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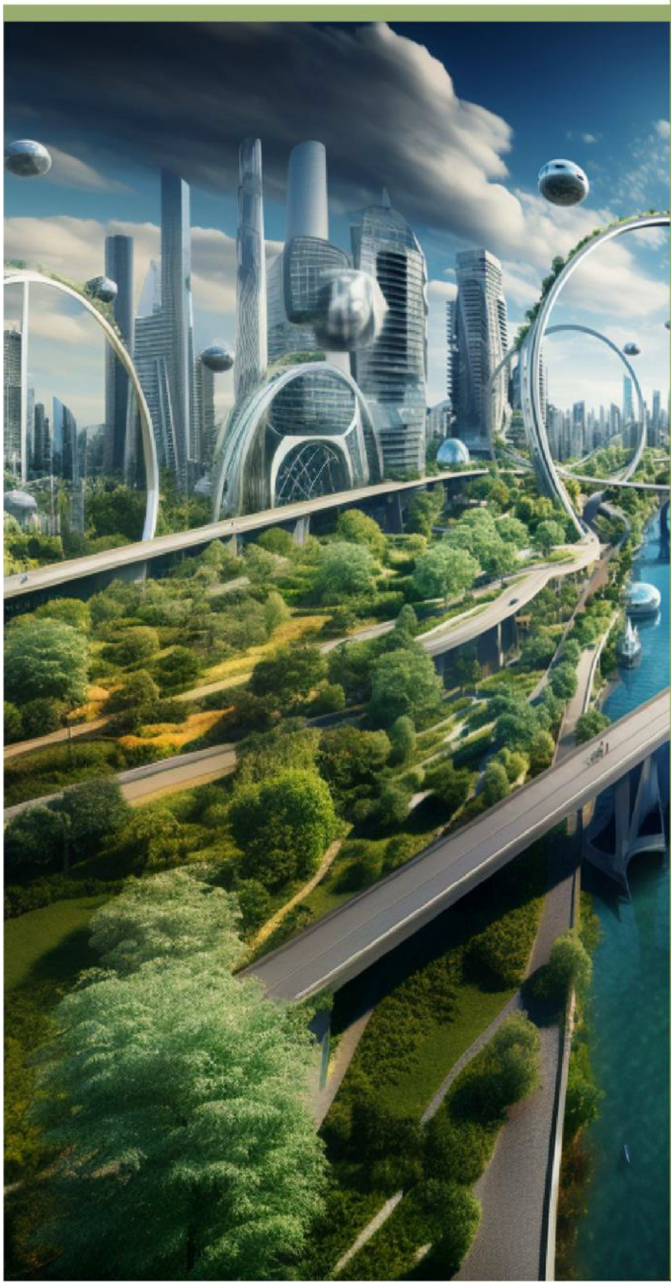

Sustainability and Resilience: Innovation and Solutions

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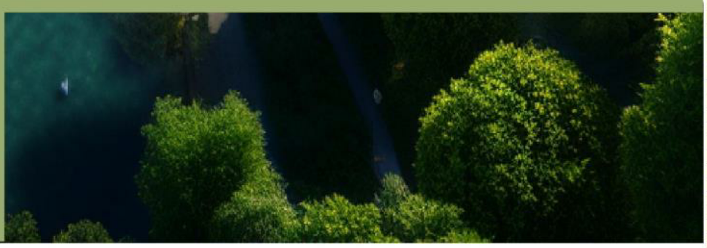

50 anos Ensino Superior Covilhã — Universidade Beira Interior

Faculdade Engenharia

Ordem dos Engenheiros

Ordem dos Arquitectos

November 2024 | Covilhã – Portugal

Info: www.iceubi2024.pt

Proceedings of the International Congress on Engineering UBI – ICEUBI2024 - *Sustainability and Resilience: Innovation and Solutions”*

University da Beira Interior

27th-29th of November 2024 | Covilhã, Portugal

Edited by

Marisa Dinis de Almeida, PhD and Francisco Brójo, PhD

IMAGEM CAPA | DESIGN

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Abstracts, and Full Papers were read and selected by Review Committee of the ICEUBI2024.

All manuscripts went through a double peer review process to be presented at the Congress.

Further copies of these proceedings can be consulted at: www.iceubi2024.pt

DOI: https://doi.org/10.25768/9239-05-0

ISBN: 978-989-9239-05-0

SUPPORT: ELECTRONIC | FORMAT: PDF

EDITOR: UNIVERSIDADE DA BEIRA INTERIOR – FACULDADE DE ENGENHARIA

PUBLISHER: UNIVERSIDADE DA BEIRA INTERIOR – FACULDADE DE ENGENHARIA

CALÇADA DA FONTE DO LAMEIRO, 6200-358 COVILHÃ, PORTUGAL

ICEUBI2024

"Sustainability and Resilience: Innovation and Solutions"

POST-OCCUPANCY EVALUATION OF FIVE CASE STUDIES ON THERMAL COMFORT: EVALUATION AND ANALYSIS OF BEDROOM VS. LIVING ROOM

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ABSTRACT

Indoor building environments influence people's comfort and well-being. These concepts are increasingly being studied holistically, and some methods exist for their study, such as post-occupancy evaluation and sensor measurements. The current study presents the results obtained from five homes using a survey and air temperature measurements in winter and summer. This study aims to verify if there are significant differences in temperature in the main bedroom and the living room and to understand whether the occupants' perception of the indoor thermal comfort in these rooms is the same. It is also discussed whether measuring the air temperature in the two rooms is relevant, considering the answers obtained by the survey and which range of air measurements is relevant for the analysis. The study concludes that occupant perception of the bedroom and the living room thermal sensation does not always coincide in all the case studies despite the recorded temperatures not being significantly different between the rooms. Occupants indicate different perceptions of similar measured temperatures, and the relationship between measured temperature and occupant perception is complex to study since people's perceptions are subjective. The measurement intervals more relevant to this study are the time window for answering the survey and the closest hour the occupants answered the survey.

Keywords: *Comfort, Well-being, POE, Experimental methodology.*

RESUMO

Os ambientes interiores dos edifícios influenciam o conforto e o bem-estar das pessoas. Estes conceitos estão a ser cada vez mais estudados de forma holística, existindo alguns métodos para os estudar, como a avaliação pós-ocupação e medições através de sensores. O presente estudo apresenta os resultados obtidos em cinco habitações através da implementação de um questionário e de medições da temperatura do ar no inverno e no verão. Este estudo tem como objetivo verificar se existem diferenças significativas de temperatura no quarto principal e na sala de estar e perceber se a perceção dos ocupantes do conforto térmico interior nestes compartimntos da sua habitação é a mesma. É também discutido se a medição da temperatura do ar nos dois compartimentos é relevante, tendo em conta as respostas obtidas pelo questionário e qual a gama de medições do ar é relevante para a análise. O estudo conclui que a perceção dos ocupantes da sensação térmica do quarto e da sala de estar nem sempre coincide em todos os estudos de caso, apesar de as temperaturas registadas não serem significativamente diferentes entre os compartimentos. Os ocupantes indicam percepções diferentes para temperaturas medidas semelhantes, e a relação entre a temperatura medida e a perceção dos ocupantes é complexa de estudar, uma vez que as percepções das pessoas são subjectivas. Os intervalos de medição mais relevantes para este estudo são a janela de tempo para responder ao questionário e a hora mais próxima em que os ocupantes responderam ao questionário.

Palavras-chave: Conforto, Bem-estar, Metodologia experimental.

1 INTRODUCTION

People spend much of their time inside buildings. The building's indoor environment influences the comfort, productivity, health and well-being of occupants (BRAGER; ZHANG; ARENS, 2015)(ANDARGIE; TOUCHIE; O'BRIEN, 2019)(PISELLO et al., 2021)(ALHORR et al., 2016). The concepts of comfort, well-being, and quality of life in buildings have become relevant (PINTO et al., 2017). Commonly, comfort and well-being are used interchangeably and are presented as concepts related to the quality of life (PINTO et al., 2017). Current research and standards have mainly focused on establishing acceptable ranges of indoor environmental conditions to provide comfort (thermal, air quality, light, and acoustics). Acceptable indoor climates are essential to the success of a building, not only in making it comfortable but also in deciding its energy consumption and ensuring its sustainability (NICOL; HUMPHREYS, 2002).

Comfort sensation/perception/evaluation results from the interaction between the environmental and physiological conditions, the occupants' perception of psychological, social and cultural conditions/rights, architecture, clothing, eating habits and climate (FABBRI, 2015). Occupant comfort depends on personal variables and is defined by an absence of unpleasant sensations, thus positively affecting well-being and is highly subjective (ALHORR et al., 2016). It is complex, defining and achieving comfort because it responds to the physical state created by the combined effect of the environment's physical characteristics. Well-being consists of physical, mental and social factors, and overall satisfaction (ŠUJANOVÁ et al., 2019), positive psychological experiences that occur in life and reflect an individual's good psychological functioning (GASPAR, 2011). It relates to concepts of happiness, positive experiences or ideas, life satisfaction, pleasure, and prosperity (LAMBERT; PASSMORE; HOLDER, 2015)(COELHO DO VALE; MOREIRA, 2016). Well-being is broader than comfort and refers to a neutral, durable, basic, relaxed, or pleasant state (ZITARS et al., 2021).

To evaluate comfort and well-being, besides personal aspects that condition this evaluation, there are different aspects and variables of comfort and well-being that must be taken into account, namely thermal comfort, acoustics, air quality, lighting (ORTIZ; KURVERS; BLUYSSEN, 2017)(MONIKA; WARGOCKI, 2011) (MATEUS, R.; PINTO, A; PEREIRA, J. M.C, 2024)(PISELLO et al., 2021) and space-functional aspects (PASTORE; ANDERSEN, 2019)(UC DAVIS - STUDENT COMMUNITY CENTER, 2014)(MANGAN et al., 2020) (MATEUS, R.; PINTO, A; PEREIRA, J. M.C, 2024a). The factors related to the architecture and construction of buildings must also be considered since they influence the comfort and well-being felt indoors and the occupants' ability to adapt (MONIKA; WARGOCKI, 2011). Comfort and well-being are interconnected, broad and deep phenomena of a subjective nature. Also, they had contextual dynamism since they were influenced by multiple factors.

Comfort, well-being, productivity, preferences and behaviour of the occupants can be known through post-occupancy evaluation (RANDALL; CORP; SELF, 2014)(PAONE; BACHER, 2018)(HOXHA; LIARDET; JUSSELME, 2020)(DUARTE ROA; SCHIAVON; PARKINSON, 2020)(LI; FROESE; BRAGER, 2018) combined with sensor measurements (ALHORR et al., 2016)(ZHANG; ZHANG; KHAN, 2019)(WILLEMS; SAELENS; HEYLIGHEN, 2020)(KO et al., 2020). Post-occupancy evaluation (POE) evaluates buildings after being constructed and occupied (RASHEED; BYRD, 2018)(GONZALEZ-CACERES; BOBADILLA; KARLSHØJ, 2019). This evaluation aims to understand how the building functions, whether it meets the occupants' needs, whether it is satisfactory from the occupant's perspective and whether the comfort goals are achieved (ALHORR et al., 2016)(UK GREEN BUILDING COUNCIL, 2016). It is a general approach to obtain feedback about a building's performance in use, including energy performance, indoor environment quality, occupants' satisfaction, productivity, and others (LI; FROESE; BRAGER, 2018). POE also permits the discovery of solutions to detected problems, highlights what should be repeated and avoided, and disseminates design guidelines to improve future projects (GONZALEZ-CACERES; BOBADILLA; KARLSHØJ, 2019). This evaluation uses three sources for data collection: occupant feedback through questionnaires and interviews, billing and measurement collection, and measurement of indoor environmental conditions (ALHORR et al., 2016)(JONES; GOODHEW; DE WILDE, 2016).

Interviews and questionnaires are methods of gathering information by asking occupants questions (ALHORR et al., 2016)(PAONE; BACHER, 2018)(ANDARGIE; TOUCHIE; O'BRIEN, 2019). Interviews are used in a detailed study where the sample is very low, while surveys collect information remotely from multiple participants. Surveys are widely used to obtain information by sending a questionnaire to multiple people (ALHORR et al., 2016). Depending on the type of study, long-term or right-now evaluations can be applied (WILLEMS; SAELENS; HEYLIGHEN, 2020)(LI; FROESE; BRAGER, 2018). Point-in-time or right-now surveys should be required during the representative time of the building's occupancy. It may also be relevant to conduct the survey during the two periods of the year when the environmental conditions are more disparate to ascertain the level of satisfaction with the indoor environment during the two seasons (summer and winter) (PASTORE; ANDERSEN, 2019)(ZHANG; ZHANG; KHAN, 2019)(PAZHOOHESH; ZHANG, 2018)(RUPP et al., 2018)(ASHRAE, 2017). Other authors apply surveys on weekdays for about two months (DUARTE ROA; SCHIAVON; PARKINSON, 2020), while others occur over a month (KO et al., 2020) or even 4 years (RIJAL; HUMPHREYS; NICOL, 2019).

Interviews and surveys can include personal questions since they can affect the comfort and well-being of the occupants (ALHORR et al., 2016)(ZHANG; ZHANG; KHAN, 2019)(DUARTE ROA; SCHIAVON; PARKINSON, 2020)(RUPP et al., 2018)(PASTORE; ANDERSEN, 2019)(ORNSTEIN, 1995). This data can be requested at the beginning or end of the survey. However, answering at the end may help avoid conditional answers (SANT'ANNA et al., 2018). Other questions should be present in the survey to allow the evaluation of the comfort and well-being parameters. It is crucial to have a well-planned communication approach and to use an optimised survey regarding duration and content (ASHRAE, 2017). Different surveys that evaluate satisfaction, comfort, and well-being are available and can be applied to residential buildings and/or commercial and service buildings. Several building standards and surveys/questionnaires focus on energy consumption and occupant comfort (ALHORR et al., 2016). These surveys developed by organisations and/or presented in norms and scientific articles that evaluate comfort and well-being contributed to developing the survey intended to apply in this study.

Devices and sensors are used to measure indoor environmental conditions. Sometimes, they are already integrated into buildings (ALHORR et al., 2016), but in other cases, sensors are used and placed in the spaces to be studied. Measuring the indoor environmental conditions of the building can be done with many types of sensors. Usually, is used humidity and temperature sensors (PAZHOOHESH; ZHANG, 2018)(DUARTE ROA; SCHIAVON; PARKINSON, 2020)(RUPP et al., 2018)(STOPPS; TOUCHIE, 2020)(RIJAL; HUMPHREYS; NICOL, 2019) and sensors that detect different indoor gases (ALHORR et al., 2016)(PASTORE; ANDERSEN, 2019)(ELNAKLAH; WALKER; NATARAJAN, 2021)(LI; FROESE; BRAGER, 2018). Sensors for lighting and acoustics can also be used (LI; FROESE; BRAGER, 2018), and to obtain external data, it is from a meteorological station near the study (RIJAL; HUMPHREYS; NICOL, 2019)(RUPP et al., 2018) or using proper sensors. The period of measurements was typically every 5 minutes (ALHORR et al., 2016)(JONES; GOODHEW; DE WILDE, 2016)(PASTORE; ANDERSEN, 2019)(ASHRAE, 2017). It is also important to say that the sensors/loggers should be sited away from heat sources and direct sunlight (JONES; GOODHEW; DE WILDE, 2016)(DARTEVELLE et al., 2021).

The Appendix Table summarises the comfort and well-being parameters and the methods of measuring and obtaining data from the bibliographic studies consulted on housing. Generally, a survey is the most commonly used method for obtaining feedback from occupants. Sensors are also widely used to extract data from the indoor environment. However, the way in which these methods are applied, the size, the type of questions, the scale of assessment and the frequency with which it is applied varies significantly depending on the type of study.

2 PROBLEM STATEMENT AND CONTRIBUTIONS

This paper will mention comfort and well-being when it pretends to refer to concepts of comfort, well-being, satisfaction and perception of occupants about the indoor environment. This study presents part of a more extensive study, which is under development, that aims to develop a holistic method for assessing comfort and well-being in its multiple aspects and its relationship with the energy efficiency of buildings. This more extensive study uses a methodology in which two types of survey are used for two different but complementary analyses: the right-now survey to assess comfort and well-being in the main bedroom and living room but with a focus on thermal comfort; the extensive survey to take a general approach to the dwelling in terms of the different comfort parameters (personal aspects, thermal comfort, acoustics, indoor air quality, lighting, functional space and architecture and construction aspects). This methodology also carries out measurements of the indoor environment and energy simulation of the case studies buildings.

That said, the current research aims to present part of the methodology applied in the more extensive study. This study presents and explores the results obtained using the right now survey and the indoor environment measurements in winter and summer and aims to verify:

- Whether people's perception of the indoor environment differs between the living room and the bedroom;
- Whether it is relevant to measure the temperature of the air in the bedroom and living room, taking into account the answers obtained by the right now survey;
- Whether people's perception of comfort and well-being in the indoor environment is different in the year's more extreme/cooler seasons;
- Which range of measurements of the indoor environment is relevant for the analysis of the two points above (all day, 9 p.m.-12 a.m., the time closest to when they answered the survey);
- Relationship between measured indoor temperature and people's perception.

Generally, this current study intends to determine whether there are significant differences in temperature in the main bedroom and the living room and to understand whether the occupants' perception of the indoor environment in these two rooms is the same or different. The living room and bedroom are typically where people spend the most time in a home and seek to feel comfortable and have a sense of well-being.

3 METHODOLOGY

3.1 Data collection

The right-now survey and the respective monitoring of indoor environmental parameters lasted two weeks and did not occur simultaneously in all the case studies due to the geographical location of the case studies and for reasons related to the amount of equipment available. This methodology was applied to 5 homes in Portugal.

The right-now survey is quick to complete and focuses essentially on one aspect of comfort: thermal comfort. It addresses questions relating to the bedroom and living room when the occupant fills out the survey and throughout the day. The key questions in this survey are thermal sensation and perceived discomfort when the person is filling out the survey. The occupants answered this survey every day from 9 p.m. for two continuous weeks. This survey was applied at two different times: two weeks in winter and two weeks in summer. The right-now survey can be found in the Appendix. It is mandatory to answer all the questions, and there is no anonymity since the goal is to study a specific house and a specific occupant. Only one person answered for each dwelling because these are dwellings where only one person lives permanently.

At the same time as this right-now survey, measurements were taken of the indoor environment to compare the answers given with the temperature values recorded during the day and night in the living room and in the main bedroom of each case study. The values were recorded every 5 minutes.

3.2 Case studies

In this study, 5 case studies were selected to apply the presented methodology. They are all residential buildings in Portugal, some apartments, others villas. The climatic zones and the characteristics of the construction and systems vary. The occupants of these dwellings have lived there for at least a year, and their ages range from 28 to 80 years old.

The intention was to ensure diversity in terms of the occupant's profile, the building characteristics, and the use of the dwelling since the aim was to test the method developed with different inputs, homogeneity and generalisation are not of interest in this study because it is not intended to study relationships or correlations between certain characteristics of the occupants and/or the dwelling. Statistical validation is not the aim of this study. This study aims to respond to each case's different needs and specific characteristics, i.e., housing and occupants. Table 1 describes the various case studies.

Table 1 - Case studies characteristics

Case study	Climate zone	Construction year	Envelope characteristics		Energy systems	
			Opaque	Glazed	Heating	Cooling
1	I1;V2	2000	Double brick wall with air gap and insulation and inclined reinforced concrete roof	Simple double-glazed windows with metal frames	Electric	-
2	I1;V2	2000	Double brick wall with air gap and insulation and inclined reinforced concrete roof with insulation	Simple double-glazed windows with metal frames	Electric	Electric
3	I2;V1	2010/2011	Double brick wall with air gap and insulation and inclined reinforced concrete roof with lusa tiles	Simple double-glazed windows with metal frames	Biomass, electric	-
4	I1;V2	≈1960	Simple brick wall and inclined reinforced concrete roof with lusa tiles	Simple double-glazed windows with metal frames	Electric	-
5	I2;V1	≈1960	Simple brick wall and inclined reinforced concrete roof with lusa tiles	Simple single-glazed windows with wooden frames	Electric	-

4 RESULTS AND DISCUSSION

4.1 Range of indoor environment measurements

As mentioned above, it was not possible to simultaneously measure the indoor environment in the five case studies. This fact must be taken into account when analysing the results obtained. Table 2 shows the bedroom mean temperature (T_B), living room mean temperature (T_{LR}), mean outdoor temperature (T_{Out}) and the difference between the mean temperature values measured in the living room and outdoor (ΔT) during the period in which the right now survey was applied. Table 3 shows the bedroom (T_B), living room (L_R) and outdoor minimum and maximum temperatures recorded during the period in which the right now survey was applied.

Table 2 shows that during the application period of the right now survey, the difference in mean outdoor temperatures is not very significant, with a maximum of 2.5°C in winter and 3.5°C in summer (T_{Out}). Table 3 also shows that the minimum outside temperatures in winter are similar, with a difference between them of 1.7 °C and the maximum with a difference of 3.4°C. In summer, these differences are 2.9 °C for minimum outside temperatures; for the maximum, the value is 8.1°C. In this sense, it is possible to compare the results obtained since the difference in the outside temperatures recorded is not very significant between cases. Although the difference between the maximum outside temperatures in summer is significant.

In winter, the difference in average living room and bedroom temperatures is 0.6°C in two cases, 0.5°C in another and less than 0.2°C in the others. In summer, this difference is 1°C in one case study, 0.5°C and 0.4°C in others and less than 0.2°C in the others. The temperature difference between the room and the outside (ΔT) in winter is less than 4°C in all case studies, and in summer, less than 2°C, as shown in Table 2.

Table 2 – Mean indoor and outdoor measured temperatures during the right now survey [°C]

Case study	Winter				Summer			
	T_B	T_{LR}	T_{Out}	ΔT	T_B	T_{LR}	T_{Out}	ΔT
1	17.5	16.9	13.1	3.8	25.2	24.7	26.2	1.5
2	18.4	19.0	15.6	3.4	24.2	25.2	23.2	2.0
3	16.5	17.0	13.4	3.6	23.3	23.2	22.7	0.5
4	16.2	16.1	13.5	2.6	26.5	26.3	26.2	0.1
5	16.5	16.3	15.2	1.1	24.9	24.5	24.0	0.5

Table 3 - Measured minimum and maximum indoor and outdoor temperatures during the right now survey [ºC]

Case study	Winter						Summer					
	T min			T max			T min			T max		
	B	LR	Out	B	LR	Out	B	LR	Out	B	LR	Out
1	16.3	12.3	6.7	18.7	18.4	19.0	23.7	21.4	20.5	26.4	27.9	37.5
2	14.3	15.6	6.4	20.6	21.3	22.4	23.1	23.4	18.9	25.1	27.4	30.0
3	14.2	13.4	6.1	18.5	20.2	20.6	21.7	21.3	17.6	24.2	25.3	29.4
4	14.1	13.3	6.7	17.8	22.7	19.0	25.1	24.4	20.5	28.3	28.7	37.5
5	10.9	10.0	5.0	20.2	20.2	21.6	22.4	22.1	19.2	27.9	27.4	30.2

The living room and bedroom temperature values were recorded every 5 minutes. To process the data, it was found that there could be different time intervals that could be considered: during the time the occupants could answer the survey (9 p.m.-12 a.m.); throughout the day (Daily); at the time closest to when the occupant filled in the survey (Closest hour). By averaging the recorded indoor temperatures, graphical representations were obtained for each case study by compartment (living room and main bedroom) and by season (winter and summer), as shown in Figures 1 to 5. Some case studies do not have the 14 days of evaluation period (x-axis) completed as they did not answer the survey on that day.

Both in summer and winter, the measurement intervals that have the closest values, in general, are between 9 a.m. and 12 p.m. and the closest hour the occupants answered the survey. On certain days when the occupants answered the survey, the daily values were closer to these two other intervals, but this happens less often. This analysis applies to all the case studies. The fact that the "daily" time interval is generally further away from the others may be because it is a longer interval (24 hours) and may not reflect the use of HVAC equipment (heating and cooling). It should also be noted that in most of the cases analysed, the difference in temperature between these three time intervals is around 0.5º/1º or less. In some cases, some days of the evaluation period have a greater difference and may reflect the use of air conditioning equipment or other actions carried out by the occupant.

Figures 1 to 5 show that the temperature profile of the three measurement periods in the living room does not always correspond to that of the bedroom in summer and winter. This is more evident in some of the case studies. However, as mentioned above in the analysis of Tables 2 and 3, when comparing the temperatures obtained from the measurements in the living room and the bedroom, it turns out that there are no significant differences in mean temperature in the main bedroom and the living room.

Figure1 – Graphical representation of air temperature measurement intervals for each case study 1 by compartment and season

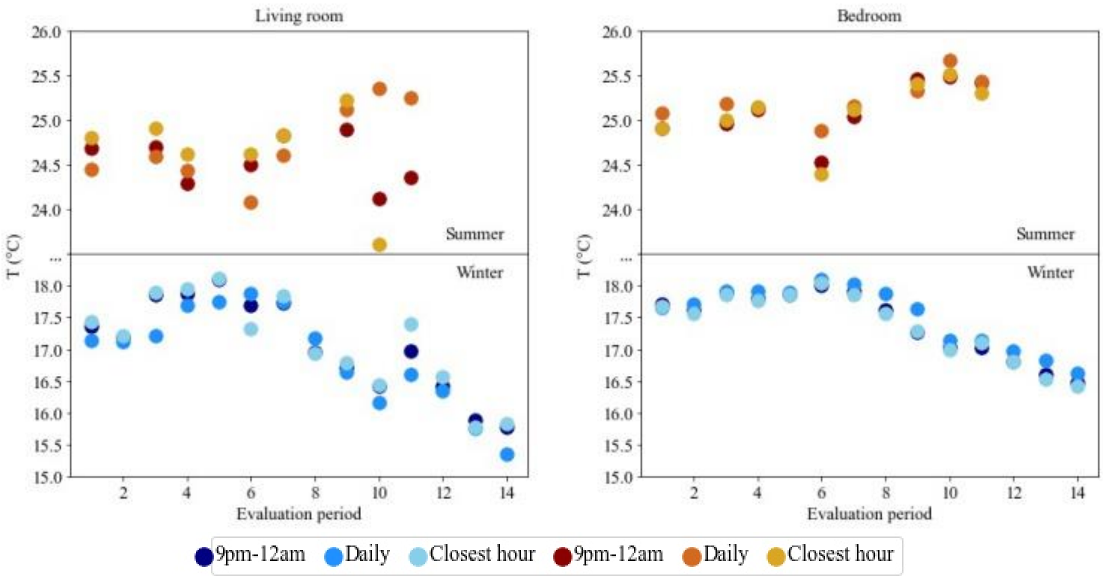


Figure2 – Graphical representation of air temperature measurement intervals for each case study 2 by compartment and season

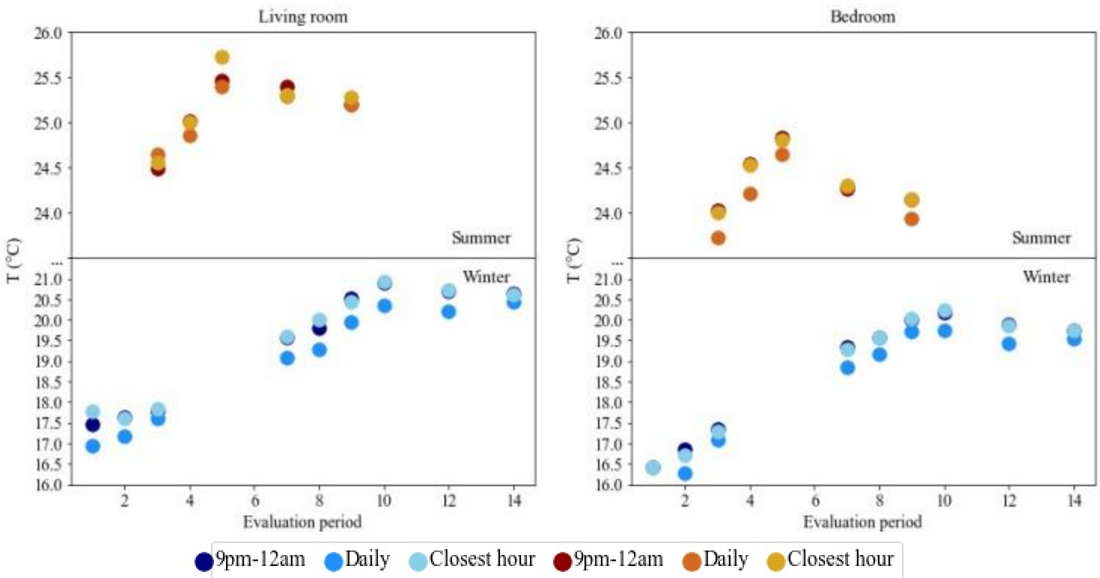


Figure3 – Graphical representation of air temperature measurement intervals for each case study 3 by compartment and season

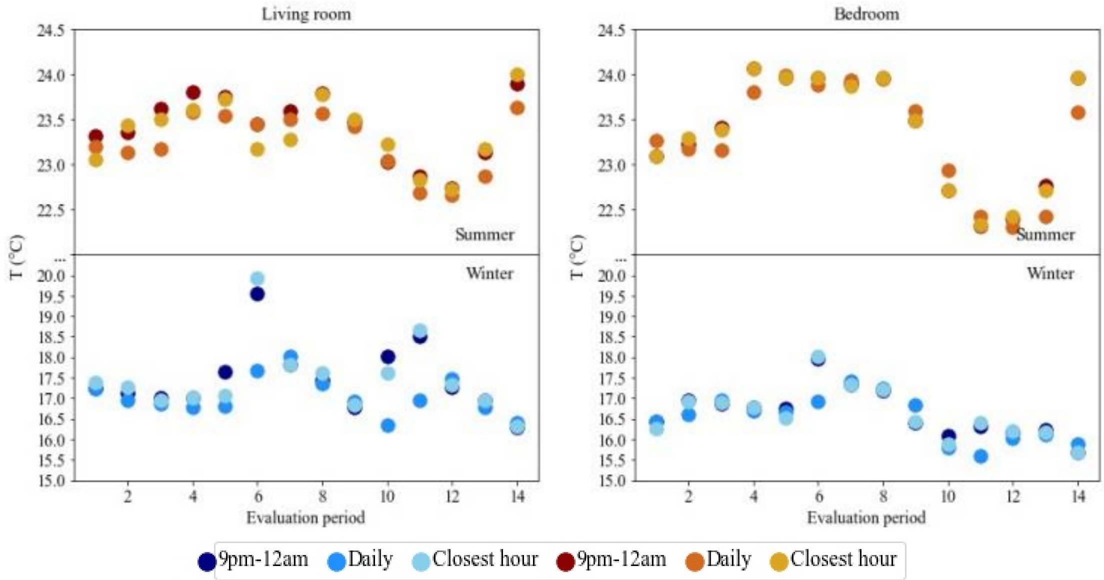


Figure4 – Graphical representation of air temperature measurement intervals for each case study 4 by compartment and season

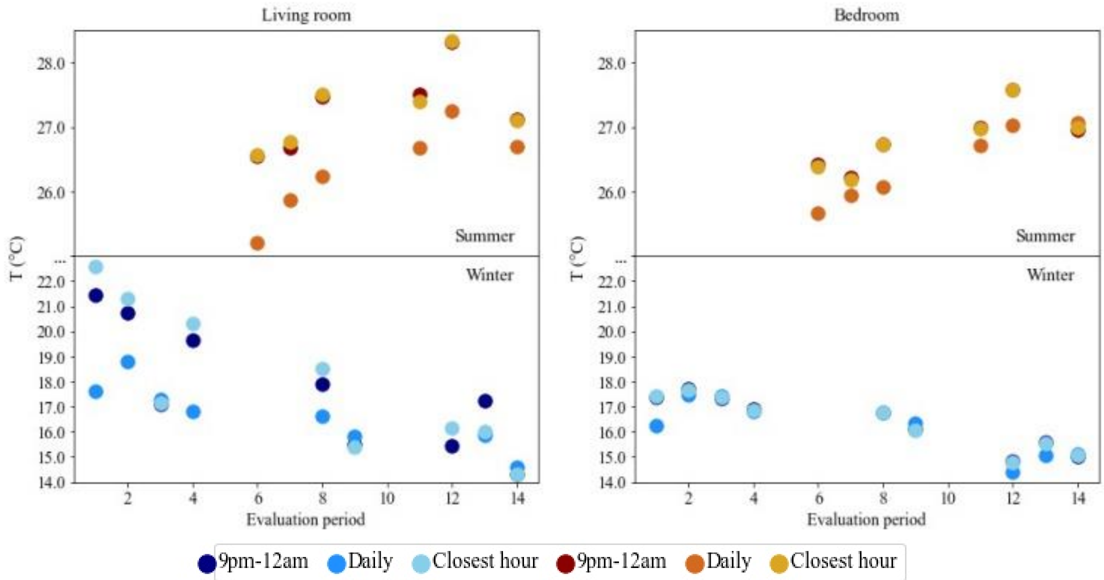
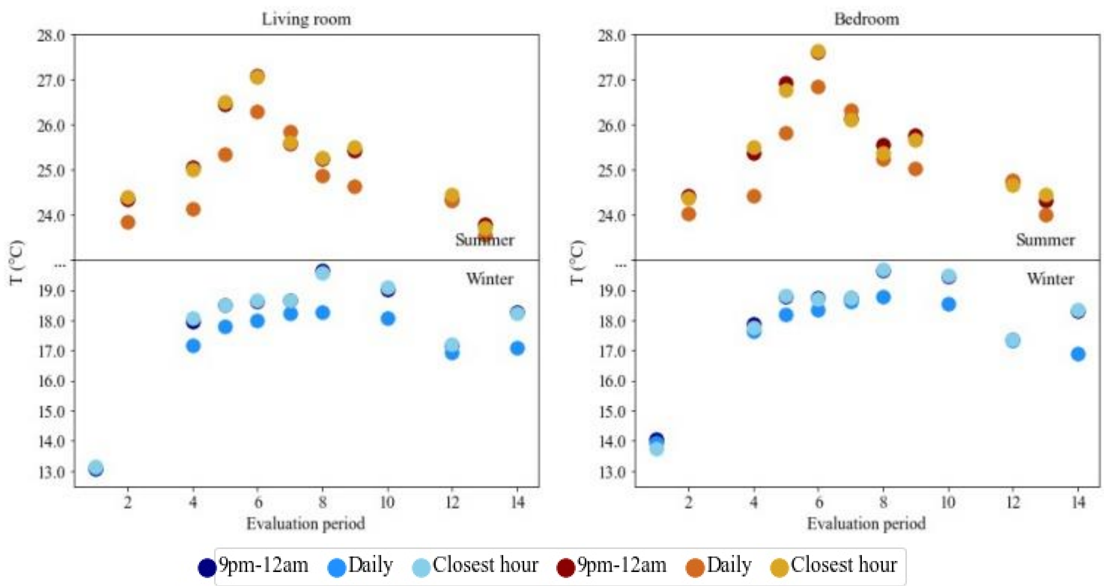


Figure5 – Graphical representation of air temperature measurement intervals for each case study 5 by compartment and season



4.2 Measured indoor temperature and people's perception

Knowing that one of the intentions of this study is to understand whether the occupants' perception of the indoor environment in the living room and bedroom is the same or different, it is necessary to consider the measured temperatures and the responses obtained in the survey. The temperature closest to the time when the occupants started answering the survey (Closest hour) was the range measurement selected to perform this analysis. The occupant's response to the thermal sensation at that moment and thermal comfort or discomfort were the variables considered to be obtained for each case study, the graphical representation shown in Figures 6 to 10.

4.2.1 Relationship between measured indoor temperature and people's perception

In case study 1, it can be seen that the occupant always indicates being slightly cool in the living room in the winter. In contrast, the occupant indicates being comfortable only a few times in the bedroom. However, they never said they felt uncomfortable with the temperature. The temperatures recorded when the occupant started filling in the survey varied between 15.8°C and 18.1°C in the living room and bedroom. Note that the occupant indicates being slightly cool and comfortable in the bedroom at the same/similar temperatures. In the summer, the occupant indicates that they are always comfortable with recorded temperatures of 23.6°C to 25.5°C in the bedroom and living room.

In case study 2, it can be seen that the occupant in both winter and summer indicates that he is more often in the slightly cold and slightly warm room, respectively. In winter, he said he was always comfortable in the living room, and in the bedroom, the occupant said that it was slightly cold and comfortable. The temperatures recorded when the occupant started filling in the survey varied between 16.4ºC and 20.9ºC in the living room and bedroom. Note that the occupant indicates being slightly cool and comfortable in the bedroom at the same/similar temperatures. In the summer, the occupant indicates that they are sometimes comfortable and sometimes slightly hot (more so in the bedroom), with temperatures recorded between 24.0ºC and 25.7ºC in the bedroom and living room. The occupant never said they felt uncomfortable with the living room and bedroom temperature.

In case study 3, it can be seen that the occupant indicates being slightly cold, slightly warm and comfortable in the living room in the winter. In the bedroom, he said he was slightly cool but more often comfortable. The temperatures recorded when the occupant started filling in the survey varied between 15.7ºC and 19.9ºC in the living room and bedroom. In the summer, the occupant indicates that he is more often comfortable and sometimes slightly hot, with recorded temperatures between 22.3ºC and 24.1ºC in the bedroom and living room. However, they never indicate feeling uncomfortable with the bedroom and living room temperature. It should also be noted that the occupant indicates being slightly cold, slightly warm and comfortable in the living room for the same/similar temperatures in winter and slightly warm and comfortable in the bedroom and living room in summer.

In case study 4, it can be seen that the occupant in winter indicates that the living room is slightly cold, slightly warm and comfortable. In the bedroom, they said they were slightly cold more often and comfortable once. Sometimes, the occupant indicated feeling uncomfortable in terms of temperature in the bedroom and the living room when they indicated feeling slightly cold and even when they indicated feeling comfortable. The temperatures recorded when the occupant started filling in the survey varied between 14.3ºC and 22.6ºC in the living room and bedroom. In summer, the occupant indicates that they are sometimes comfortable and sometimes slightly warm and hot in the living room and slightly warm and hot in the bedroom, with temperatures recorded between 26.2ºC and 28.3ºC in the bedroom and living room. It should also be noted that the occupant indicates being slightly cold and comfortable in the living room and bedroom for the same/similar temperatures in winter and slightly warm, hot and comfortable in the living room in summer.

Finally, in case study 5, it can be seen that in winter, the occupant indicates that the living room and bedroom are always comfortable, with temperatures recorded at the time the occupant started filling in the survey varying between 13.2ºC and 19.7ºC in the living room and bedroom. In the summer, the occupant indicated that they were always comfortable in the living room and mostly in the bedroom, although once they indicated that they were slightly warm. The temperatures recorded range from 23.7ºC to 27.6ºC in the bedroom and living room. It should also be noted that when the occupant says they are in the bedroom, they report the same/similar temperatures in the winter and slightly warm, warm and comfortable in the living room in the summer.

By analysing the recorded temperature and the perception of the occupants, it can be seen that in the case studies analysed, the occupants indicate two different perceptions of the same temperature; that is, sometimes, it is comfortable, and other times indicates, for example, slightly cool/hot. It also happens in other cases, indicating that they feel comfortable at a higher/lower temperature, and at an intermediate temperature, they indicate that they feel, for example, slightly cold or warm. It can also be seen that in case study 4, for the question "Do you feel uncomfortable in terms of the temperature felt?" sometimes "yes" and sometimes "no" are said for the same perception. Therefore, this relationship between measured temperature and occupant perception is challenging to study and understand. However, this was expected since the literature already indicates that people's perception is subjective as it is affected by different variables (mood, experiences, among others).

4.2.2 People's perception of the indoor environment (living room vs bedroom) and air temperature measurements considering the right now survey

When the perceptions obtained by the right-now survey are analysed between the bedroom and the living room, it can be seen that the perception of the thermal sensation felt in the living room and bedroom does not always coincide in all the case studies. This difference in responses occurs in the winter in case studies 1,2,3, and 4 and in the summer in case studies 2,3,4 and 5. Still, even when the recorded temperatures are analysed, there is no clear justification regarding the difference in temperature between the bedroom and the living room as to why these perceptions are different. Possible justifications could be that people's perceptions are influenced by their state of mind, their mood, their experiences, the way they have lived through the day and also the way they view their home. In other words, a person may have the intrinsic feeling that the bedroom is colder than the living room, or vice versa, and in fact, the temperature recorded does not show this.

4.2.3 People's perception of comfort and well-being in the indoor environment in the year's more extreme/cooler seasons

Analysing the perception of comfort in terms of the temperature felt in the interior environment, from the data collected, it is impossible to say clearly whether the houses under analysis provide greater comfort or discomfort in summer or winter. However, in case study 1, it can be seen that the occupant feels more discomfort in winter than in summer.

Figure6 – Graphical representation of air temperature measurements and sensation for case study 1 by compartment and season

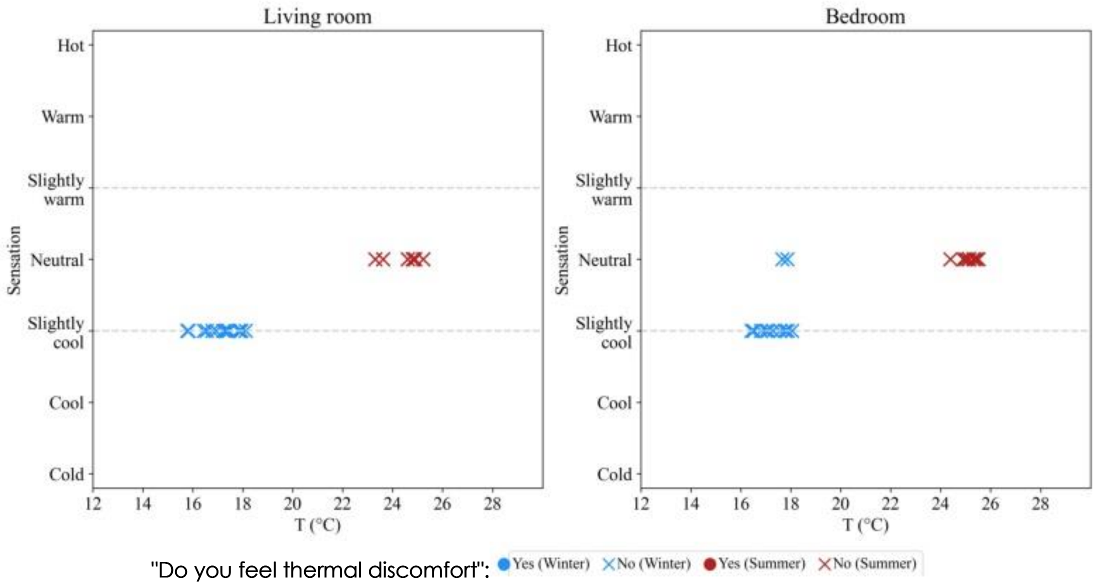


Figure7 – Graphical representation of air temperature measurements and sensation for case study 2 by compartment and season

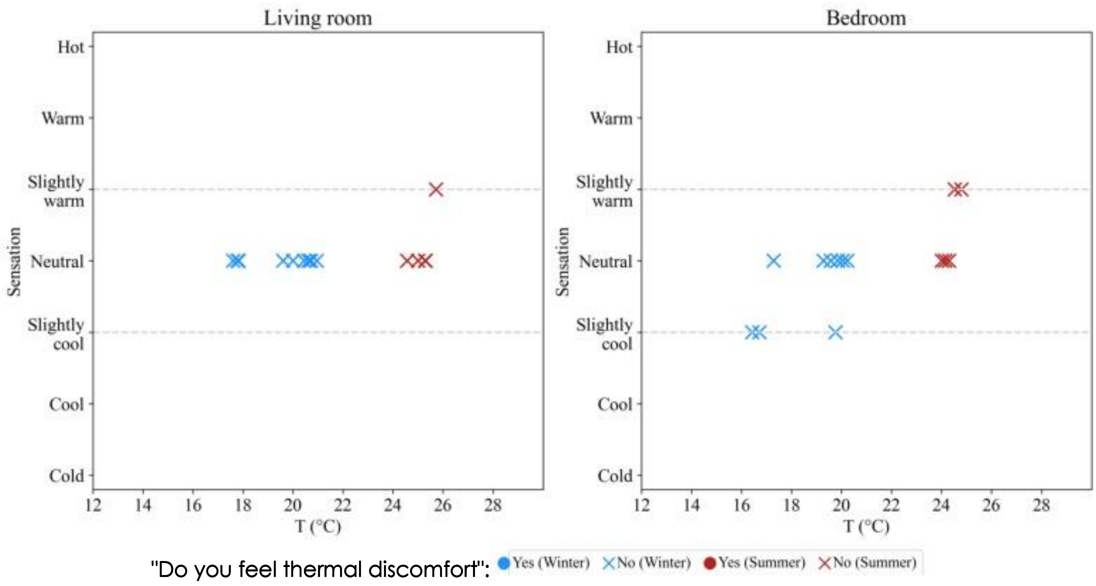


Figure8 – Graphical representation of air temperature measurements and sensation for case study 3 by compartment and season

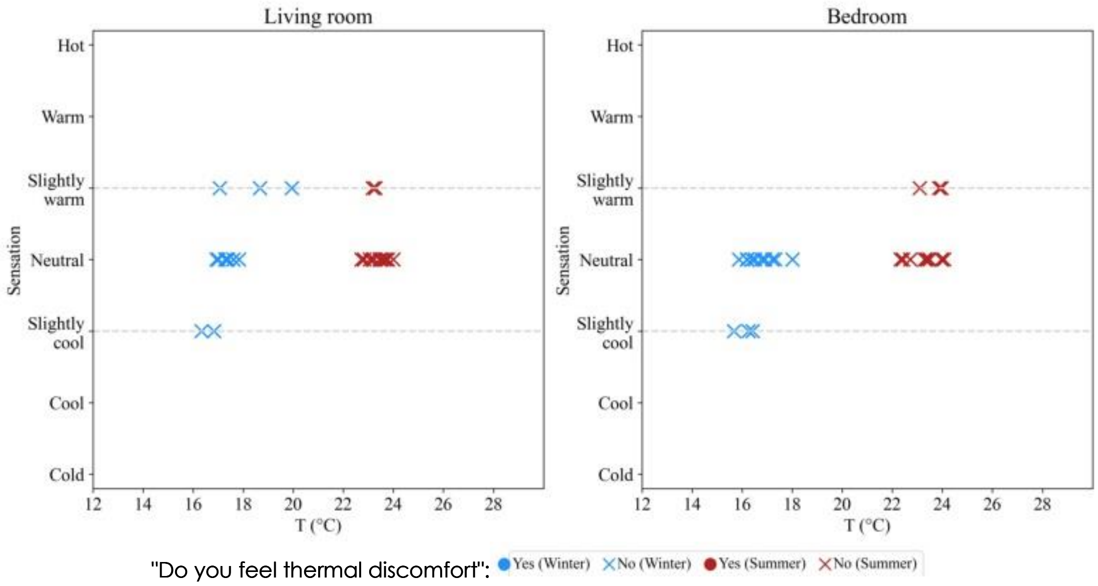


Figure9 – Graphical representation of air temperature measurements and sensation for case study 4 by compartment and season

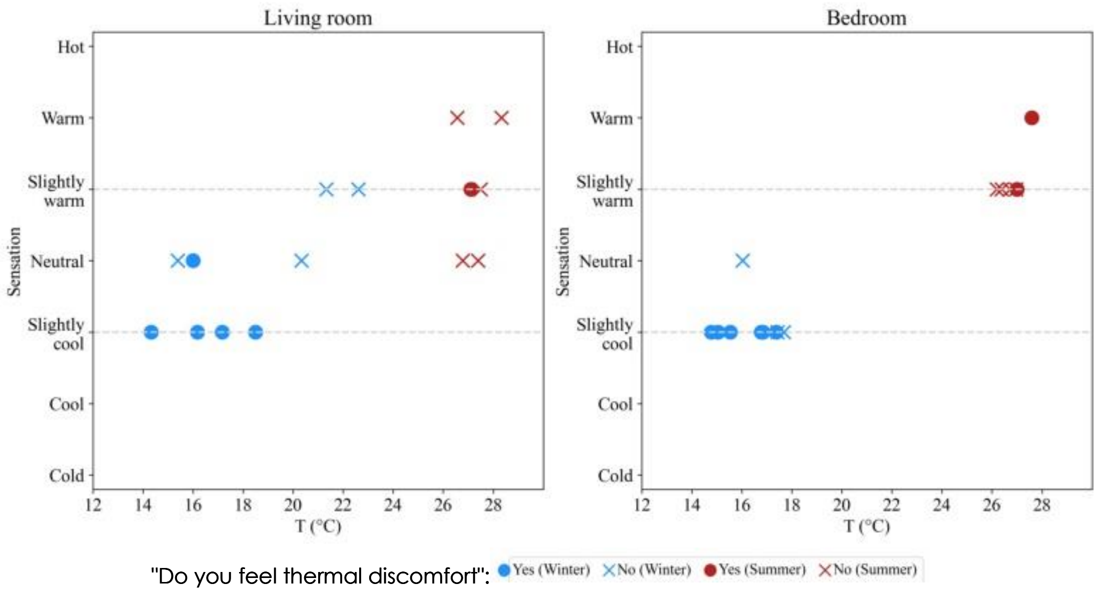
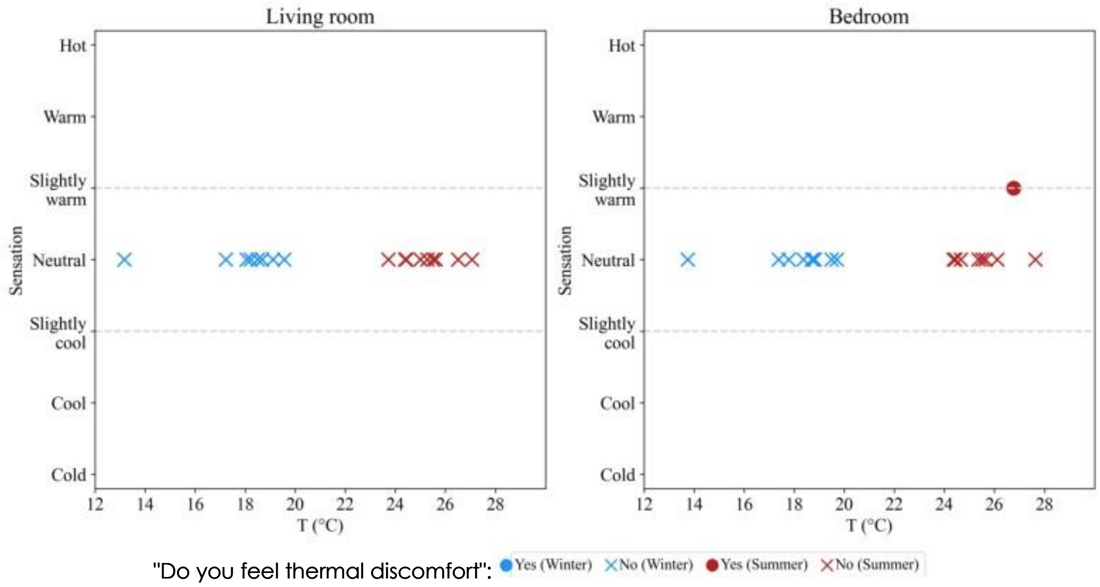


Figure10 – Graphical representation of air temperature measurements and sensation for case study 5 by compartment and season



Although we have case studies with different constructions and locations, it is impossible to say that better constructions bring greater comfort to a given person. For example, case study 5 presents, for the winter measurement period, a minimum temperature of 10.9°C in the bedroom and a maximum temperature of 27.9 °C in the summer (Table 3) and indicated that it always felt comfortable in the right now survey monitoring period, winter and in summer except one day in the summer in the bedroom. Also, in case study 1, being a more recent construction, the occupant indicates that it is always slightly cold in the winter in the living room and practically always in the bedroom, and this is the case study where the minimum temperature recorded in winter is the highest in the room, 16.3 °C (Table 3). It is known that the conditions of more recent constructions may be better, not allowing the house to reach such low minimum temperatures or such high maximum temperatures. Still, the perception of the person who lives in the house depends a lot on that specific person, their perception of your home, and what your demands and life experiences are.

5 CONCLUSIONS

Comfort and well-being inside buildings, particularly homes, are increasingly important for construction and renovation. According to the literature, temperature is one factor that most influences home comfort. Therefore, this study aimed to investigate how to assess home thermal comfort. Knowing that the methodology used involved measurements of the indoor environment and daily surveys for 14 consecutive days in summer and winter, some conclusions were reached in the case studies analysed:

- The measurement intervals that have the closest values, in general, are between 9 a.m. and 12 p.m. and the closest hour the occupants answered the survey, both in summer and winter. The fact that the "daily" time interval is generally further away from the others may be because it is a longer interval (24 hours) and may not reflect the use of HVAC equipment during the day.
- Temperature profile of the three measurement periods in the living room does not always correspond to that of the bedroom, both in summer and winter. This is more evident in some of the case studies. However, when comparing the temperature measurements in the living room and the main bedroom, there are no significant differences in mean temperature in these two rooms.
- Occupants indicate different perceptions of the same/similar measured temperature. It also happens that they feel comfortable at a higher/lower temperature. At an intermediate temperature, they indicate that they feel, for example, slightly cold, warm or other sensations.
- Therefore, the relationship between the measured temperature and occupant perception is difficult to study and understand because people's perception is subjective as it is affected by different variables (mood, experiences, among others).
- In winter, the average temperature of the living room and bedroom difference is 0.6°C in two cases, 0.5°C in another and less than 0.2°C in the others. In summer, this difference is 1°C in one case study, 0.5°C and 0.4°C in others and less than 0.2°C in the others. Therefore, measuring two of the most used house rooms for this study may not be justified since the temperature differences are not very significant.
- Occupant perception of the bedroom and the living room thermal sensation does not always coincide in all the case studies despite the recorded temperatures not being significantly different between the bedroom and the living room. Possible justifications could be that people's perceptions are influenced by their state of mind, their mood, their experiences, how they have lived through the day, and how they view their home.
- From the data collected, it is not possible to say clearly whether the houses under analysis provide greater comfort or discomfort to the occupants in summer or winter.
- Although we have case studies with different constructions and locations, it is impossible to say that better constructions bring greater comfort to a given person. It is known that conditions can be better by not allowing the home to reach such low minimum or high maximum temperatures. Still, the perception of the person who lives in the house depends a lot on that specific person and the perception they have of their home.

Although this study does not intend to be generalist, that is, it aims to analyse each house with the occupant who lives there to understand how they feel in their home, this study may present limitations in some conclusions due to the small number of study cases. For conclusions to be more solid, increasing the number of case studies would be necessary.

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APPENDIX

Table A – Methods for analysing the indoor environment

Survey/Interviews		Loggers/Sensors			Ref
Parameter	Type	Parameter	Location	Recorded period	
-	-	Air temperature	Living rooms and main bedrooms and outdoor	Every 5 minutes during almost 2 summer months	(JONES; GOODHEW; DE WILDE, 2016)
Thermal comfort	Questionário após o período de medição	Air temperature, average radiant temperature, relative humidity, air speed	Home (don't specify)	Summer and winter Every 1 minute during one hour	(MATIAS; SANTOS, 2013)
Thermal comfort	Surveys before, during and after the monitoring period	Temperature and relative humidity Wind speed and solar radiation	Roof-top weather station Living area Suite	Every 5 minutes during 14 months	(STOPPS; TOUCHIE, 2020)
Moisture and mould	Surveys and questionnaires	Air temperature, humidity, and CO_2 levels.	Main bedrooms	-	(GONZALEZ-CACERES; BOBADILLA; KARLSHØJ, 2019)
Thermal comfort	Face-to-face semi-structured interviews Questionnaire	Air temperature	Living rooms and in the main bedrooms	Every 10 minutes during an entire year.	(DARTEVELLE et al., 2021)
Emotional well-being Natural lighting	Adaptation of the Watson and Clark PANAS-X	-	-	-	(MORALES-BRAVO; NAVARRETE-HERNANDEZ, 2022)

Survey/Interviews		Loggers/Sensors			Ref
Parameter	Type	Parameter	Location	Recorded period	
	questionnaire				
Thermal Comfort	Long-term survey six times a day in the living rooms and twice in the bedroom 5 survey periods	Air temperature and relative humidity	Bedrooms and living rooms Closest meteorological station	During 4 years	(RIJAL; HUMPHREYS; NICOL, 2019)
Lighting: artificial light	Interviews: open-ended and photo album	Light exposure	Home	During the day and night over six consecutive weeks	(GERHARDSSON; LAIKE; JOHANSSON, 2020)