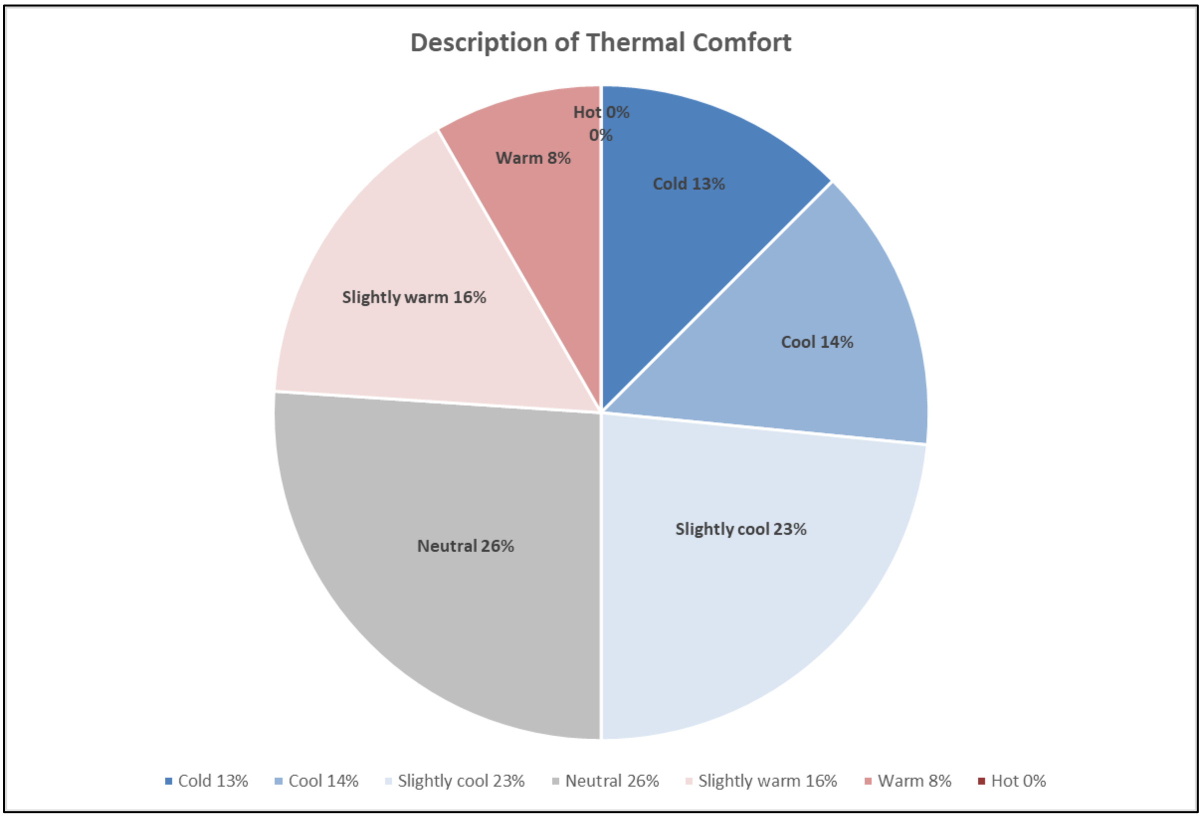

Figure 3. Description of thermal comfort responses (in percentages) across the 9 case study offices

Responses showed that most participants reported their offices on the 'colder spectrum' with 50% of occupants suggesting they either felt 'Slightly cool', 'Cool' or 'Cold' (see Figure 3). This is noted in comparison to responses on the 'warmer spectrum' where 24% reported being either 'Slightly warm' or 'Warm'. No occupant considered their office to be 'Hot' and 26% reported their office as being 'Neutral'.

4.2.2.1. Gender response rate x Thermal comfort

Analysis of participant responses on thermal comfort for a typical workday based on gender has been illustrated in Figure 4. The results show of the 107 male responses, over 40 would best describe their office as 'Neutral' in comparison to only 8 of the 83 female participants. The swing of 9 males who reported being either 'Cold' or 'Cool' is significantly overshadowed by the 43 females who reported either of the two responses. A contrast in response is seen in the number of participants who reported being either 'Warn' or 'Slightly warm' with 35 males in comparison to only 10 females.

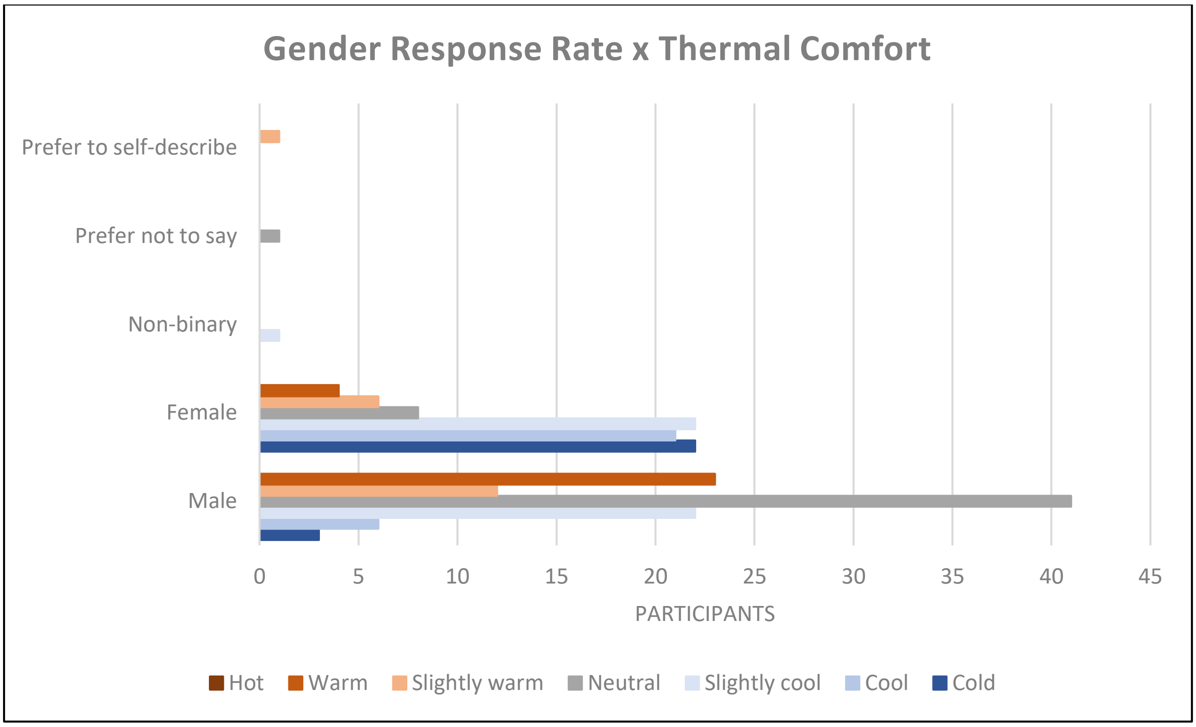

Figure 4. Gender response rate x thermal comfort

The study acknowledges that the actual thermal preferences of participants may not be entirely interpreted in the answers selected – for example, a participant who may have selected 'Slightly cool' may in fact prefer their office to be like this therefore, choosing this option does not necessarily mean they are thermally dissatisfied. As such, for reporting purposes, occupants who selected 'Slightly cool', 'Neutral' or 'Slightly warm' were deemed as *comfortable* with thermal conditions providing an optimum indoor working environment. Interpreting the data based on this thought process suggests a larger proportion of males found their office to be *comfortable* in comparison to their female counterparts.

Note: As this study aims to explore differences in male and female thermal perceptions, the three responses to gender, which do not fall under either the 'Male' or 'Female' sex type have not been included in further analysis of the results.

4.2.2.2. Thermal comfort x Case study location

The thermal comfort results presented in Figure 4 above have been split separately into male and female responses (see Figure 5 and Figure 6, respectively) for each case study location. A comparison of both shows a significant proportion of male participants found their office to be on the 'warmer spectrum' or 'Neutral' in London and San Francisco, whilst a significant proportion of female participants reported being on the 'colder spectrum' with a few reporting being 'Neutral'. A review of the same data for Rio de Janeiro and Doha shows only 1 male participant of the 26 from both cities reported being 'Slightly warm' with all others reporting either 'Neutral' or being on the 'colder spectrum'. Interestingly, all 14 female participants from both cities reported being on the 'colder spectrum'.

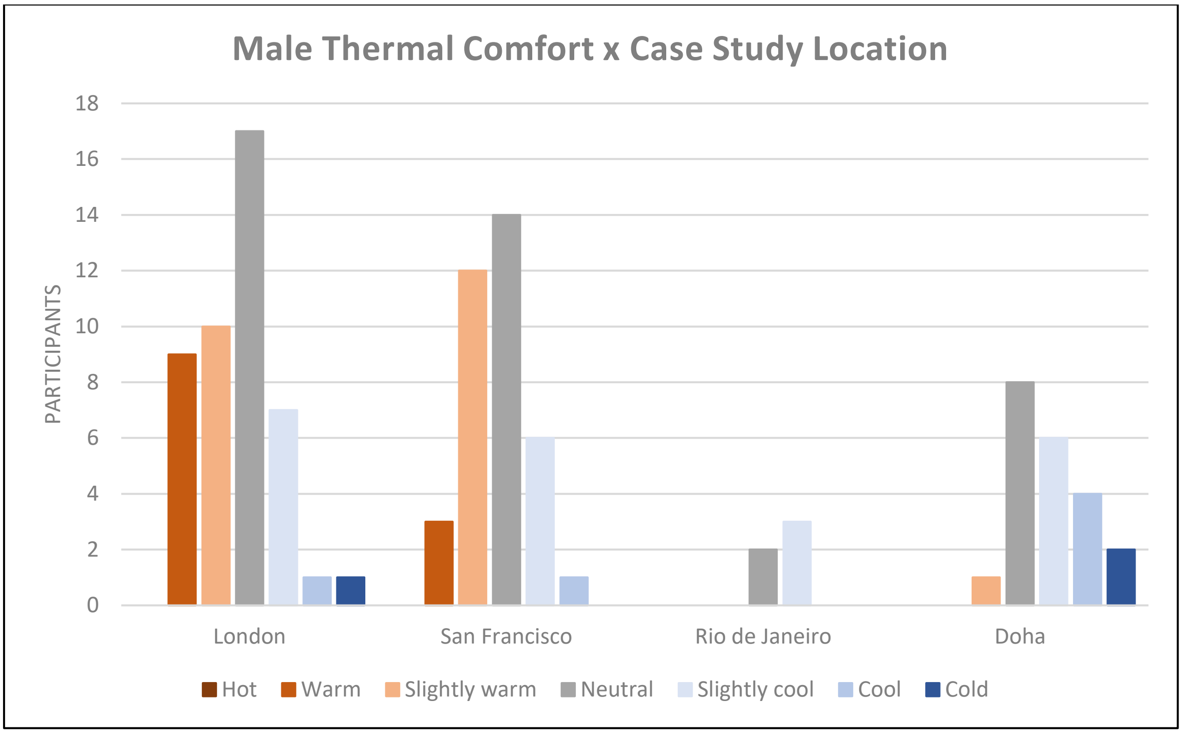

Figure 5. Male thermal comfort x case study location

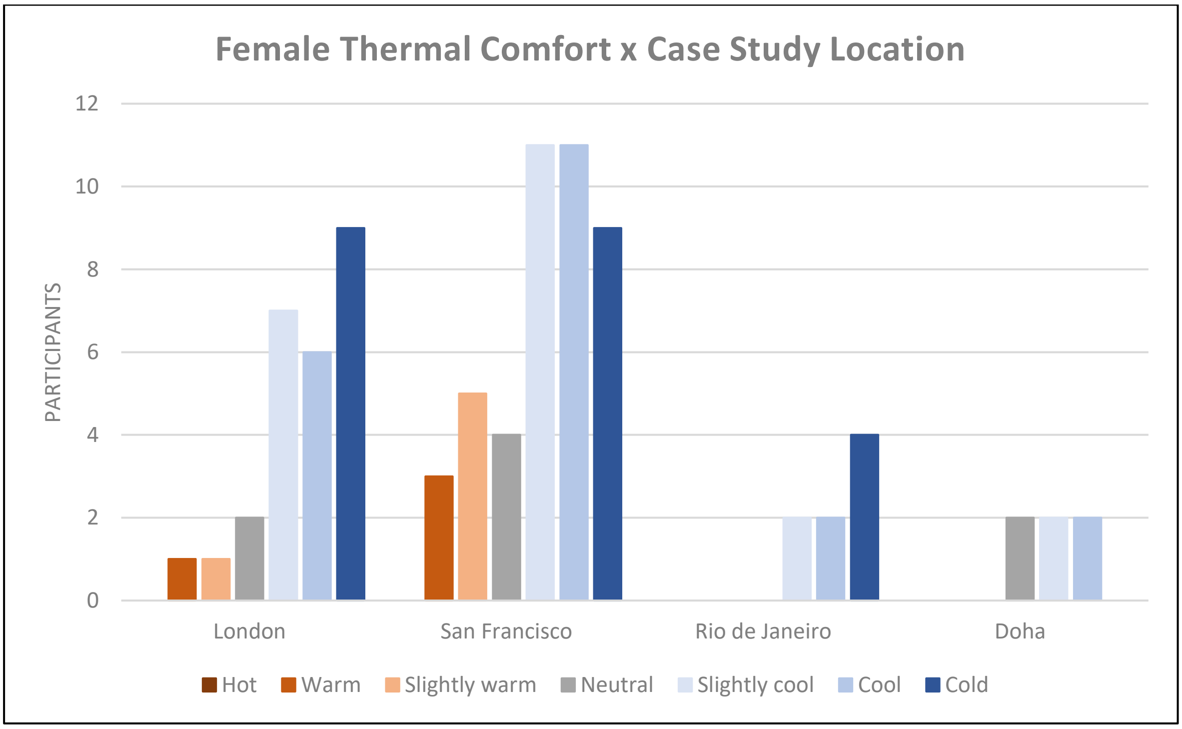

Figure 6. Female thermal comfort x case study location

4.2.3. Time of day perception of thermal comfort occurs

All participants were then asked to give the time of day when they most regularly felt the thermal comfort perception reported in the prior question. Responses from both males and females varied with reports occurring throughout the working day as seen in Figure 7.

A point to note is no male or female participant reported '*Weekends/holidays'* or '*Monday mornings'*.

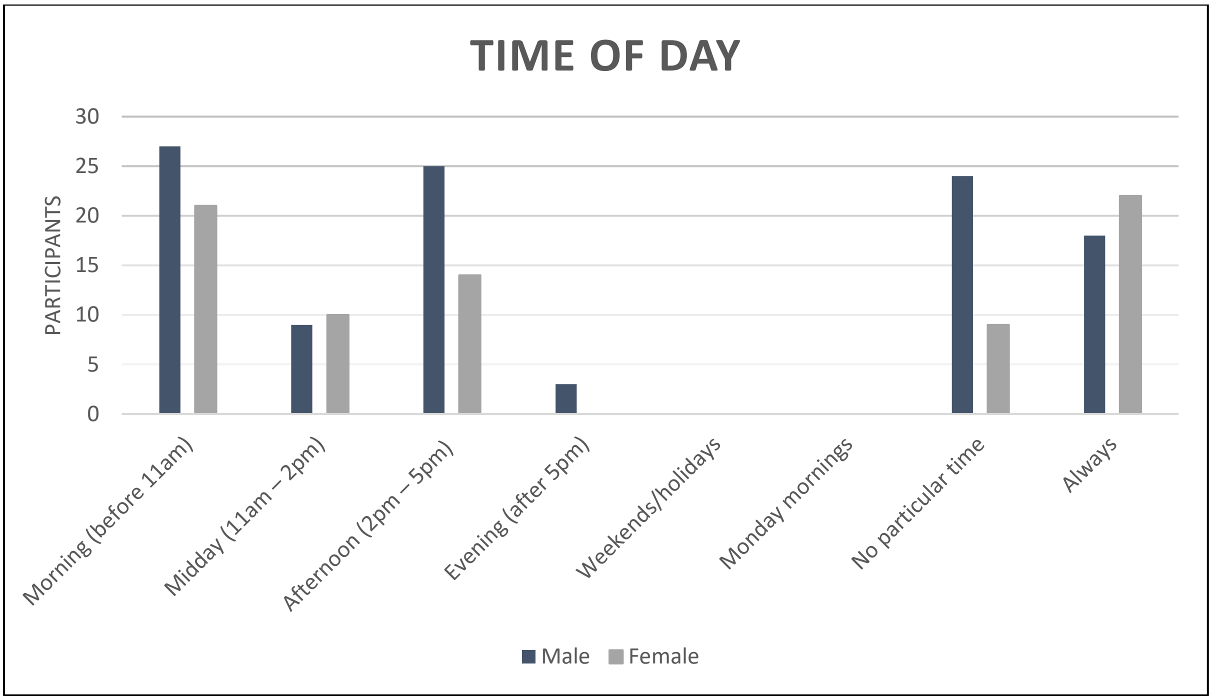

Figure 7. Male and female responses to time of day perception of thermal comfort occurs

Male and female responses have been split and reported in Figure 8 and Figure 9, respectively. The results show, with exception to 13 participants who reported being 'Slightly cool' in the *morning (before 11am*), most males felt either 'Slightly warm' or 'Warm' in the *afternoon (2pm – 5pm)*. Those who described their thermal perception as 'Neutral' felt this sensation either *Always* or at *No particular time*. The results from female participants show those who reported feeling either 'Cold', 'Cool' or 'Slightly cool' were distributed across the working day with most selecting either one of such sensations in the *morning (before 11am)* or *Always*. Similarly, to male responses, increased reporting of either 'Slightly warm' or 'Warm' came in the *afternoon (2pm – 5pm)*.

A general review of both results clearly shows more females reported their office to always being on the colder spectrum (i.e. 'Cold', 'Cool' or 'Slightly cool') in comparison to their male co-workers who reported either feeling 'Neutral', 'Slightly warm' or 'Warm'. Those who selected *Other (please specify)* reported answers already covered in the multichoice selection provided, with exception to one response which mentioned temperature differences were usually spontaneous and typically meant their thermal perception was unpredictable.

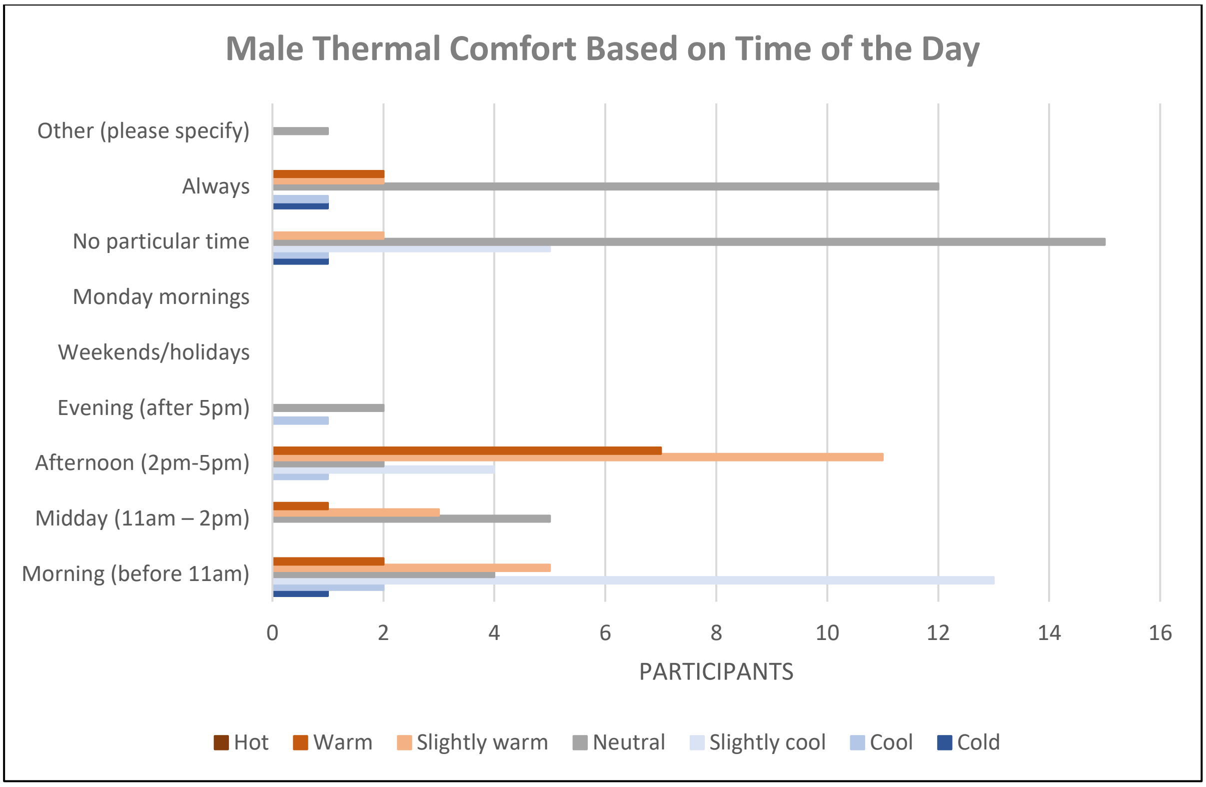

Figure 8. Male participants response to thermal comfort based on time of the day

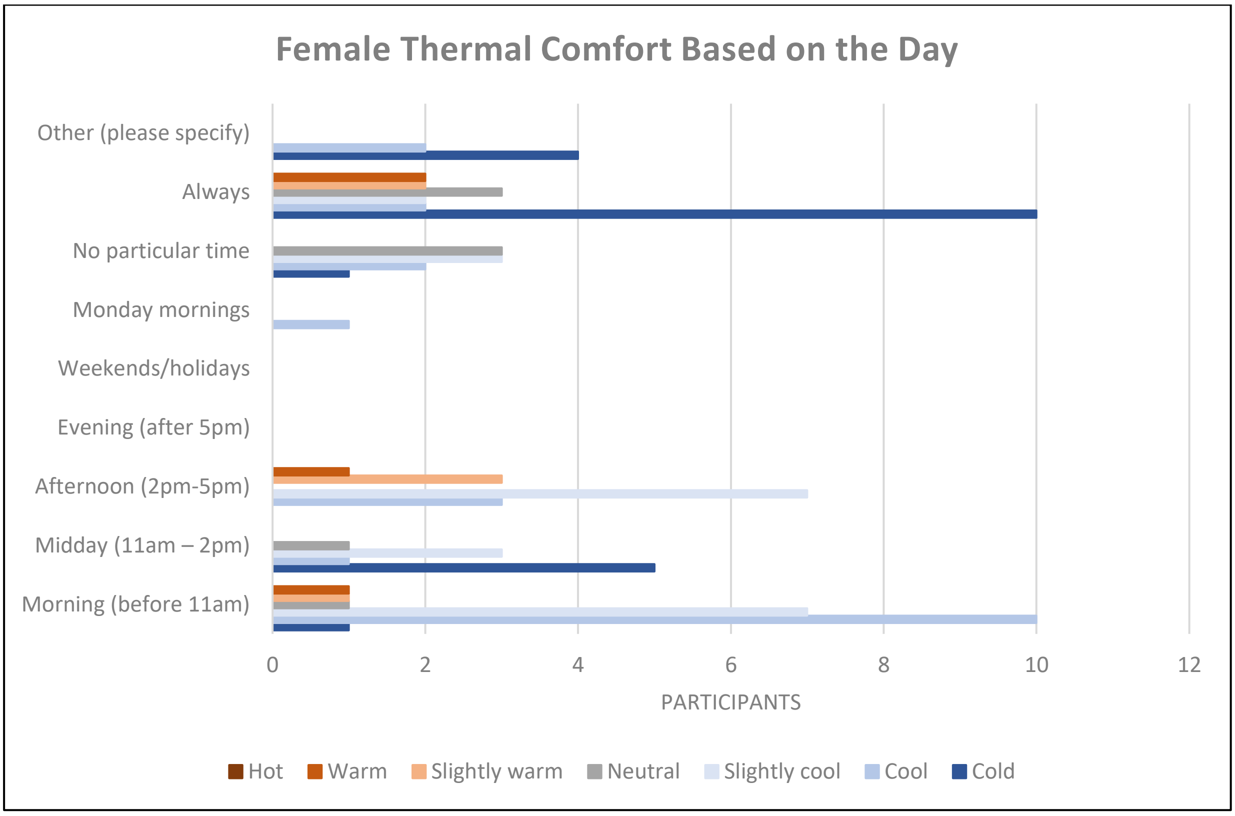

Figure 9. Female participants response to thermal comfort based on time of the day

4.2.4. Participants location in the office

All participants were asked to best describe their working location when in the office during a typical working day. Responses illustrated in Figure 10 show most occupants were located near an external window (41% of total participants) or sat in the centre of their open plan office (31% of total participants). Further analysis of the results shows most occupants near an external surface wall reported feeling either 'Neutral' or 'Slightly warm' whilst responses from those who were sat near an inner surface wall varied across 'Cold' to 'Warm'.

Most participants who selected *Other (please specify)* noted agile working where they would typically change location depending on availability of adequate workspaces daily. These results show an almost equal split between those who reported on the 'colder spectrum', 'neutral' and 'warmer spectrum'.

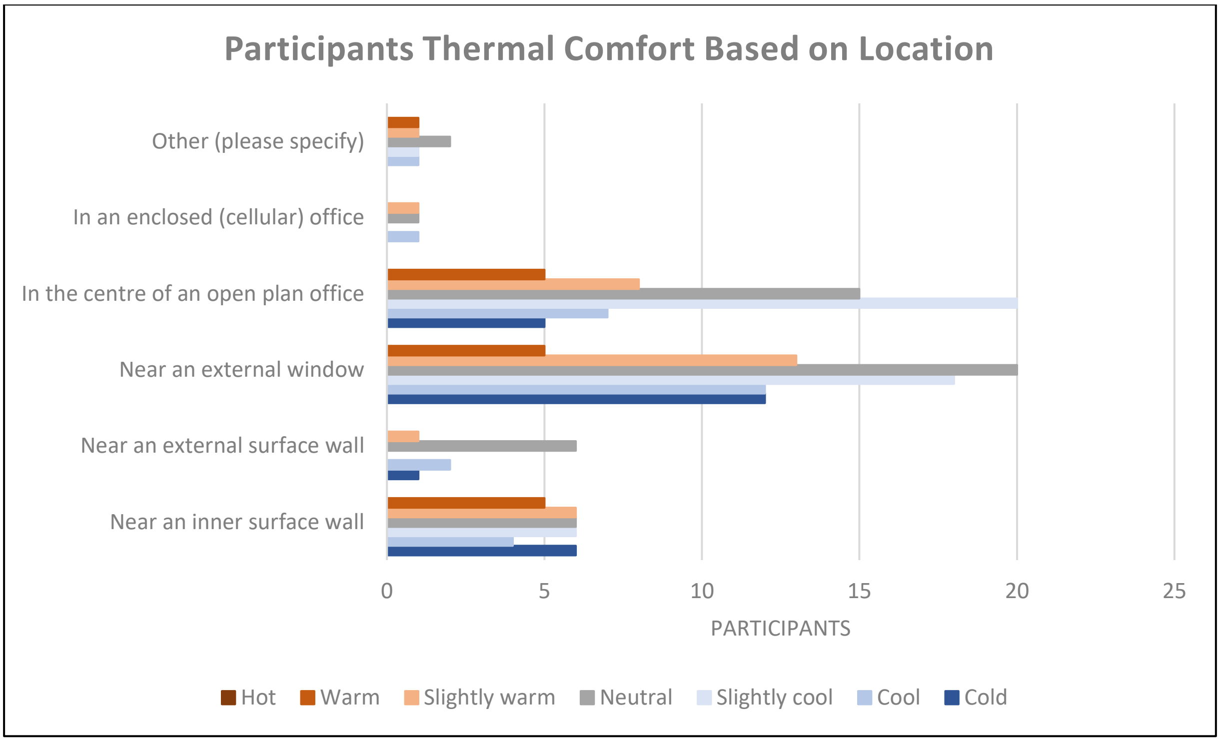

Figure 10. Participants response to thermal comfort based on their location in the office

4.2.5. Participants clothing

A description of clothing worn by participants on a typical day in the office was also asked in the survey (see Figure 11). Most male participants typically wore a long-sleeve shirt, trousers and a pair of socks and shoes. On the other hand, most female participants reported wearing a sweater/jumper, trousers and a pair of socks and shoes. The results show more females reported wearing a long-sleeve sweatshirt and/or jacket when compared to their male co-workers suggesting an increased priority to remedy unfavourable thermal conditions in their offices. Participants who selected *Other*, most of whom were females, noted shawls, scarfs and additional cardigans/sweaters to best describe their typical clothing levels.

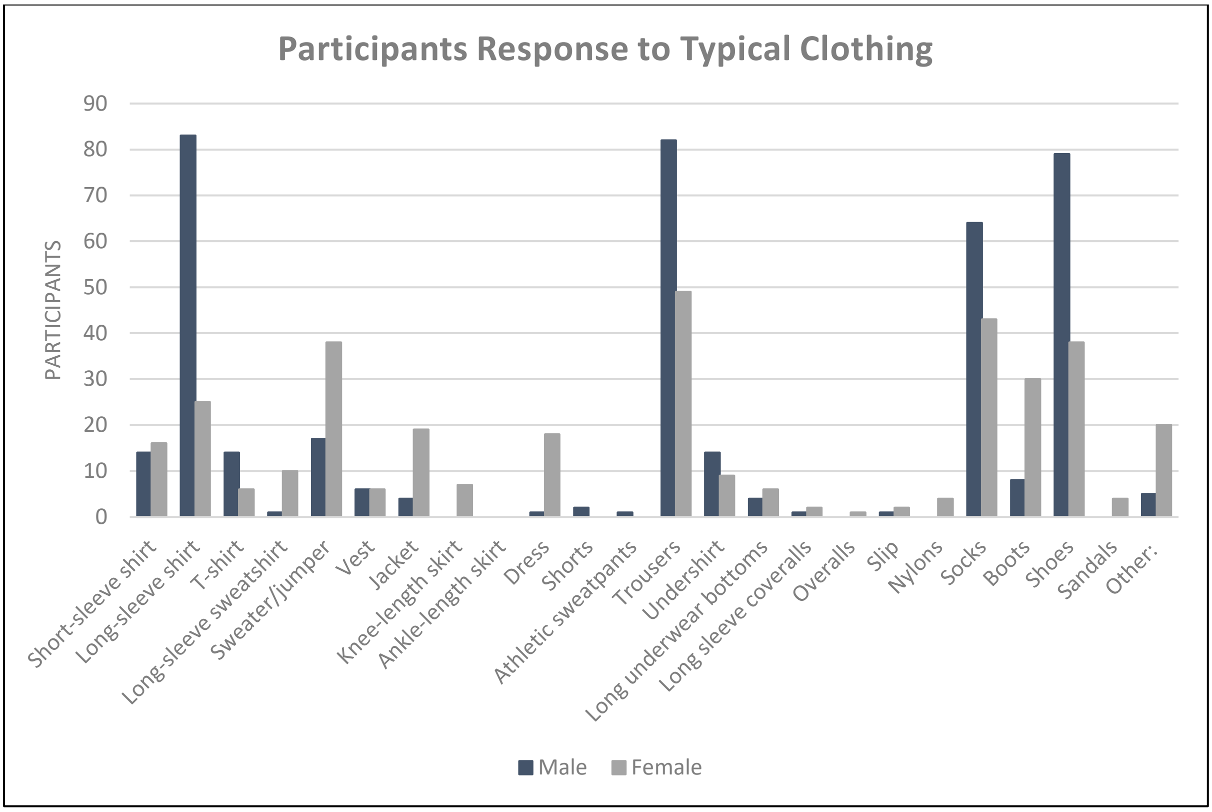

Figure 11. Participants response to typical clothing worn in the office

4.2.6. Activity level

Participant's activity levels were also reported based on a typical working day in the office. Across responses received from both male and female occupants, '*predominately at your desk'* was selected as the most common answer, as expected in a modern commercial office environment. Male responses illustrated in Figure 12 show that although almost all were sat at their desk for most of the time during the working day, many of those that were moving around the office or in between meetings still perceived their office to be either in the 'warmer spectrum' or 'Neutral'. This differed to responses from female participants illustrated in Figure 13, which shows a majority of those who spent most of their time moving around the office, still considered their office to be more towards the 'colder spectrum'.

Overall, the results show irrespective of activity level, respondents were more inclined to report their office being either in the 'warmer spectrum' or 'Neutral', if they were male (71% of male participants) or more towards the 'colder spectrum', if they were female (78% of female participants).

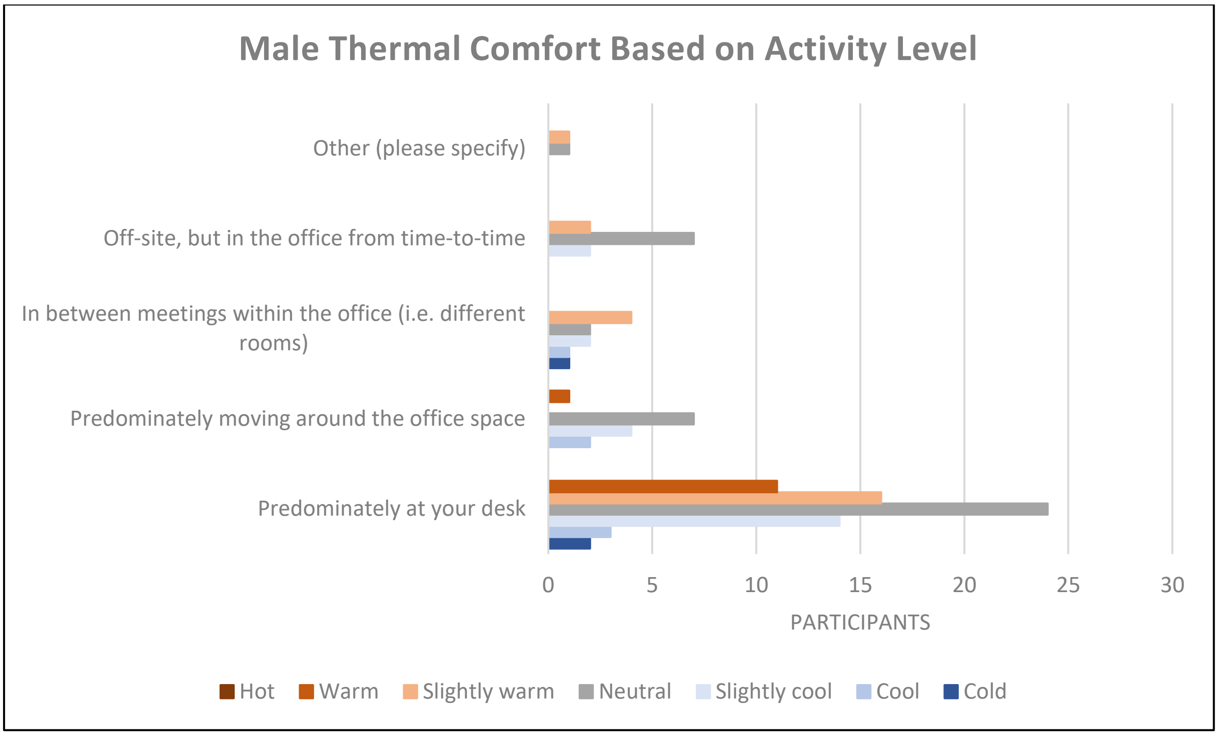

Figure 12. Male participants response to thermal comfort based on activity level

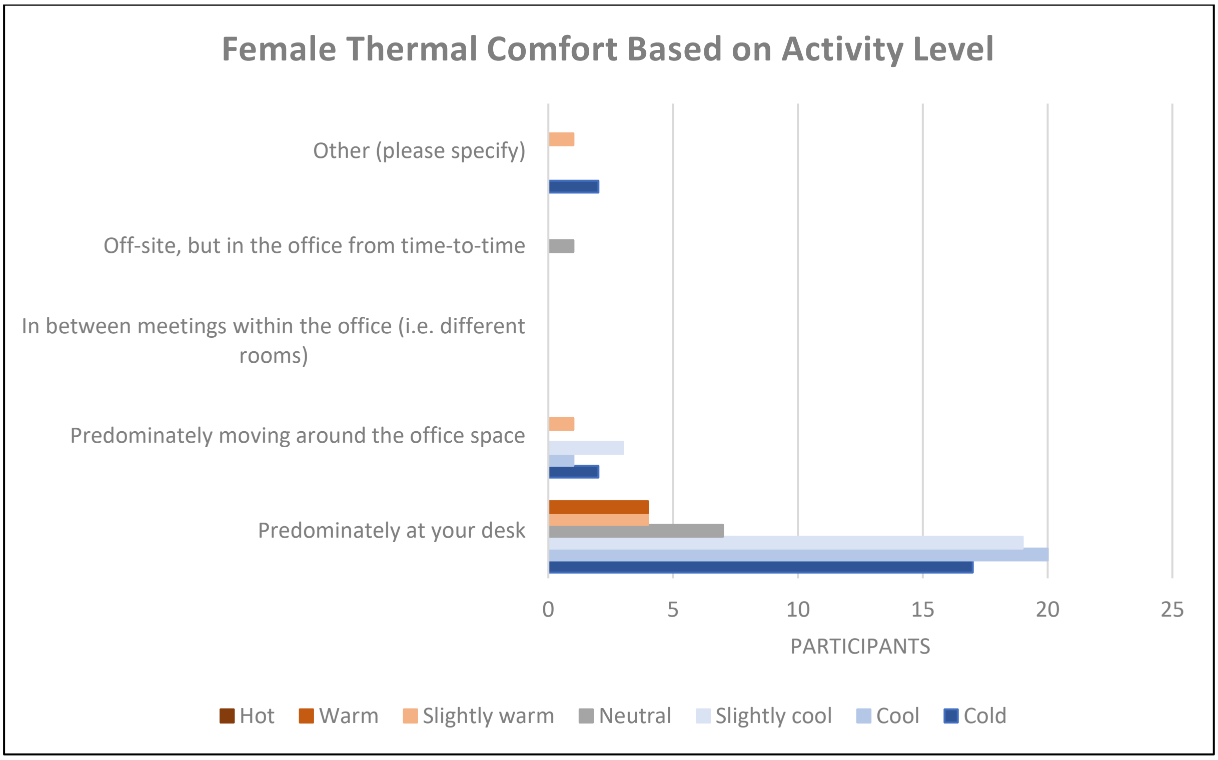

Figure 13. Female participants response to thermal comfort based on activity level

4.2.7. Thermal comfort adjustments

Finally, all participants were asked to select the most relevant option when attempting to adjust or control conditions within their personal space to meet their thermal comfort needs. Male and female responses based on the available options to select from have been illustrated in Figure 14 and Figure 15, respectively.

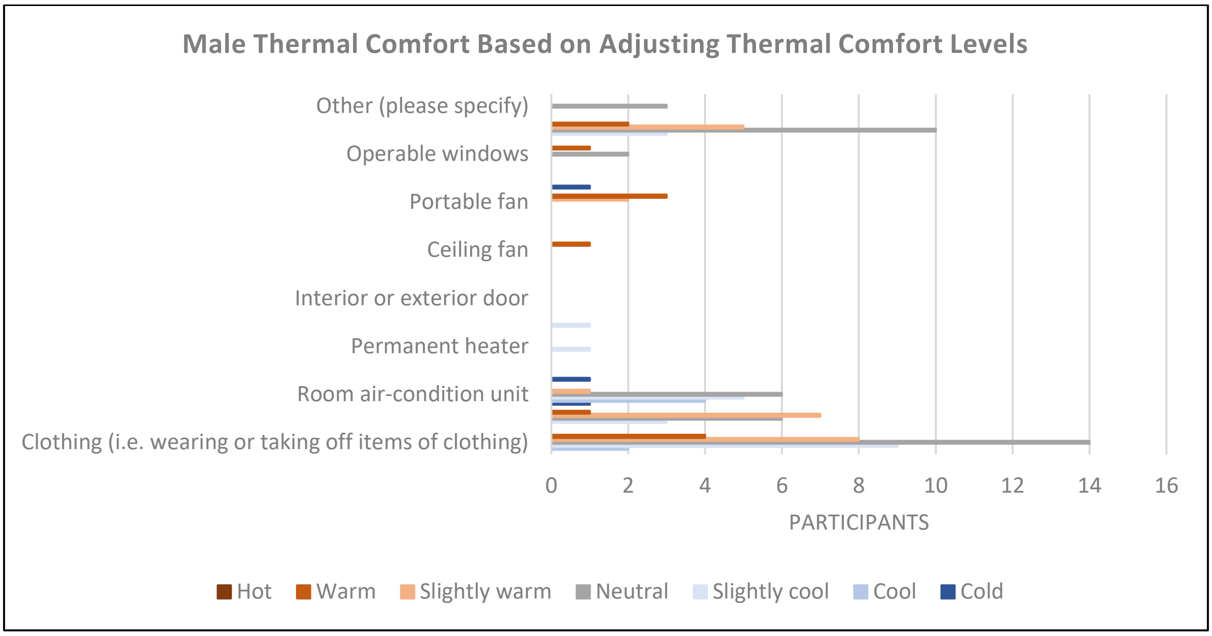

Figure 14.Male participants response to adjusting thermal comfort levels

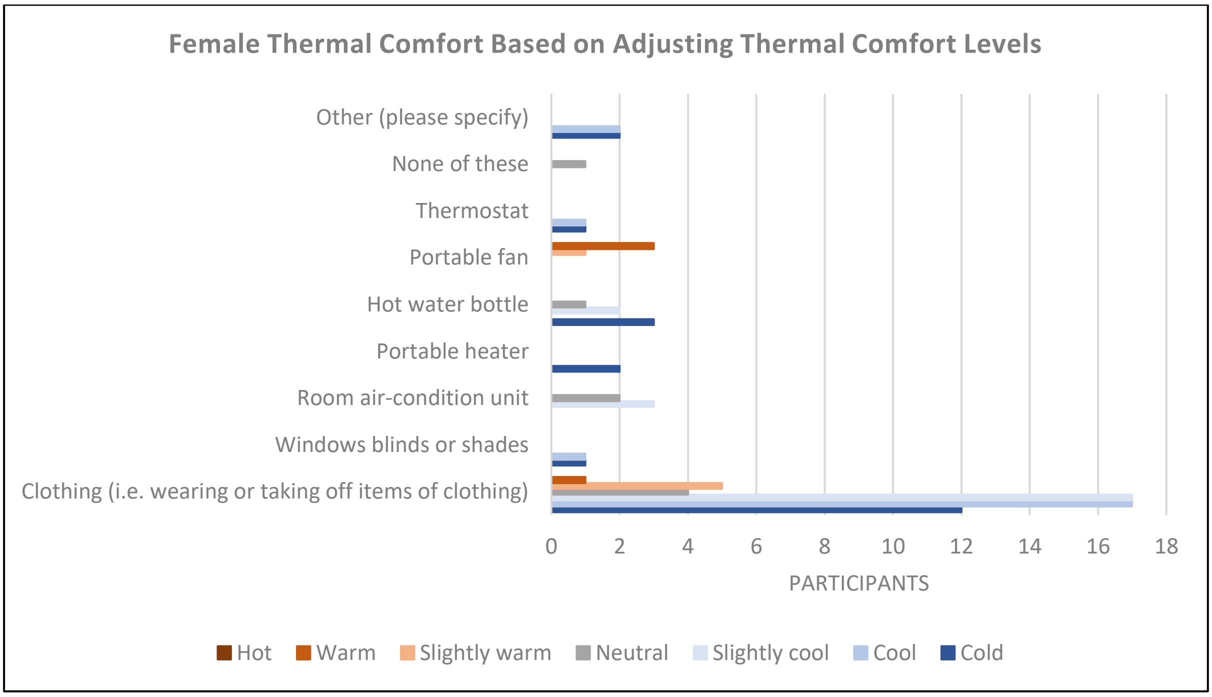

Figure 15.Female participants response to adjusting thermal comfort levels

Across both sets of results, *Clothing* was the highest-ranking option suggesting many participants primarily resorted to either wearing additional layers or taking off clothing to adjust their thermal comfort during a typical day in the office.

Many male participants who reported feeling 'Neutral', 'Slightly warm' or 'Warm' responded by selecting *None of these,* whereas a considerable number of female participants who reported feeling 'Cold' 'Cool' or 'Slightly cool' responded by selecting *Room air-condition unit*, *Portable heater* or *Hot water bottle* as their primary option. The selection of *Windows blinds or shades* have been assumed as a reactive measure used to minimise the penetration of sunlight and potential solar glare issues on screens.

Participants who chose *Other (please specify)* typically wrote descriptions, which were covered in the selection of answers provided including, wearing additional layers of clothing and using portable cooling fans in the summer. Responses worth noting included a participant who reported using an electric heated blanket, drinking a cold or warm beverage to modulate body temperature and moving to another part of the office in an agile working environment to seek thermal comfort.

4.2.8. Key survey findings

The data collection process through participant surveys has provided the study with an opportunity to analyse thermal comfort perceptions from occupants across all case study offices in each city. The following key findings have been established based on a thorough review of participants' responses to the thermal comfort survey:

- An individual's thermal comfort perception in an office may differ based on city location as can be seen when comparing results for each sex/gender type across the case studies. For example, male and female responses to thermal comfort in London and San Francisco suggests a sizeable portion of occupants considered their office to be on the 'warmer spectrum' but more towards the 'colder spectrum' in the relatively warmer climatic conditions of Rio de Janeiro and Doha.

- Generally, most female participants across all city locations considered their office to be on the 'colder spectrum' in comparison to their male co-workers, which suggests internal temperature conditions were more conducive for the latter. This was evident based on typical clothing levels reported showing females wore additional layers of clothing including, shawls, scarfs and jackets when compared to most males who reported wearing long-sleeve shirts, trousers and a pair of socks and shoes.

- Contrary to the author's expectation, increased activity levels and metabolic rates associated did not necessarily impact the number of female participants who reported feeling cold on a typical day in the office. A review of such occupants who reported moving around the office on a typical day still selected a 'colder spectrum' thermal comfort option. However, it is noted that the number of females who reported moving around the office may not represent a large enough sample size to conclusively confirm this will be the case for most.

- Early working hours in the morning (before 11am) was reported by a large proportion of male and female participants as the most likely time where colder thermal perceptions were likely to occur. This was particularly the case among male participants whilst female participants reported this sensation across most of the working day. Across both sets of participants, the afternoon after lunch (assumed to be anywhere between 12:00 – 14:00), appeared to show signs of an increase in temperature with less reports from participants in the 'colder spectrum'.

- Remedial measures to achieve thermal comfort levels were primarily sought through personal adjustments (i.e. clothing, hot water bottles and portable fans) over central room conditioning systems for heating and/or cooling. This is assumed to be based on the lack of central controls for most occupants in the offices, which are typically under facilities and building management responsibility therefore, requiring formal instruction before adjustments can be made.

4.3. Observatory sessions

The observatory segment for each case study office involved taking notes on behavioural patterns of occupants with sessions taking anywhere between 1 – 3 hours. Participant interactions varied in each case study office, which was dependent on occupant's willingness to engage with the study and contribute by providing informal feedback. Notes from each session have been documented in a series of tables containing a brief description and a summary of key points.

Sessions across case study offices took place at different times during the workday, and where relevant to the key points highlighted, have been noted for consideration when discussing occupancy feedback.

Table 2. Case study 1 – Observatory session notes

<table>
<tr><th></th><th colspan="12"></th></tr>
<tr><td>Location</td><td colspan="3">☒ London</td><td colspan="3">☐ San Francisco</td><td colspan="3">☐ Rio de Janeiro</td><td colspan="3">☐ Doha</td></tr>
<tr><td>Occupancy density</td><td colspan="3">☐ 0 – 49</td><td colspan="3">☐ 50 – 99</td><td colspan="3">☐ 100 – 149</td><td colspan="3">☒ 150+</td></tr>
<tr><td>Internal layout</td><td colspan="4">☒ Open plan</td><td colspan="4">☐ Cellular</td><td colspan="4">☐ Other</td></tr>
<tr><td>Windows</td><td colspan="6">☐ Openable</td><td colspan="6">☒ Sealed</td></tr>
<tr><td>Heating/Cooling</td><td colspan="4">☐ Natural (windows)</td><td colspan="4">☒ Mechanical (A/C)</td><td colspan="4">☐ Both</td></tr>
<tr><td>Observatory notes</td><td colspan="12">This case study office occupied an entire single floor in a multi-tenanted commercial office block within Central London. Occupants had individual workspaces with ancillary break-out areas and perimeter cellular meeting rooms.

The following points were taken during the observatory session:

▪ There were considerably more male occupants in comparison to females across the office open-plan layout
▪ Occupants were predominately seen in smart casual wear – male workers typically wore long-sleeve shirts and a pair of trousers with females wearing a smart shirt or blouse and a pair of trousers
▪ Individual workspaces were made available to occupants through agile working practices and communal break-out areas
▪ A few female occupants were seen wearing additional layers of clothing – cardigans/sweaters, shawls, etc
▪ Electric radiators were noticed under some desks occupied by females, but these were not in operation during the visit
▪ Occupants located near full-height glazed windows appeared to show ‘colder spectrum’ signs of thermal comfort, particularly females who were all seen wearing additional clothing
▪ Engagement with occupants were as follows:
    ○ Female occupant mentions the ceiling-mounted grilles on the office perimeter creates a downdraught, which increases thermal discomfort of occupants who sit beneath them
    ○ Window blinds were typically rolled down in the afternoon to minimise solar glare on computer screens, particularly in the spring and summer seasons
    ○ Some perimeter cellular meeting rooms can be a bit too cold when not filled and there are no local controls for occupants to adjust.</td></tr>
</table>

Table 3. Case study 2 – Observatory session notes

Location	☒ London	☐ San Francisco	☐ Rio de Janeiro	☐ Doha
Occupancy density	☐ 0 – 49	☐ 50 – 99	☒ 100 – 149	☐ 150+
Internal layout	☒ Open plan	☐ Cellular	☐ Other	
Windows	☒ Openable	☐ Sealed		
Heating/Cooling	☐ Natural (windows)	☐ Mechanical (A/C)	☒ Both	
Observatory notes	This case study office occupied a single floor in a multi-tenanted commercial office block in the City of London. Occupants had dedicated individual workspaces with ancillary break-out areas and perimeter cellular meeting rooms. The office floor plate was enclosed by a combination of solid walls and windows (some of which were openable). The following points were taken during the observatory session: ▪ There appeared to be more male occupants in comparison to females – based off a visual estimation 65:35 split ▪ Session took place on a *casual Friday* – male occupants were predominantly seen wearing a short-sleeve or polo shirt and a pair of trousers with female occupants seen wearing casual clothing and additional layers (i.e. sweaters/cardigans) ▪ Occupants (particularly female) who sat at desks located near either an external wall or window were mostly seen wearing a sweater ▪ Occupants who were located further into the office floor space (i.e. away from an external wall or window) appeared to be less affected by a colder sensation and were seen in slightly lighter clothing across both males and females ▪ Engagement with occupants were as follows: o The external walls were reported as having increased levels of air permeability as such, allowed draughts of cold air to infiltrate and was felt by those who had workspaces located near the wall o Internal office areas provide better thermal environments with suggestion that they feel relatively comfortable throughout the working day – message reiterated by female occupant who spent most of her day in an internal office area away from an external window or wall.			

Table 4. Case study 3 – Observatory session notes

<table>
<tr><th></th><th colspan="12"></th></tr>
<tr><td>Location</td><td colspan="3">☐ London</td><td colspan="3">☒ San Francisco</td><td colspan="3">☐ Rio de Janeiro</td><td colspan="3">☐ Doha</td></tr>
<tr><td>Occupancy density</td><td colspan="3">☐ 0 – 49</td><td colspan="3">☐ 50 – 99</td><td colspan="3">☒ 100 – 149</td><td colspan="3">☐ 150+</td></tr>
<tr><td>Internal layout</td><td colspan="4">☒ Open plan</td><td colspan="4">☐ Cellular</td><td colspan="4">☐ Other</td></tr>
<tr><td>Windows</td><td colspan="6">☒ Openable</td><td colspan="6">☒ Sealed</td></tr>
<tr><td>Heating/Cooling</td><td colspan="4">☐ Natural (windows)</td><td colspan="4">☐ Mechanical (A/C)</td><td colspan="4">☒ Both</td></tr>
<tr><td>Observatory notes</td><td colspan="12">This case study office occupied multiple floors within a larger commercial development in the San Francisco Bay Area. Occupants had dedicated individual workspaces with ancillary break-out and co-working areas. Meeting rooms were made available through internal ‘pods’ with cellular office spaces for senior members of staff.

The following points were taken during the observatory session:

▪ There appeared to be more male occupants in comparison to females – based off a visual estimation 70:30 split
▪ The session took place when the office was in natural ventilation mode with windows open, as ambient (outdoor) temperature was recorded as being ≈20°C during visit
▪ Many occupants across both genders/sexes were seen wearing lighter, smart casual clothing suggesting indoor conditions were leaning towards the ‘warmer spectrum’
▪ Occupants sat near perimeter walls were seen in lighter clothing with windows open suggesting they felt more comfortable in comparison to those similarly located in conditioned offices visited in London – possibly confirmed by seeing female worker wearing a sleeveless vest
▪ Ceiling-mounted fans under control of facilities management are switched on to assist with circulating the indoor air, when required – these were not in operation during visit
▪ Engagement with occupants were as follows:
    ○ It is understood that operation of individual windows is under the control of occupants sat near it and is typically opened or closed depending on their collective thermal preference
    ○ Occupant (with academic research background in building occupant’s behaviour) suggests research shows people in buildings prefer workspaces where they have access to control thermal conditions.</td></tr>
</table>

Table 5. Case study 4 – Observatory session notes

Location	☐ London	☒ San Francisco	☐ Rio de Janeiro	☐ Doha
Occupancy density	☐ 0 – 49	☒ 50 – 99	☐ 100 – 149	☐ 150+
Internal layout	☒ Open plan	☐ Cellular	☐ Other	
Windows	☐ Openable	☒ Sealed		
Heating/Cooling	☐ Natural (windows)	☒ Mechanical (A/C)	☐ Both	

Observatory notes	This case study office occupied an entire single floor in a larger multi-tenanted commercial office skyscraper in the San Francisco Bay Area. Occupants had dedicated individual workspaces with ancillary break-out areas. Glazed perimeter offices were reserved for senior members of staff with additional perimeter and internal meeting room spaces for all.
	
	The following points were taken during the observatory session:
	▪ Based off an initial comparison, the number of male occupants appeared to be slightly more than females – a visual estimation 60:40 split
	▪ Occupant clothing levels appeared to vary depending on location in the office (focusing on females):
	  ○ Those sat to the east and west on the office floorplate were seen in sweaters with a few wearing shawls
	  ○ Those sat to the south were seen in short-sleeve shirts with no sedentary occupants sat in the north
	▪ Males across the office were in smart casual wear with many who had their sleeves rolled-up and others in polo shirts, irrespective of desk location
	▪ Male and female occupants in glazed perimeter offices and meeting rooms appeared comfortable with most seen wearing light smart or smart casual clothing
	▪ Engagement with occupants were as follows:
	  ○ There appears to be slightly varying thermal zones (unclear whether this is by design strategy or ageing of installed heating and cooling equipment), which results in occupant's thermal sensation being dependent on workspace location
	  ○ Male occupant who typically moves around the office for most of the day mentions he tends to feel warm, particularly in the afternoon when the sky is clear and solar gain into the office space increases
	  ○ Several occupants confirmed increased sunlight through lack of surrounding buildings (for provision of shade), increased the indoor temperature in specific areas of the office resulting in these areas becoming warm.				

Table 6. Case study 5 – Observatory session notes

<table>
<tr><th></th><th colspan="12"></th></tr>
<tr><td>Location</td><td colspan="3">☐ London</td><td colspan="3">☒ San Francisco</td><td colspan="3">☐ Rio de Janeiro</td><td colspan="3">☐ Doha</td></tr>
<tr><td>Occupancy density</td><td colspan="3">☐ 0 – 49</td><td colspan="3">☐ 50 – 99</td><td colspan="3">☒ 100 – 149</td><td colspan="3">☐ 150+</td></tr>
<tr><td>Internal layout</td><td colspan="4">☒ Open plan</td><td colspan="4">☐ Cellular</td><td colspan="4">☐ Other</td></tr>
<tr><td>Windows</td><td colspan="6">☐ Openable</td><td colspan="6">☒ Sealed</td></tr>
<tr><td>Heating/Cooling</td><td colspan="4">☐ Natural (windows)</td><td colspan="4">☒ Mechanical (A/C)</td><td colspan="4">☐ Both</td></tr>
<tr><td>Observatory notes</td><td colspan="12">This case study office shared occupancy on a single floor within a larger commercial development in the San Francisco Bay Area. Occupants had dedicated individual workspaces with ancillary break-out and co-working areas. Additional spaces were provided through internal meeting/group working rooms.

The following points were taken during the observatory session:

▪ This was the first case study where the number of males and females appeared equal or slightly leaning either to one over the other. As no formal numbers were provided – based off a visual estimation, a 50:50 split has been assumed
▪ Occupants similarly to all other case studies were seen wearing mostly smart casual clothing
▪ A small number of females were noted as being seen with shawls, but this number was significantly less than had been seen in other case studies
▪ Most male occupants were seen with long-sleeve shirts with a few who rolled up their sleeves – interestingly, several males were also seen wearing gilets (also known as ‘bodywarmers’) during the visit
▪ The office appeared to be slightly less occupied in comparison to the maximum occupancy design allowance, as many desks were unoccupied
▪ Engagement with occupants were as follows:
o Male participant suggested office temperature remained consistent throughout the working day and additional clothing (gilet) was a precautionary measure if he began to feel cold – as well as noting it became part of his office clothing attire
o Female participant mentions some areas in the office are colder, which she attributes to relatively low office occupancy rate suggesting cooling may be oversupplied based on a maximum capacity office.</td></tr>
</table>

Table 7. Case study 6 – Observatory session notes

<table>
<tr><th></th><th colspan="12"></th></tr>
<tr><td>Location</td><td colspan="3">☐ London</td><td colspan="3">☐ San Francisco</td><td colspan="3">☒ Rio de Janeiro</td><td colspan="3">☐ Doha</td></tr>
<tr><td>Occupancy density</td><td colspan="3">☒ 0 – 49</td><td colspan="3">☐ 50 – 99</td><td colspan="3">☐ 100 – 149</td><td colspan="3">☐ 150+</td></tr>
<tr><td>Internal layout</td><td colspan="4">☐ Open plan</td><td colspan="4">☐ Cellular</td><td colspan="4">☒ Other</td></tr>
<tr><td>Windows</td><td colspan="6">☒ Openable</td><td colspan="6">☐ Sealed</td></tr>
<tr><td>Heating/Cooling</td><td colspan="4">☐ Natural (windows)</td><td colspan="4">☒ Mechanical (A/C)</td><td colspan="4">☐ Both</td></tr>
<tr><td>Observatory notes</td><td colspan="12">
This case study office shared occupancy on a single floor within a larger commercial development in the south zone Botafogo district of Rio de Janeiro. The internal office layout was divided into various spaces including an open plan area, individual meeting rooms and an ancillary break-out zone – kitchenette/eating and drinking area.
The following points were taken during the observatory session:

There appeared to be an equal split of male-to-female occupants – based off a visual estimation 50:50 split.
Male and female occupants were seen wearing smart casual clothing
Several female occupants were seen wearing additional layers of clothing (i.e. jumpers/shawls) and those without, had clothing hung on the back of their seats, should they be needed at any time during the working day
Male occupants who wore long-sleeve shirts tended to have the sleeves rolled up
Ceiling-mounted grills provided cool air into the office and increased levels of thermal discomfort to female occupants that had their desks located directly below or surrounding areas
Engagement with occupants were as follows:

Occupant mentions that air-conditioning within the office space is required to achieve thermal comfort of occupants considering ambient (outdoor) temperatures can exceed 30°C regularly during the warmer periods of the year
Perimeter windows are never opened and active cooling with the air-conditioning units are used during office hours to maintain indoor temperatures
Male occupant seen in light T-shirt explains this is enough as he spends most of his time moving around the office – female occupants explain they would feel too cold if they attempted to wear the same.

</td></tr>
</table>

Table 8. Case study 7 – Observatory session notes

<table>
<tr><th></th><th colspan="12"></th></tr>
<tr><td>Location</td><td colspan="3">☐ London</td><td colspan="3">☐ San Francisco</td><td colspan="3">☒ Rio de Janeiro</td><td colspan="3">☐ Doha</td></tr>
<tr><td>Occupancy density</td><td colspan="3">☒ 0 – 49</td><td colspan="3">☐ 50 – 99</td><td colspan="3">☐ 100 – 149</td><td colspan="3">☐ 150+</td></tr>
<tr><td>Internal layout</td><td colspan="4">☒ Open plan</td><td colspan="4">☐ Cellular</td><td colspan="4">☐ Other</td></tr>
<tr><td>Windows</td><td colspan="6">☐ Openable</td><td colspan="6">☒ Sealed</td></tr>
<tr><td>Heating/Cooling</td><td colspan="4">☐ Natural (windows)</td><td colspan="4">☒ Mechanical (A/C)</td><td colspan="4">☐ Both</td></tr>
<tr><td>Observatory notes</td><td colspan="12">This case study office shared occupancy on a single floor within a larger commercial development in the south zone Botafogo district of Rio de Janeiro. The internal office provided an open plan layout with dedicated individual workspaces.

The following points were taken during the observatory session:

▪ There appeared to be an equal split of male-to-female occupants – based off a visual estimation 50:50 split.
▪ Male and female occupants were seen wearing smart casual clothing
▪ Some female occupants were seen wearing shawls and those who were not, had them hung on the back of their seats should they be needed
▪ Male occupants were seen wearing long-sleeve shirts, where a few had their sleeves rolled up
▪ Engagement with occupants were as follows:
    o Female occupant mentions indoor temperatures are usually ‘too cold’ and she requires additional layers of clothing or a blanket to remain warm
    o Occupants suggests thermal comfort in the office varies during the year as it typically gets colder in the office when ambient (outdoor) temperature get warmer during November – December
    o Male occupant says he typically feels comfortable with exception to some afternoon hours (after lunch) where solar gain through windows increase the indoor temperature.</td></tr>
</table>

Table 9. Case study 8 – Observatory session notes

Location	☐ London	☐ San Francisco	☐ Rio de Janeiro	☒ Doha
Occupancy density	☐ 0 – 49	☐ 50 – 99	☒ 100 – 149	☐ 150+
Internal layout	☒ Open plan	☐ Cellular	☐ Other	
Windows	☐ Openable	☒ Sealed		
Heating/Cooling	☐ Natural (windows)	☒ Mechanical (A/C)	☐ Both	
Observatory notes	This case study office occupied an entire floor in a larger single-tenanted commercial development in the Al Sadd district, west of Hamad International Airport, in Doha. Occupants had dedicated individual workspaces split in grouped cubicles. Glazed perimeter offices were reserved for senior members of staff. The following points were taken during the observatory session: ▪ There appeared to be an equal split of male-to-female occupants – based off a visual estimation 50:50 split. ▪ Most occupants were seen in western smart casual clothing with a few males wearing the traditional *thobe* (these male occupants were in the general reception area during the visit) ▪ Female occupants were seen to be in light clothing material with scarfs/shawls and males with long-sleeve shirts rolled up ▪ Office (building) construction was made up of dense concrete, which a member of the design team mentions was delivered to optimise absorption of heat during the day and reduce reliance on air-conditioning cooling capacity ▪ The office is air-conditioned throughout the working day with relatively high-level ceiling grills dispersing cool air into the office space ▪ Engagement with occupants were as follows: o The location of air-conditioning grills along the perimeter of the office reduced downdraught experienced by occupants as there are no desks located beneath them o Operation of air-conditioning for open office area is done centrally via floor building management system with perimeter offices being operated locally o Female occupant mentions comfort levels were neutral during the visit, but this did not represent her typical comfort levels as she said the office is usually too cold for comfort o Office workers are given the choice to dress in traditional clothing, if they wish (formally known as the *thobe* for males and *abaya* for females).			

Table 10. Case study 9 – Observatory session notes

<table>
<tr><th></th><th colspan="12"></th></tr>
<tr><td>Location</td><td colspan="3">☐ London</td><td colspan="3">☐ San Francisco</td><td colspan="3">☐ Rio de Janeiro</td><td colspan="3">☒ Doha</td></tr>
<tr><td>Occupancy density</td><td colspan="3">☒ 0 – 49</td><td colspan="3">☐ 50 – 99</td><td colspan="3">☐ 100 – 149</td><td colspan="3">☐ 150+</td></tr>
<tr><td>Internal layout</td><td colspan="4">☐ Open plan</td><td colspan="4">☐ Cellular</td><td colspan="4">☒ Other</td></tr>
<tr><td>Windows</td><td colspan="6">☒ Openable</td><td colspan="6">☐ Sealed</td></tr>
<tr><td>Heating/Cooling</td><td colspan="4">☐ Natural (windows)</td><td colspan="4">☐ Mechanical (A/C)</td><td colspan="4">☒ Both</td></tr>
<tr><td>Observatory notes</td><td colspan="12">
This case study office occupied a single floor within a larger multi-tenanted office development in the Madinat Khalifa district, north-west of Hamad International Airport, in Doha. Occupants had dedicated individual workspaces with an adjoining meeting room and perimeter glazed offices for senior members of staff.
The following points were taken during the observatory session:

There appeared to be considerably more male occupants in comparison to females – based off a visual estimation 90:10 split
The session took place on a casual Thursday – male occupants were predominantly seen wearing a short-sleeve or polo shirt and a pair of trousers with female occupants seen wearing casual western clothing or the traditional abaya
Openable windows were available however, during the visit, the three air-conditioning units serving the main office area were switched on (it is worth mentioning ambient temperature was recorded at ≈28°C)
Occupants had access to the air-conditioning unit controls (via a handheld remote) for both the open office area and adjoining meeting room
‘Make-shift’ air distribution of the units had been created by occupants through paper and tape onto outlet grill to reduce downward draught on desks located directly below
Male occupants in short-sleeve polo shirts who were sat near ceiling-mounted vents appear to feel cold after prolonged sitting down at desk (requests for colleague with remote control to increase supply temperature)
Engagement with occupants were as follows:

Windows are typically used in the early morning hours when ambient temperature is mild. As the temperature increases towards the later morning/early afternoon, windows are closed, and air-conditioning switched on
Temperature during this time of the year (early December) is manageable and allows for windows to be open for some time in the day – not practical when ambient temperature exceeds 35°C during warmer parts of the year

</td></tr>
</table>

	- Occupants mention their perception on thermal comfort in the indoor environment is influenced by outdoor conditions – for example, once they are in the office after being outside for a while, they typically require air-conditioning to be set to the lowest supply temperature (i.e. maximum cooling) before their body adjusts and require a change in cooling settings - Two male occupants who agreed to be monitored during the visit were both wearing short-sleeve polo shirts and mention they usually feel comfortable during the day with the air-conditioning switched on - Female occupant in abaya explains clothing material is light in texture (ideal, when considering warm outdoor conditions) and does not necessarily provide adequate thermal insulation in the office when the air-conditioning is switched on.

4.3.1. Key observatory session findings

The observatory sessions across the 9 case study offices provided the research with an opportunity to explore typical behavioural practices of occupants in each to further assess trends in the thermal comfort perception of male and female occupants. The following key findings have been gathered from the observatory notes:

- An overview of data collated through the sessions indicates a correlation to responses received as part of the thermal comfort survey issued to all participants in advance of each observatory visit taking place.

- Additional clothing was a common trend among all female occupants in each case study office, where sweaters/cardigans/shawls and some cases, jackets were used to provide warmth. This was particularly evident with females who were located near supply grills (air vents) and perimeter walls/windows in conditioned offices but not observed in the office where natural ventilation and cooling was provided via open windows in San Francisco.

- Generally, male occupants appeared to have an increased tolerance to lower office temperatures in comparison to their female co-workers. Most were seen dressed in smart casual wear and became common to see male occupants in all but London, have their sleeves partially rolled up. In cases where relaxed dressing was practiced, many were seen in short-sleeve polo shirts.

- There is a point of view suggesting the consistent conditions in most case study offices based on mechanical heating (where applicable) and cooling created a dissimilarity between internal conditions with that of the outdoor environment. As such, the disproportional trend of female-to-male occupants who appeared to find their offices cold remained consistent irrespective of the office city location.

5. DISCUSSION AND CONCLUSION

The process of exploring both quantitative and qualitative research methodologies in this study have been instrumental in defining the key findings, which have been extracted in each section of this paper for further discussion. It goes without saying that the importance of data in assessing perceptions on thermal comfort in the case study offices are fundamental in attempting to draw on comprehensive conclusions for this study, which can be applied as the basis for further research in both academia and industry.

5.1. Study findings

An overview of findings from both participant responses to the online thermal comfort survey (quantitative) and case study feedback from the observatory sessions (qualitative) demonstrate uniformity, which fundamentally serves as appropriate verification of the results as follows:

- Occupancy behaviour based on gender (sex) type reiterated findings from reviewed literature, which suggest the mechanical (heating and cooling) design of conditioned offices arguably factor in the male user over that of females. This was evident across multiple case study offices, where females appeared to show increased levels of thermal discomfort when compared to their male co-workers. This was discussed in '*Energy consumption in buildings and female thermal demand*' (Kingma and van Marken Lichtenbelt, 2015), where the authors explain an overestimation of the female metabolic rate creates a thermal disparity in the thermal comfort perception between both genders. This research extends these findings further by concluding such an overestimation may be visible across offices in differing weather and climatic conditions as observed in London, San Francisco, Rio de Janeiro and Doha.

- The case study offices assessed through this research were predominately conditioned with sealed windows, with exception to 2 offices (1 each in San Francisco and Doha), where openable windows were utilised to provide natural ventilation and cooling when ambient (outdoor) temperatures made this practical. All offices that were classified as fully conditioned showed similarities in occupancy behaviour based on what may be described as a "bubble-effect", which created a dissonance between the indoor office and outdoor environment. To explain further, outdoor temperatures in Rio de Janeiro and Doha frequently exceed 25°C, a temperature that under any circumstance, many would consider as being warm. However, it appeared the case study offices overcompensated for the warm outdoor conditions by lowering the supply air temperature, which subsequently led to offices being too cold for comfort on average across both male and female occupants (refer to Figure 5 and Figure 6 where all, except one participant, reported either feeling 'Neutral' or on the 'colder spectrum' in both aforementioned cities).

- Literature reviewed on the topic of thermal comfort to inform this study have maintained consistency on the apparent subjectivity when assessing occupant perceptions of comfort in buildings. This thought process has been applied on observational feedback from the naturally ventilated case study office in San Francisco, which was the only recorded office to use their openable windows at the time of the session. It was clear that the openable windows provided all-round better thermal comfort to both male and female occupants in comparison to the remaining 8 conditioned offices. However, the study acknowledges that behavioural patterns observed in 1 case study of the 9 explored may not be appropriate to draw any conclusion on this, but does accept there were signs to suggest, where outdoor conditions permit, and windows are openable, natural ventilation and cooling may provide an overall improved thermal environment for occupants. Such theory is in line with the findings from '*Mixed mode buildings: A double standard in occupants' comfort expectations*' (Deuble and de Dear, 2012).

- The discussion of a potential 'performance gap' in the design of commercial offices and the use of these spaces in practice may be fundamental in identifying where thermal discomfort amongst occupants stems from. A few case studies visited proved to be liberal with available floorspace relative to the number of occupants thus, querying the cooling allowance provided by the designers. Explaining this thought further, if the mechanical designers responsible for determining the expected cooling capacity based their calculation on an office expecting 100 occupants, but in practice is only occupied by 40, there will potentially be an overestimation (in this case by as much as x2.5) creating a thermal imbalance between the proposed design and use in practice.

This research through the CIBSE Ken Dale Travel Bursary Award concludes on the notion that buildings provide a tendency to demonstrate gender bias when exploring thermal comfort perceptions of occupants in a typical conditioned commercial office. The review of pre-existing literature and use of quantitative and qualitative research methodologies has provided the opportunity to explore case study offices in London, San Francisco, Rio de Janeiro and Doha. The rationale for the cities used in this study was based on the explicit differences offered on weather and climatic conditions, influence of local culture in the workplace, typical clothing levels worn by male and female occupant amongst many others.

The key findings of this study have been presented in the case study analysis section this report. The first set of key findings were based on results from 193 survey responses suggest females in conditioned offices appear to have increased sensitivity to lower temperatures. The explicit differences identified in the number of female participants who considered their office to be on the 'colder spectrum' echoes the underlying disparity in thermal comfort between male and female occupants. The second set of key findings were based on feedback from observatory sessions across the 9 case study offices in all four cities. These sessions provided invaluable qualitative data for comparison to findings from existing literature and participant responses from the survey.

5.2. Recommendations

Cohesion of results from both sets of key findings allows this study to close by providing the following recommendations:

- Any further research that may wish to explore this topic in greater detail should consider expanding case study offices in climatic regions, which have not been included in this study.

- An allocation of 3 weeks was used in the exploration for this study (1 week in each city), where appropriate either through an MSc or PhD thesis, more time can be designated by observing offices for an extended timeframe to give improved and more holistic feedback on typical behavioural patterns.

- Case study offices can be assessed through incremental amendments to indoor supply temperatures to better inform on office design temperatures that reduce the proportion of female occupants who consider the office as being on the 'colder spectrum' – this will need to be optimised to avoid substantially increasing thermal discomfort with their male co-workers.

- This study understands a disparity may exist in the thermal comfort results reported and what may be deemed as thermally comfortable in practice. An example may be seen where a participant selects 'Warm' in the thermal comfort survey but was not given the opportunity to disclose whether this was in fact, their preference. Further studies and surveys should explore this area of ambiguity to provide 'real' results based on preference rather than standard thermal comfort responses in line with industry recommendations.

- Given the limited timeframe to select an appropriate sample size and contact potential case study offices, this research was unable to provide consistency in the number of participants across the four cities. London and San Francisco had a considerable increase in survey responses compared to Rio de Janeiro and Doha, which were due to reasons including, permanent residence of the author and wider network of contacts in London, as well as extensive professional network in the San Francisco Bay Area. Further studies are encouraged to consider creating a substantial network in all proposed locations to provide an improved balance in case study feedback.

- The application of data analytics for such studies creates a platform to assess information and draw informed conclusions from findings. Depending on practicality, further research should incorporate a range of tools in measurements of temperature, relative humidity, CO_2 levels, etc. to identify the implications on a range of parameters and understanding the disparity of thermal comfort in male and female occupants.

The study would like to thank you for your engagement with this research and the incredible journey that has been fundamental in creating this report. It is hoped that the findings and discussion have presented valuable contributions to the topic of thermal comfort in offices and buildings generally, as the voyage in research towards achieving comfort for all building users continues.

• • •

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APPENDIX – A

A Global Study: Designing for Gender Equality
Thermal Comfort Survey

In an ever-changing and fast-paced world, one might argue that history, and possibly the future, have been set-up primarily focusing on the evolution of men, rather than being inclusive of women and other genders. An article titled, *'The deadly truths about a world built for men...'* published by The Guardian, suggests the lives of men have subconsciously been used to represent all genders within the built environment, therefore neglecting a significant proportion of the global population.

This survey is looking to assess the subject further by exploring the thermal comfort levels experienced by different genders within the contemporary office. A similar study on this topic, '*Air quality and thermal comfort in office buildings: Results of a large indoor environmental quality survey*' (*Huizena C, et al, 2006*) has shown that over 40% of office workers have expressed dissatisfaction with their thermal environment. As a result, this survey has been developed specifically to target commercial offices in London, San Francisco, Rio de Janeiro, and Doha – to see whether a bias in occupancy thermal comfort and the idea of 'a world designed for men' transcends into the way our offices are designed.

- **Location**
    - London
    - San Francisco
    - Rio de Janeiro
    - Doha

1. **How would you describe your gender?**
    - Male
    - Female
    - Non-binary
    - Prefer not to say
    - Prefer to self-describe: __________

2. **Your thermal comfort**
    a. **Part I – On average, how would you best describe the thermal comfort in your office:**
        - Cold
        - Cool
        - Slightly cool
        - Neutral
        - Slightly warm
        - Warm
        - Hot

b. **Part II – Time of day you most regularly feel the above? (Tick/check all that apply)**
  - Morning (before 11am)
  - Midday (11am – 2pm)
  - Afternoon (2pm – 5pm)
  - Evening (after 5pm)
  - Weekends/holidays
  - Monday mornings
  - No particular time
  - Always
  - Other

3. **How would you describe your location in the office?**

- Near an inner surface wall
- Near an external surface wall
- Near an external window
- In the centre of an open plan office
- In an enclosed (cellular) office
- Other: _____________

4. **How would you best describe your clothing and activity level for a typical day in the office?**

a. **Part I – Using the list below, please tick each item of clothing that you are currently wearing: (Tick/check all that apply)**
- Short-sleeve shirt
- Long-sleeve shirt
- T-shirt
- Long-sleeve sweatshirt
- Sweater/jumper
- Vest
- Jacket
- Knee-length skirt
- Ankle-length skirt
- Dress
- Shorts
- Athletic sweatpants
- Trousers
- Undershirt
- Long underwear bottoms
- Long sleeve coveralls
- Overalls
- Slip
- Nylons
- Socks
- Boots
- Shoes
- Sandals
- Other: (please note if you are wearing something not described above, or if you think something you are wearing is especially heavy) ___________________

b. **Part II – During your average workday, how do you spend your time?**

- Predominately at your desk
- Predominately moving around the office space
- In between meetings within the office (i.e. different rooms)
- Off-site, but in the office from time-to-time
- Other: __________________

5. **Which of the following do you adjust, control or use within your personal space to meet your thermal comfort needs? (Tick/check all that apply.)**

- Clothing (i.e. wearing or taking off items of clothing)
- Windows blinds or shades
- Room air-condition unit
- Portable heater
- Permanent heater
- Hot water bottle
- Interior or exterior door
- Adjustable air vent in wall or ceiling
- Ceiling fan
- Adjustable floor vent (air diffuser)
- Portable fan
- Thermostat
- Operable windows
- None of these
- Other: ______________

Um Estudo Global - Projetando para a Igualdade de Gênero
Pesquisa de conforto térmico

Em um mundo em constante e acelerada evolução, pode-se argumentar que a história, e possivelmente o futuro, estão focados primordialmente na evolução dos homens, em vez de incluir mulheres e outros gêneros. Um artigo intitulado 'As verdades mortais sobre um mundo construído para homens...' (*'The deadly truths about a world built for men...')* publicado pelo jornal britânico The Guardian, sugere que as vidas dos homens foram subconscientemente usadas para representar todos os sexos no ambiente construído, negligenciando, portanto, uma proporção significativa da população global.

Esta pesquisa explora esse tema, focando nos níveis de conforto térmico experienciados por diferentes gêneros no ambiente de escritório contemporâneo. Um estudo semelhante sobre esse tópico, 'Qualidade do ar e conforto térmico em edifícios de escritórios: resultados de uma grande pesquisa de qualidade ambiental em ambientes fechados' ('*Air quality and thermal comfort in office buildings: Results of a large indoor environmental quality survey*' by Huizena C, et al, 2006) mostrou que mais de 40% dos trabalhadores de escritório manifestaram insatisfação com seu ambiente térmico. Em consequência, esta pesquisa foi desenvolvida especificamente focada em escritórios comerciais em Londres, São Francisco, Rio de Janeiro e Doha - buscando verificar se existe um viés no conforto térmico e a idéia de 'um mundo projetado para homens' na maneira em que nossos escritórios são projetados.

- **Localização**
    - Londres
    - São Francisco
    - Rio de Janeiro
    - Doha

1. **Sexo:**
    - Masculino
    - Feminio
    - Não-binário
    - Prefiro não dizer
    - Prefiro me auto-descrever: __________

2. **O seu conforto térmico**
    a. **Parte I – Em média, como você descreveria o conforto térmico em seu escritório:**
        - Muito frio
        - Frio
        - Ligeiramente frio
        - Neutro (Nem calor/nem frio)
        - Ligeiramente quente
        - Quente
        - Muito quente

b. Parte II – A hora do dia em que você se sente como marcado na questao anterior? (Marque todas as opções aplicáveis)

- Manhã (antes 11:00)
- Meio dia (11:00 – 14:00)
- Tarde (14:00 – 17:00)
- Fim de tarde (depois das 17:00)
- Fins de semana / feriados
- Segunda-feira de manhã
- Nenhum horário em particular
- Sempre
- Outros ______

3. Como você descreveria sua localização no escritório?

- Perto de uma parede interna
- Perto de uma parede externa
- Perto de uma janela externa
- No centro de um escritório ‘open plan’
- Em uma sala de escritório individual
- Outro: ____________

4. Como você descreveria melhor seu nível de roupas e atividades em um dia típico no escritório?

a. Parte I – Usando a lista abaixo, marque cada peça de roupa que você está usando no <u>momento</u>: (Marque todas as opções aplicáveis)

- Camisa de manga curta
- Camisa de manga longa
- Camiseta
- Moletom de manga comprida
- Suéter
- Regata
- Jaqueta
- Saia até os joelhos
- Saia até o tornozelo
- Vestido
- Calção
- Calças esportivas
- Calças
- Colete/camiseta interior
- Cuecas compridas
- Macacão de manga comprida
- Macacões
- Chinelo
- Nylons
- Meias
- Botas
- Sapatos
- Sandálias
- Outros: (favor incluir se você está usando algo não descrito acima ou se acha que algo que está vestindo é especialmente grosso/quente) __________________

b. **Parte II – Durante o seu dia de trabalho típico, como você passa seu tempo?**

- Predominantemente em sua mesa
- Movendo-se predominantemente pelo espaço do escritório
- Entre reuniões dentro do escritório (ou seja, salas diferentes)
- Predominantemente fora do escritório, mas no escritório de tempos em tempos
- Outros: __________________

5. **Qual das seguintes opções você ajusta, controla ou utiliza dentro do seu espaço pessoal para atender às suas necessidades de conforto térmico? (Marque todas as opções aplicáveis.)**

- Roupas (ou seja, usar ou tirar itens de roupas)
- Persianas ou cortinas
- Unidade de ar condicionado da sala
- Aquecedor portátil
- Aquecedor permanente
- Bolsa de água quente
- Porta interior ou exterior
- Entrada de ar ajustável na parede ou no teto
- Ventilador de teto
- Ventilador de chão ajustável (difusor de ar)
- Ventilador portátil
- Termostato
- Janelas operáveis
- Nenhum desses
- Outros: ______________

This report has been written by Ifeanyi Raphael Amajuoyi as winner of The Ken Dale Travel Bursary Award 2019
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