

Analysis and Design Optimization Strategy of Indoor Thermal Comfort for Different Thermal Experience Groups of Ethnic Minority Homestay-style Renewal Dwellings in Northern Guangxi

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Abstract: North Guangxi, as an international tourist destination, brings people from all over the world together. New research shows that people with different thermal experience backgrounds respond differently to thermal environments. In order to study the indoor thermal environment and thermal comfort in the transition season of minority homestay-style updated dwellings in northern Guangxi, we investigated and analyzed Longji homestay-style updated dwellings by means of questionnaires and field measurements. The results show that the indoor temperature in this area is slightly cold, except that the rooms affected by the western sun will be stuffy in the afternoon, and other rooms are generally slightly cold; The acceptability of the climate is generally high, the thermal environment satisfaction is over 95%, and the surveyed population's satisfaction with thermal comfort and meteorological factors has also reached 85%. Finally, we come to the conclusion that the ethnic minority homestays in northern Guangxi are updated. The interior of residential buildings is humid and the temperature is low. In order to optimize this problem, we have considered the optimization of architectural design such as moisture-proof heating, such as: floor heating system, integration with modern new functions, new technologies, and new materials to form a homestay-style updated residential house Moisture-proof design looking for new ideas.

Keywords: Residential buildings, Northern Guangxi, Thermal environment, Dry-column buildings, Indoor thermal comfort.

1. The Introduction

The report to the 19th National Congress of the Communist Party of China pointed out that the principal contradiction facing Chinese society has been transformed into that between unbalanced and inadequate development and the people's ever-growing needs for a better life. This shows that our country's society is gradually moving towards a well-off society, people's requirements for the quality of life are also constantly improving. With the development of science and technology, people's life is more and more convenient, without leaving home can know the world, can solve the needs of life. The comfort of indoor environment has been paid more and more attention, and residents have higher requirements for indoor thermal comfort. However, the traditional agricultural houses in Longsheng and other areas of northern Guangxi are relatively old, which cannot meet the needs of the living environment for tourists from all over the world.

In this respect, many scholars in our country are also discussing the topic of thermal comfort, which provides us with a lot of necessary data and research conclusions. Li Guangying [1] Through a continuous one-year survey of the subjects, it was found that the different thermal experience backgrounds of the subjects from different regions had an impact on their thermal comfort and adaptive behavior. At the same time, the statistical method was used to calculate that the subjects who live in Hainan for a long time and those who live in the central heating area for a long time have significant differences in thermal sensation, wet sensation and thermal resistance of clothing. The adaptive behavior adjustment methods of subjects in different regions are also affected by

the thermal experience of subjects., and there is a pattern .Gong Xinzhi et al.[2] analyzed the measured data and questionnaires by temperature frequency regression method, and showed that there were differences in the thermal sensation of residential buildings in different environments and residents of different ages and genders. According to the theory of dynamic thermal comfort and adaptation, Zheng Wenqian [3] conducted field research and climate chamber research in winter and summer for more than one year on non-heating and air-conditioned residential buildings in typical cities in Chongqing, Wuhan and Nanjing, which are hot in summer and cold in winter. It comprehensively reflects the indoor thermal environment of non-heating and air conditioning buildings in hot summer and cold winter areas, the characteristics of residents' thermal adaptive response, and the change rules of psychological and physiological thermal response of subjects in the climate chamber. Li Junge [4] made a detailed investigation of the indoor thermal environment conditions in hot summer and cold winter areas and the suitability measures for active adjustment of the thermal environment by combining measurement and questionnaire survey, and recorded the subjective responses of residents to thermal sensation with ASHRAE 7-level thermal sensation scale. By means of statistical analysis and investigation of the test results of statistical regression analysis, concluded that the thermal sensation in people in the real environment by the heat of the past experience, architectural features, indoor and outdoor climate, and many other factors, the influence of indoor thermal comfort temperature and outdoor climate significantly correlated, comfortable temperature changes with the change of outdoor temperature; Liu Jing [5] used the method of combining objective environmental parameter test and subjective

questionnaire survey to conduct field investigation, research and analysis on indoor and outdoor thermal environment and subjective thermal sensation of naturally ventilated buildings in hot summer and cold winter areas. Through further analysis of regression curves, it was found that under the prediction mode of PMV, the respondents' thermal sensation voting, differential critical temperature, thermoneutral temperature, acceptable temperature and the sensitivity degree of subjective thermal sensation to air temperature are different from the actual situation. Yang Wei [6] to take indoor and field test combined with questionnaire survey method, it is concluded that natural ventilation and air conditioning buildings in residents of neutral temperature and acceptable temperature range, through the analysis in different temperature range of subjects on the vote value of wind speed, and the relationship between the indoor air flow, found in indoor air flow rate has a great influence on the residents' comfort, and the higher the temperature, The higher the requirement of indoor air velocity.

This study explores the influence of people with different thermal experiences on the assessment of thermal comfort. Thermal experience refers to the fact that human body will form "memory" of the corresponding thermal environment in a certain thermal environment. When people enter another environment, the temperature and humidity, air velocity and so on are different from the familiar environment before. The experience in the previous thermal environment may affect the feelings of the subjects and their expectations of other environments, thus affecting their evaluation of thermal comfort.

In this paper, tourists and local residents of Longsheng tourist site in Guilin were selected as the research objects for three consecutive days to study the thermal comfort of people from different regions in Longsheng, Guilin, and to compare the adaptability differences of people from different regions in Longsheng residential houses in Guilin. Some suggestions are put forward to improve the thermal environment of new dwellings in North Guangxi in terms of enclosure structure performance, room opening orientation, middle courtyard and overhead structure design.

2. Research Methods

2.1. Scheme Design

2.1.1. Study Object Selection

Longsheng is located in Guilin City, Guangxi Zhuang Autonomous Region, belongs to the subtropical monsoon climate, summer high temperature and rainy, mild winter less

rain, the average annual temperature of 18.1 °C, with a beautiful ecological environment, unique natural landscape and strong ethnic customs and other characteristics. As a result, it attracts a large number of tourists from all over the world. Several ethnic minority villages in the scenic area still retain a relatively complete and traditional architectural culture, and in recent years, the homestay renewal of the houses as a more popular local building has attracted many tourists from all over the world.

2.1.2. Thermal Comfort Survey

First of all, the questionnaire survey was used to study the thermal comfort of the local homestay renewal dwelling, the survey subjects were tourists staying in Longji Scenic Area and local residents living in Longji Scenic Area, and a total of 156 valid questionnaires were collected, including the basic information of the respondents (including gender, age, place of birth, nature of work, living area, etc.), and the evaluation of the environmental comfort quality in the local residential building (including the overall satisfaction with the living thermal environment - five-level ruler, satisfaction with air quality - five-level ruler, Satisfaction with the lighting situation - the overall satisfaction of the indoor environment of the residence with the five-level scale and the comprehensive consideration of various factors - the five-level scale), the overall feeling of the local seasonal climate (the feeling and evaluation of the hot and cold in the room - the seven-level ruler, whether the indoor has and whether to use those equipment to adjust and control the living environment - multi-choice parallel ruler, the evaluation of the sense of blowing - the four-level ruler, the evaluation of the odor intensity in the room, the location of the illumination, the sound intensity in the room - - Five-level ruler) consists of three parts.

2.1.3. Indoor Thermal Environment Testing

The main parameters of this test are the temperature, relative humidity and wind speed in the room, and the AZ8829AZ humidity self-reporter and ST-730S hotline anemometer are used to continuously monitor and record the temperature and relative humidity. Instrument parameters are: temperature -40 ~ 85 °C, accuracy of 0.6 °C; Relative humidity 0~100%, accuracy of 3%.; The wind speed is 0m/s to 40m/s, and the accuracy is 0.03m/s. The two rooms of Longji Grain Farm House were monitored 24h at the same time, and the test time was October 4, 2021. The two rooms are 205 (2nd floor, south facing) and 405 (top floor, south facing) and are furnished in the same size and bed.

2.1.4. Measured Data Analysis

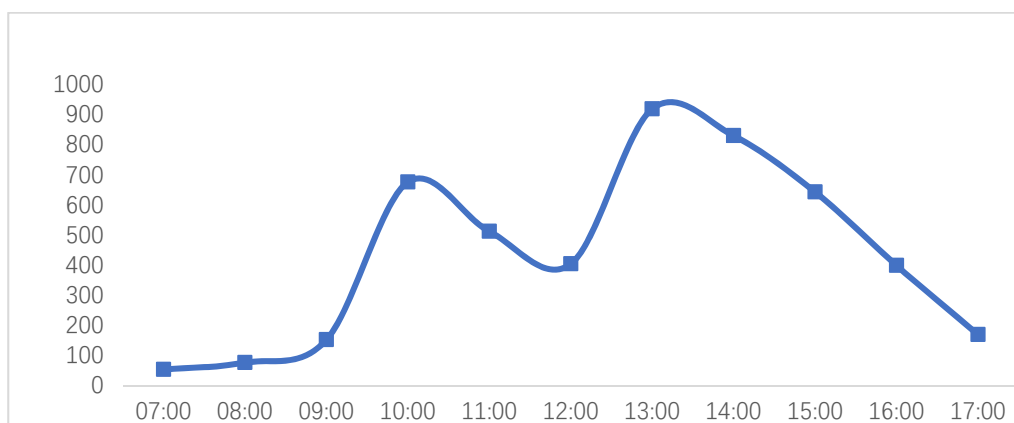


Figure 1. 10.04 Solar radiation intensity

Solar radiation intensity

The test time for solar radiation intensity is 7:00-18:00 on October 4, 2021, and the test results are shown in Figure 1. On the 3rd day when the weather was easy to measure, the

solar radiation intensity fluctuated more during the test period, with a maximum solar radiation intensity of 919 W/m² at 13:00.

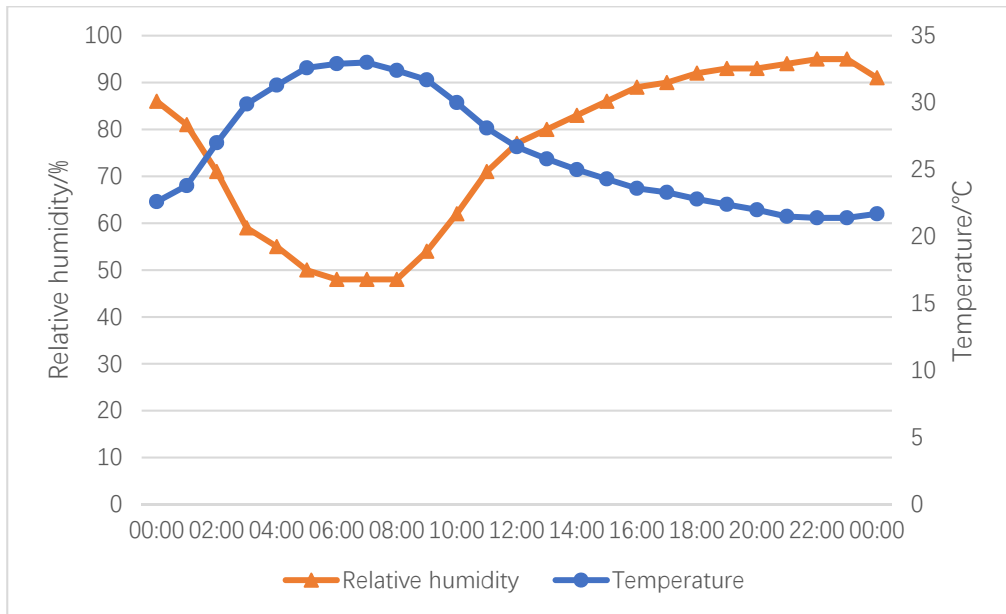


Figure 2. 10.04 Outdoor air temperature and humidity

The results of the outdoor air temperature and humidity test for a typical day in early October are shown in Figure 2. During the test period, the air temperature ranged from 21.4 to 33 °C, and the average temperature was 26.29 °C, of which the peak appeared at 7:00 and the valley appeared at 22:00;

the relative humidity range was 48 to 95%, and the average value was 75.64%, of which the peak appeared at 22:00 and the valley appeared at 7:00. Temperature is inversely proportional to the change in humidity.

Temperature and humidity of the living area

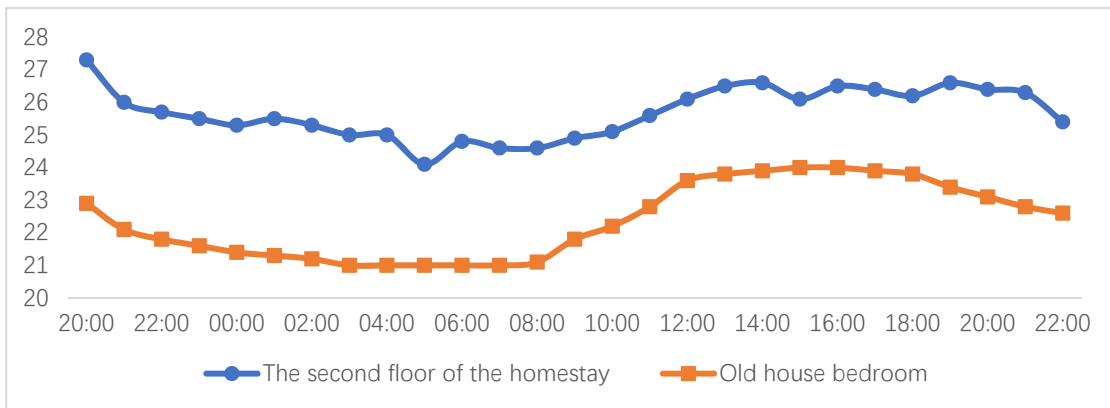


Figure 3. The air temperature of the living space of the old house and the homestay

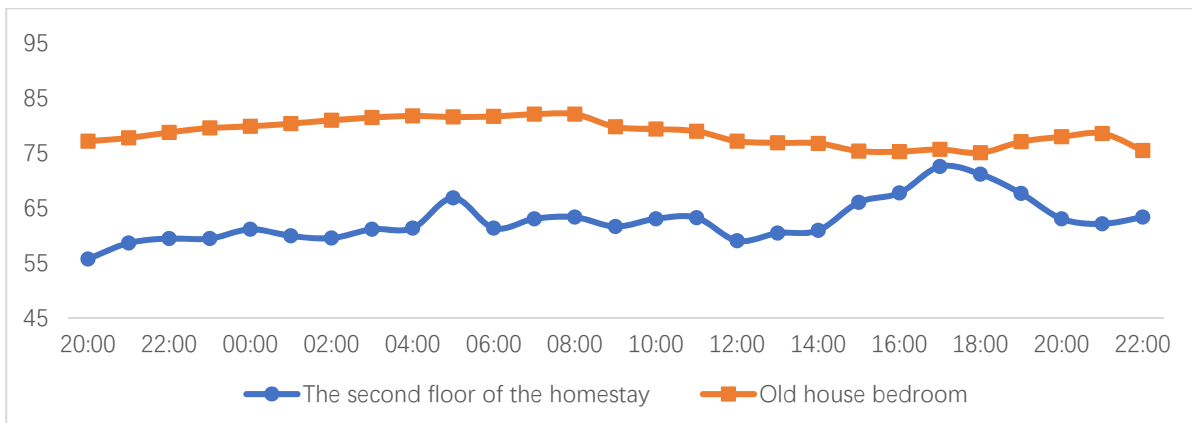


Figure 4. The living space of the old house and the homestay is relatively humid

As shown in Figure 3 and Figure 4, the data of the air temperature and relative humidity of the living space in the homestay and the old house from the evening of October 3 to October 4, the average temperature of the second-floor guest

room and the bedroom of the old house is 25.68 °C and 22.37 °C, respectively, and the average humidity is 62.76% and 78.71%, respectively.

Public space temperature and humidity

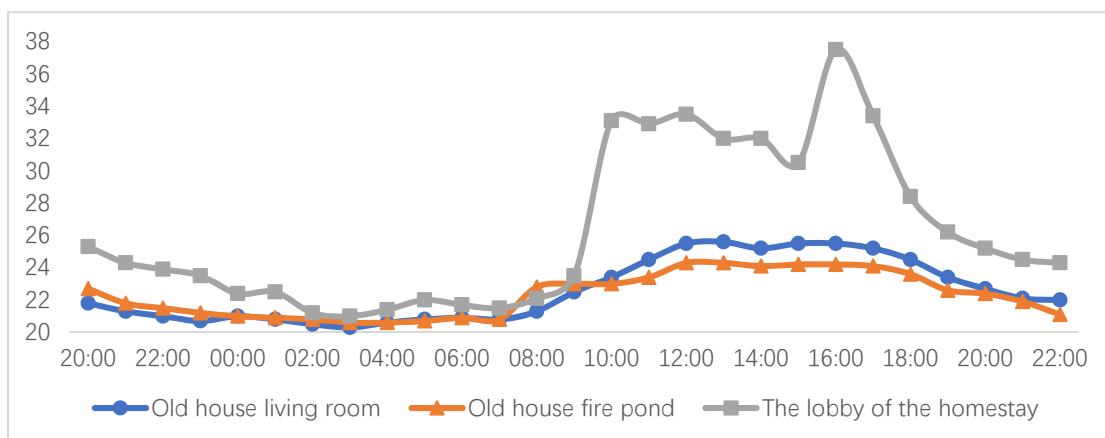


Figure 5. The air temperature of the public space of the old house and the homestay

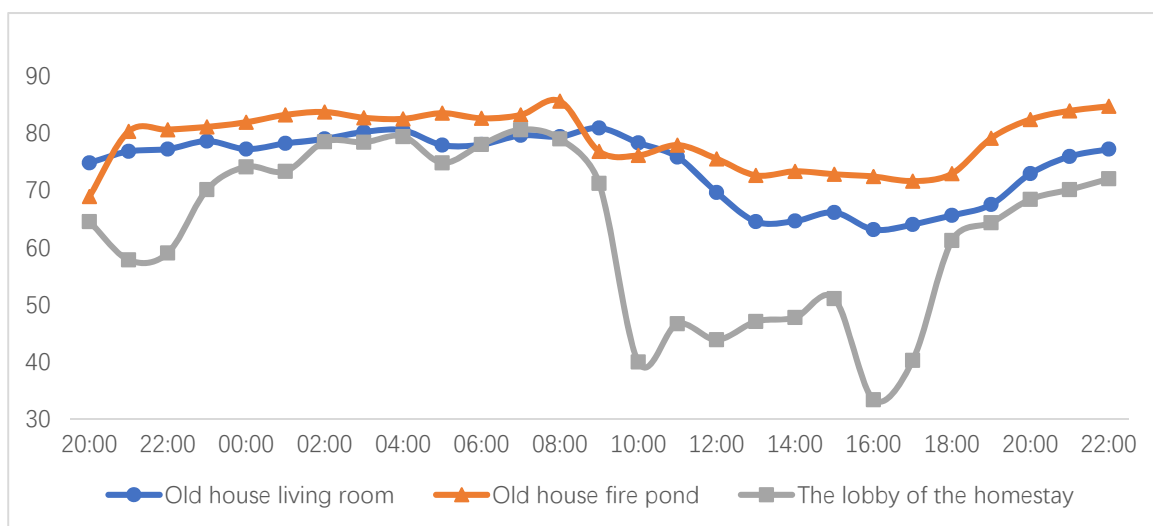


Figure 6. Relative humidity of the public space of the old house and the homestay

As shown in Figure 5 and Figure 6, the data of air temperature and relative humidity in the public space of the homestay and the old house from the evening of October 3 to October 4, the average temperature of the living room, fire pond and hall of the old house is 22.57 °C, 22.31 °C and 26.29 °C, and the average humidity is 74.30%, 79.05% and 63.21%, respectively.

2.1.5. Questionnaire design

The Questionnaire Was Conducted After the Thermal Environment Test, And the Specific Time Period Is from October 5 to 6, 2021

The questionnaire mainly consists of the basic information of the respondents (including gender, age, place of birth, nature of work, living area, etc.), the evaluation of the comfort quality of the environment in the local residential building (including the overall satisfaction with the living thermal environment - the five-level ruler, the satisfaction with the air quality - the five-level ruler, the satisfaction with the lighting situation - the five-level ruler and the overall satisfaction with the indoor environment of the residence by taking into account various factors - the five-level ruler), For the overall feeling of the local seasonal climate (the feeling and evaluation of the hot and cold in the room - the seven-level

ruler, whether and whether the equipment is used to adjust and control the living environment - choose the parallel ruler, the evaluation of the sense of blowing wind - the four-level ruler, the odor intensity in the room, the location of the illumination, the evaluation of the sound intensity in the room - the five-level ruler).

3. Thermal Comfort Survey Results and Analysis

3.1. Statistics on Basic Information of 3.1 Subjects

The sample of this questionnaire covers local residents of Longsheng and tourists from all over the country. Among them, the proportion of men and women is basically 1:1; the proportion of residents in the north and south is 3:1, of which residents in Guangdong and Guangxi account for about 90% of the total number; most of them are young tourists under the age of 30.

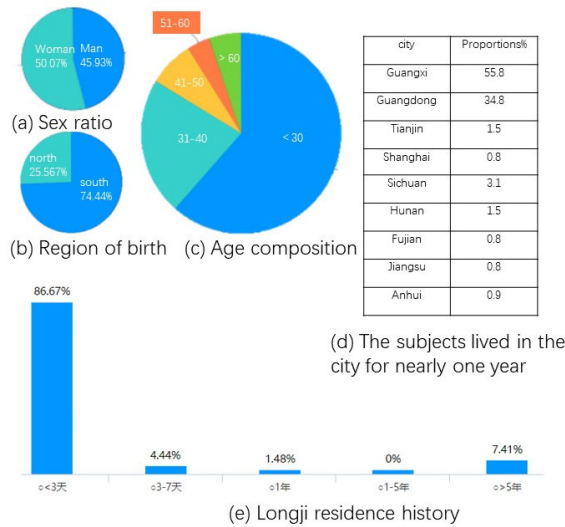


Figure 1 Basic information of the subject

Figure 7. Statistical chart of basic information of subjects

As shown in Figure 7, the subject's activity state before filling out the questionnaire is mainly occasional walking, the behavior accounted for the 63.16%, followed by standing (21.05%), sitting (10.53%), lying down (5.26%) static state, no strenuous exercise behavior. The statistical results of the thermal resistance of the whole set of clothing of the subjects

are shown in Figure 8. The clothing in the summer transition season in northern Guangxi is generally less. There are some individuals who adjust their own thermal sensation to the most comfortable state by adding clothing. Observed from the group, there is no difference in clothing among people with different thermal experiences.

Figure 8. Thermal resistance of the subject's entire clothing

Region	Complete clothing thermal resistance/clo				
	Maximum	Minimum	Average	Median value	Crowd value
South	0.7	0.3	0.39	0.4	0.3
North	0.5	0.3	0.40	0.4	0.3
Unknown	0.5	0.3	0.39	0.4	0.3

3.2. Hot Feeling and Satisfaction Voting

3.2.1. Thermal Sensation Data of People in The Same Area

In order to better understand the individual differences of the subjects' perception of the thermal environment, the distribution of the actual average thermal sensation voting (MTS) is classified and compared according to different

thermal experience groups, the length of residence of Longji, and the age. The thermal sensation voting values are hot, warm, Slightly warm, moderate, slightly cool, cool, and cold correspond to -3~3 respectively, and -1~1 is regarded as acceptable in the current environment, the results of the subjects' thermal sensation voting values are shown in the following figure.

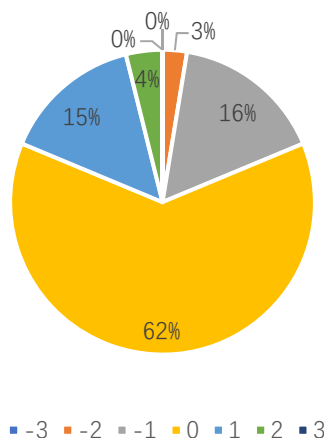


Figure 9. MTS distribution map of subjects

As shown in Figure 9, among all the subjects participating in the questionnaire survey, more than half (62%) of the

subjects felt that the current indoor thermal environment was moderate, and more than 90% (93%) of the subjects expressed acceptance of the current indoor thermal environment. This shows that most people adapt to the thermal environment

under the natural ventilation conditions in the transitional season in the mountainous area of northern Guangxi. Generally speaking, the indoor environment of Longji is more comfortable.

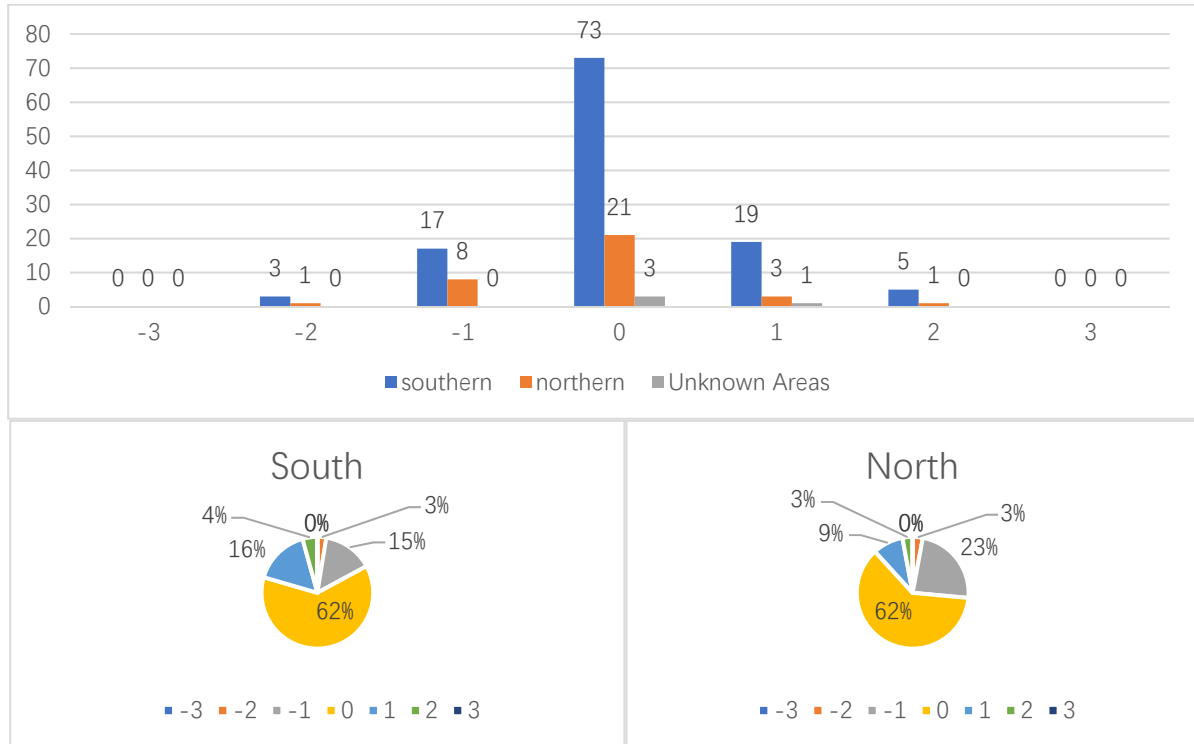


Figure 10. MTS distribution map of different thermal experience groups

As shown in Figure 10, the subjects were divided into two groups by thermal experience, mainly in the south and mainly in the north. Taking different heat experience groups as the observation object, there is little difference in heat feeling between the south and the north groups, the proportion of "moderate" feeling is the same, the proportion of "warm" and "cool" feeling is similar, but the proportion of heat experience groups in different regions is different in the feeling of "slightly warm" and "slightly cool": the proportion of the two feelings of the southern heat experience groups is similar, the

proportion of people experiencing "slightly warm" in the north is more than twice that of "slightly cool" (23% people think "slightly warm").

It can be inferred from this that the individual thermal sensation of the population with the northern thermal experience is more different in the thermal environment of Longji, and the northern population has a higher perception of heat, and its tolerance to heat is lower than that of the southern thermal experience population.

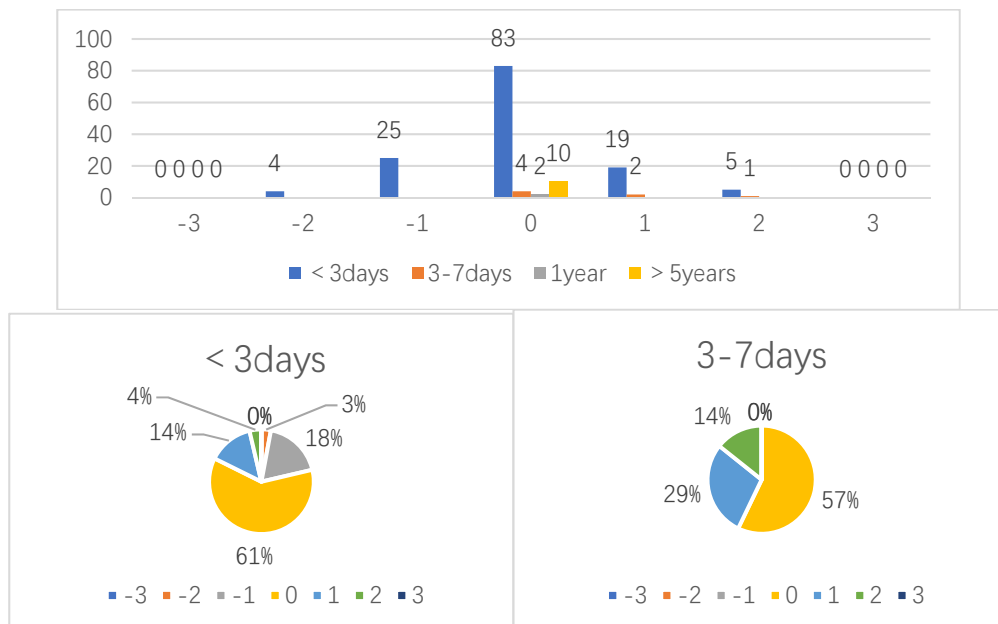


Figure 11. MTS distribution map of subjects with different dragon ridge sojourn duration

As shown in Figure 11, the subjects were divided into three types: short-term tourists (<3 days, 3-7 days), long-term resident foreigners with migratory birds (1-5 years), and local people in Longji Mountain (>5 years). Long-term residents and locals have "moderate" voting for hot feeling. Compared with residents living in Longji Mountain for a long time, short-term tourists have more diversified voting for hot feeling: tourists living in Longji for 3-7 days have 29% saying that the current thermal environment is "slightly warm" and

14% feeling is "warm"; Tourists with shorter living time (<3 days) are more sensitive to the thermal environment than other groups, its heat feels hot ("slightly warm" 14%, "warm" 4%) and cold ("slightly cool" 18%, "cool" 3%).

It is inferred that the thermal environment sensitivity is affected by the length of time of living in the local area. As the human body lives in Longji longer, the human thermal environment sensitivity decreases.

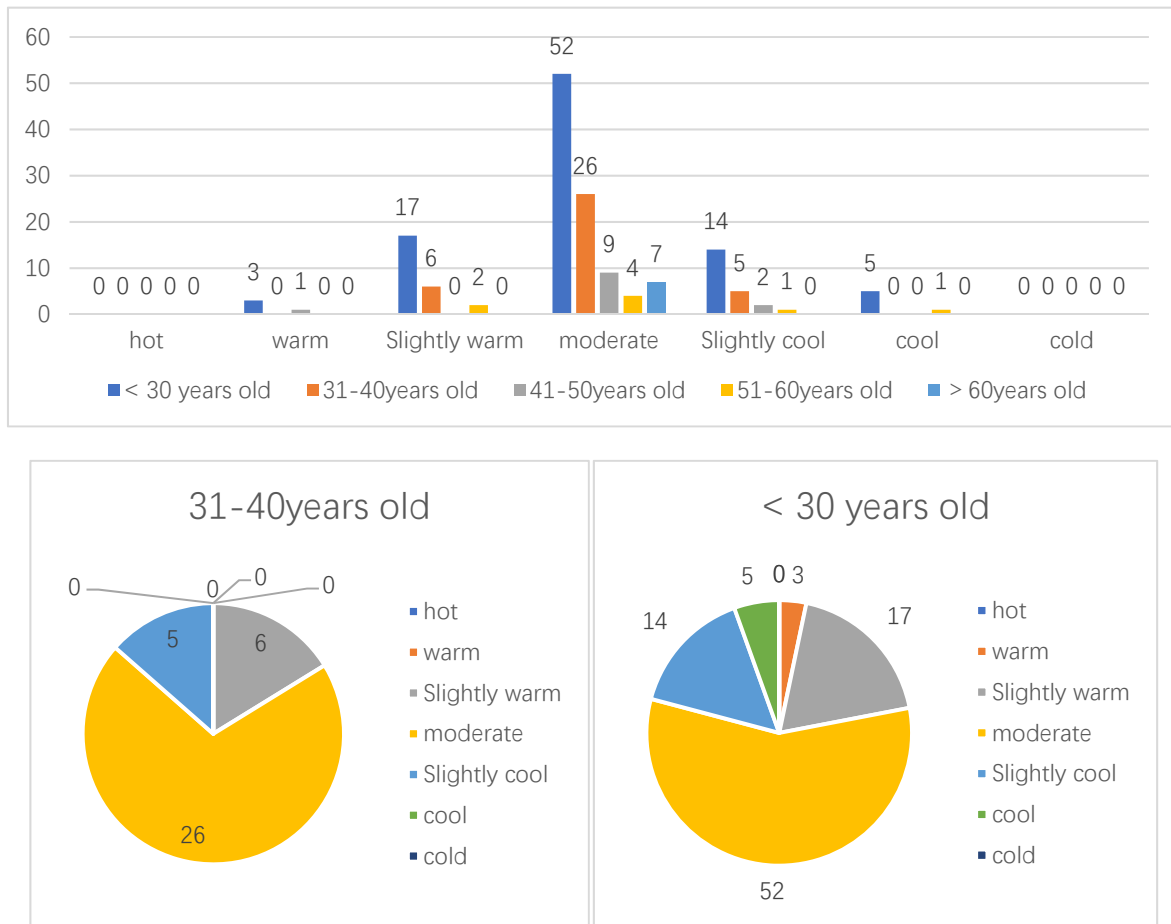


Figure 12. Distribution map of indoor cold and heat sensation MTS of subjects of different ages

As shown in Figure 12, this survey divided the subjects into adolescents (<30 years old), middle-aged (31-60 years old), and elderly (>60 years old) by age. From the analysis of the content of the chart, the subjects in the old age are all moderate, the middle age has three different feelings (moderate, slightly cool, slightly warm), and the youth has five different feelings (moderate, slightly cool, slightly warm, Cool, warm). But on the whole, most of the subjects felt suitable for the climate environment in Longji area.

It is inferred that thermal environmental sensitivity is affected by human age. With the growth of people's age, the sensitivity of human thermal environment gradually decreases.

3.2.2. Thermal Environment Satisfaction Data for People with Different Thermal Experiences

The distribution of subject satisfaction voting is shown in Fig.

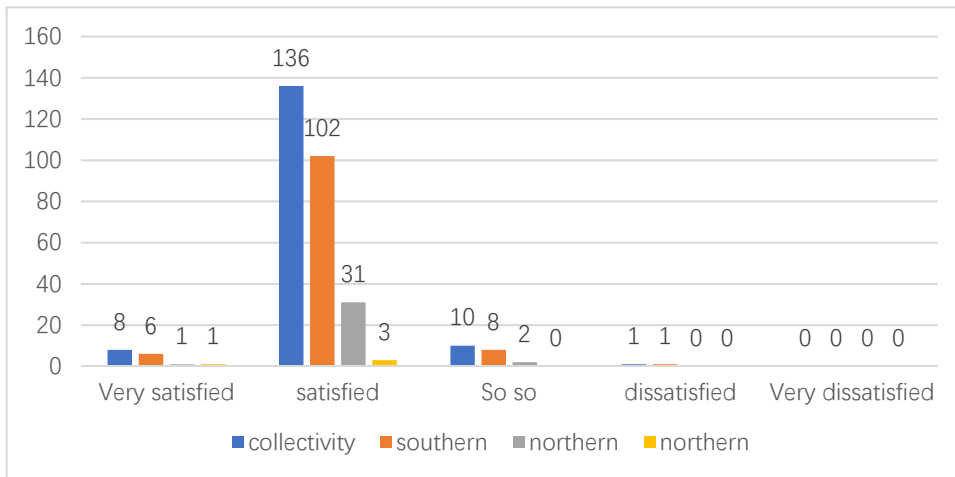


Figure 13. Voting distribution of thermal environment satisfaction among people with different thermal experiences

As shown in Figure 13, the maximum number of votes for thermal environment satisfaction among people with different thermal experiences is "satisfied" and the minimum number of votes is "very dissatisfied". There is a big difference in thermal environment satisfaction among people with different thermal experiences. There are 6 people who are "very satisfied" with the thermal environment satisfaction of the group with the southern thermal experience, and 8 people who are "very satisfied" with the thermal environment satisfaction of the group with the northern thermal experience,

Generally speaking, there are differences in the thermal environment satisfaction of people with different thermal experiences, indicating that different thermal experiences have an impact on human thermal comfort; the indoor thermal

environment satisfaction of Longji people with different thermal experiences can reach 90%, and the dissatisfaction is less than 1%. It is inferred that although thermal experience has an impact on human thermal comfort, it is not the main influencing factor.

3.3. Change Data of Thermal Comfort, Meteorological Factor Satisfaction and Thermal Expectation

3.3.1. The Voting Results of Thermal Comfort and Satisfaction of Various Meteorological Factors Are Shown in The Graph

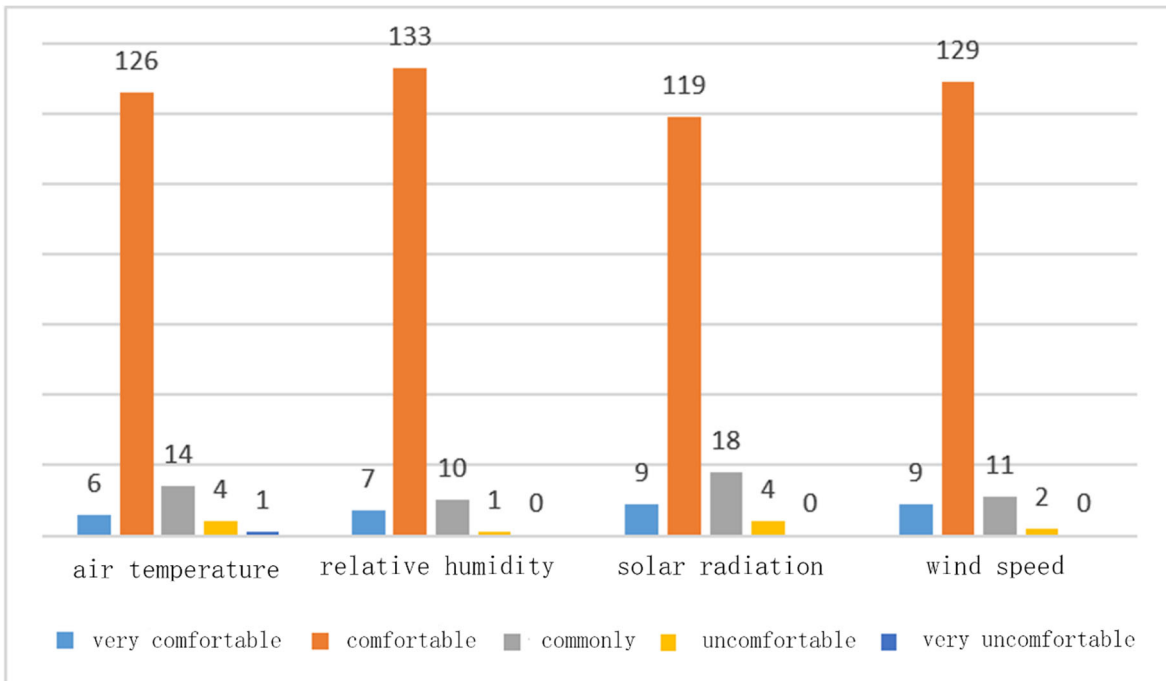


Figure 14. Overall distribution of thermal comfort satisfaction of subjects

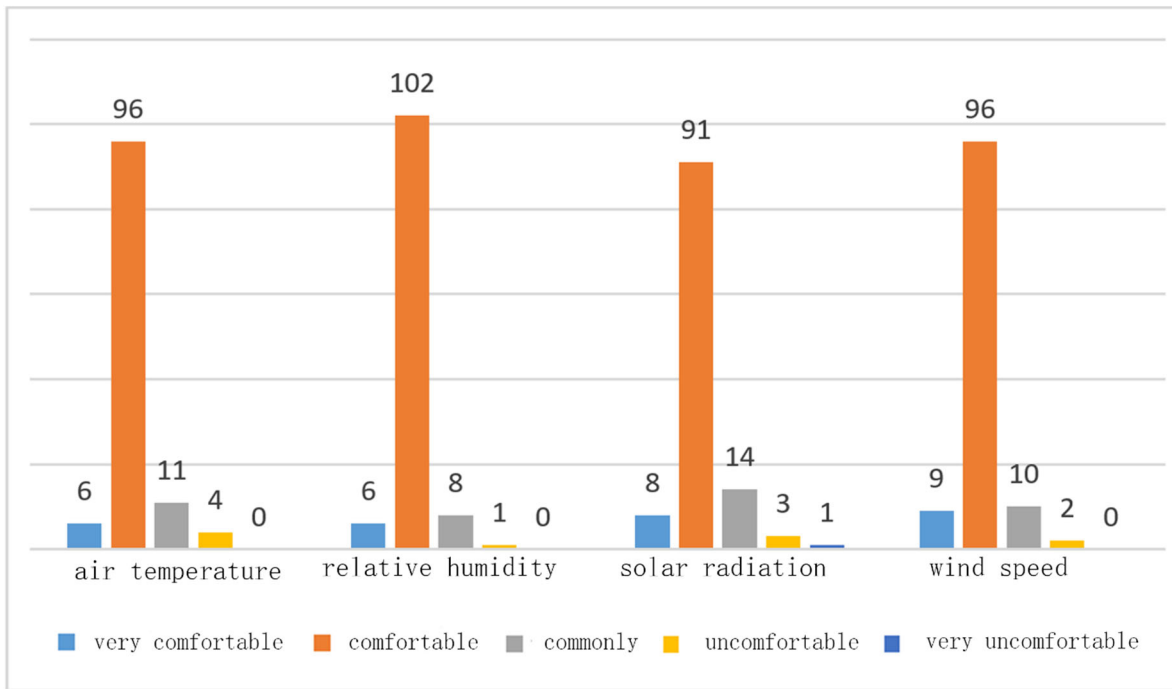


Figure 15. Distribution chart of thermal comfort satisfaction of people who mainly have thermal experience in southern China.

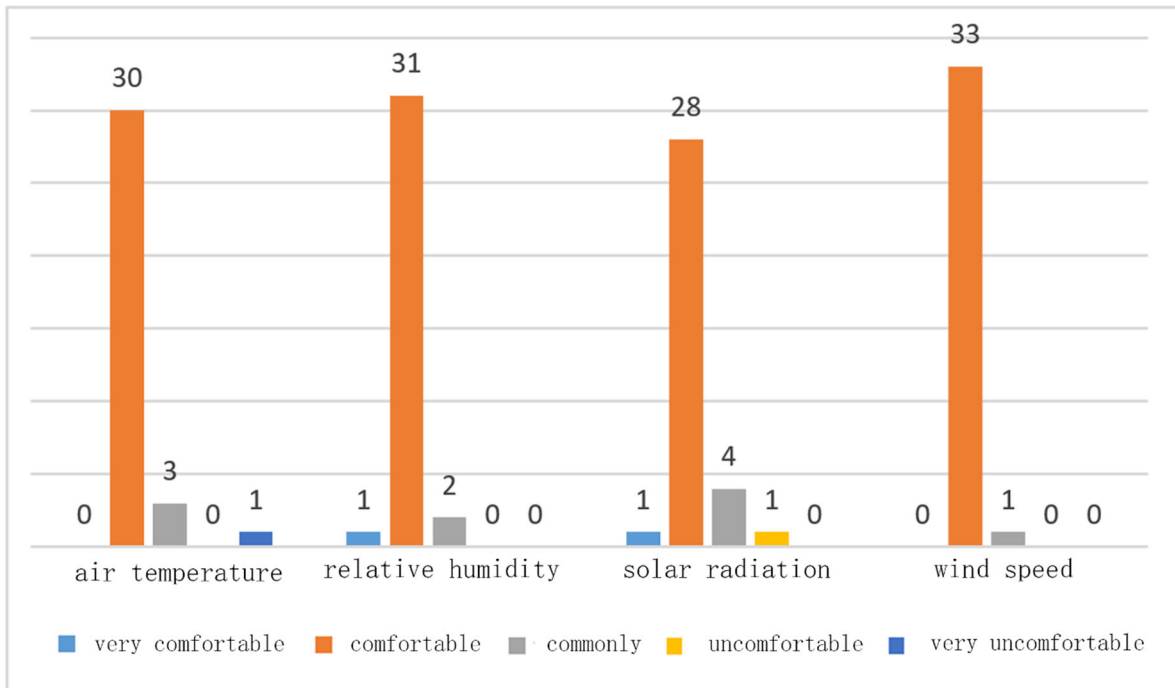


Figure 16. Distribution chart of thermal comfort satisfaction of people who mainly have hot experiences in the north.

Among all the subjects, the thermal comfort rating is "comfortable" at most, followed by "very comfortable". As shown in Graphs 14, 15, and 16, the average satisfaction of solar radiation is the lowest in the indoor thermal environment of residential houses (homestays) in northern Guangxi during the transition season in summer. The air temperature of the people with thermal experience in the south is the highest, followed by solar radiation, and other meteorological factors have dissatisfaction voting. The most unsatisfied votes of people with heat experience in the north are air temperature, solar radiation and other meteorological factors. It can be

inferred that people have the highest demand for solar radiation, followed by air temperature.

3.3.2. Analysis of Thermal Expectation Change Data of Meteorological Factors

The thermal expectations of subjects' air temperature, relative humidity, solar radiation and wind speed are shown in Graph 17. In the indoor thermal environment of Longji Residence (B&B), most subjects' expectations of air temperature, relative humidity and solar radiation are constant.

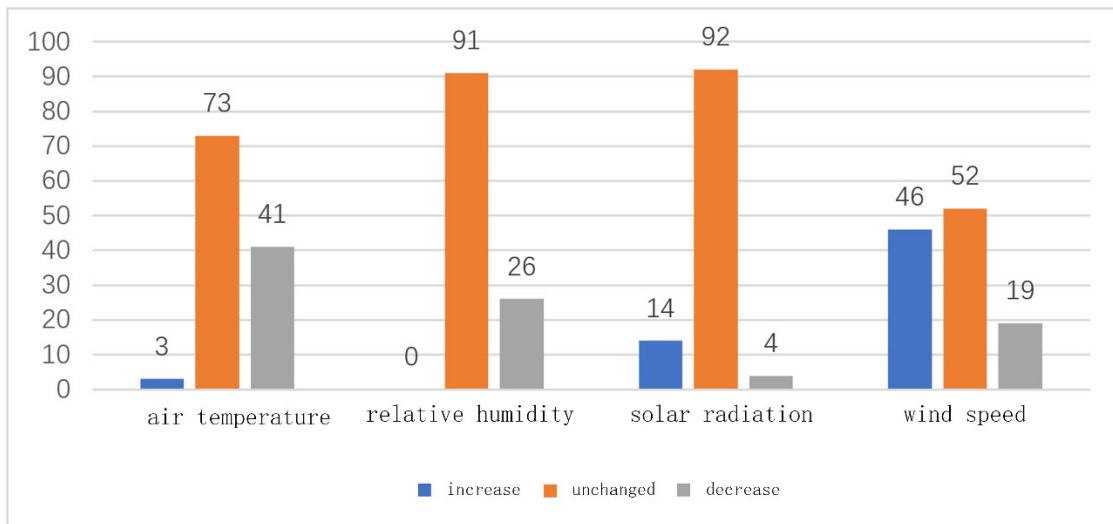


Figure 17. Expected value distribution of meteorological factors among people with heat experience in southern China

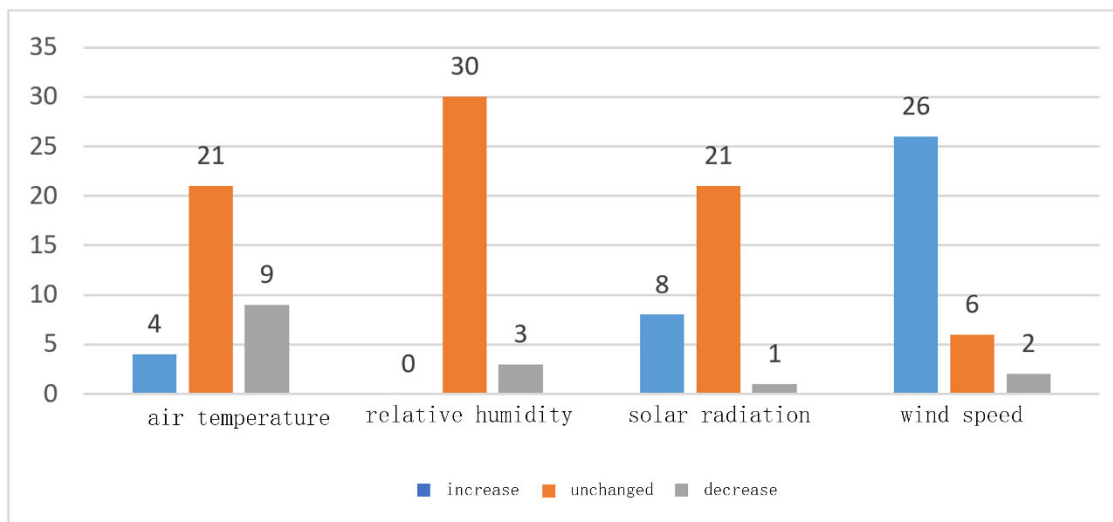


Figure 18. Expected value distribution of meteorological factors in people with heat experience in northern China

According to the table in Graph. 18, on the whole, most subjects have no expectation of changing the air temperature, and a small number of subjects have a thermal expectation of reducing the air temperature, accounting for about 34%. The air temperature of Dragon Ridge is on the high side in summer and autumn in October, which hinders the heat dissipation of human body and affects the thermal comfort of human body to some extent.

No matter whether the thermal experience is in the south or the north, the subjects have no expectation of increasing the relative humidity. More than 20% of the subjects with thermal experience in the south have expectation of decreasing the relative humidity, while 10% of the subjects with thermal experience in the north have expectation of decreasing the relative humidity. The indoor space of Longji Residence (B&B) has high relative humidity, which has a certain adverse effect on human thermal comfort.

There are group differences in indoor wind speed and thermal expectations among people with different thermal

experiences. The indoor wind speed and heat expectation vote of people with heat experience in the south is unchanged at most, accounting for 44.4%, followed by the increase, accounting for 39.3%; In the northern part of China, the expectation of indoor wind speed is increased at most, accounting for 76.5%, followed by unchanged, accounting for 17.6%. The southeast wind and breeze prevailed on the day of investigation. As can be seen from the following graph 19, 76.4% of the dwellings of thermal experience groups in the south face east and south, and 58.2% of the dwellings of thermal experience groups in the north face east and south. The window orientation of the building affects the indoor wind gain effect. The percentage of windows facing east and south in the residence of people with heat experience in the south is 18% higher than that in the residence of people with heat experience in the north, and the expected change intention of indoor wind speed is obviously lower than that of people with heat experience in the north.

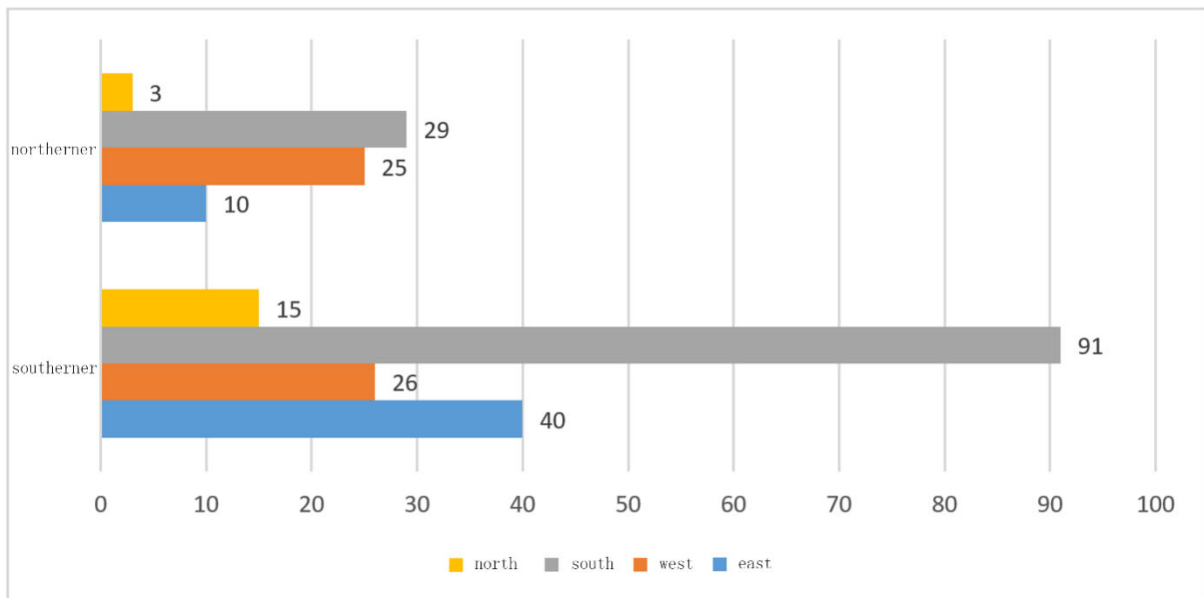


Figure 19. Window orientation of residence of people with different heat experiences

3.4. Subjective Ranking Distribution of Influencing Factors of Thermal Comfort

Subjective ranking of thermal factors is shown in Graph 20. The most important meteorological factor is air temperature,

the second is relative humidity, the third is wind speed, and the second is solar radiation. It can be seen from Graph 7 that the air temperature and relative humidity have great influence on the thermal comfort of the indoor thermal environment of Longji.

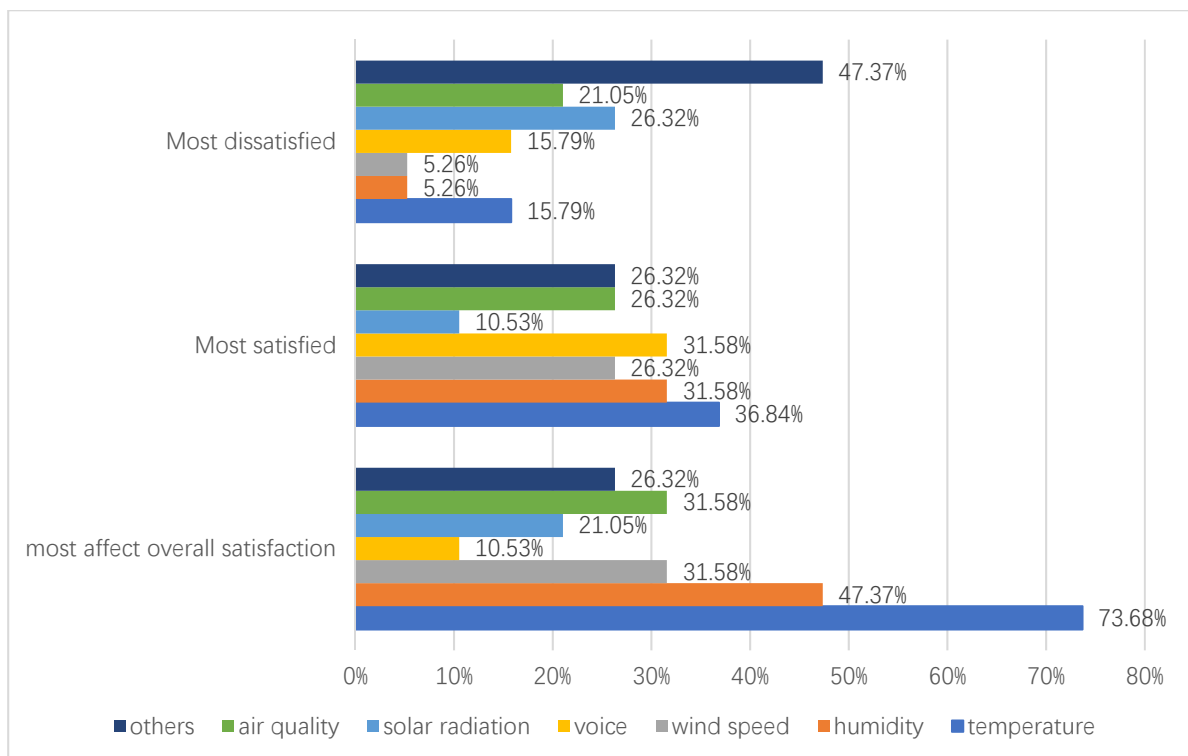


Figure 20. Subjective ranking voting of influencing factors of thermal comfort

3.5. Indoor Thermal Comfort Adjustment Improves Voting Distribution of Behavior

The voting situation of the subjects' behavior of equipment adjustment and control based on their optimal indoor thermal comfort is shown in Graph 21 below. According to the statistics, most subjects prefer the low temperature environment, and when the indoor air temperature is within

the acceptable range, they will still turn on the refrigeration equipment such as air conditioner to reduce the indoor air temperature. The subjects with southern heat experience are more inclined to open windows for natural ventilation, and the subjects with northern heat experience are 11% less inclined to indoor natural ventilation than those with southern heat experience, so they need mechanical ventilation.

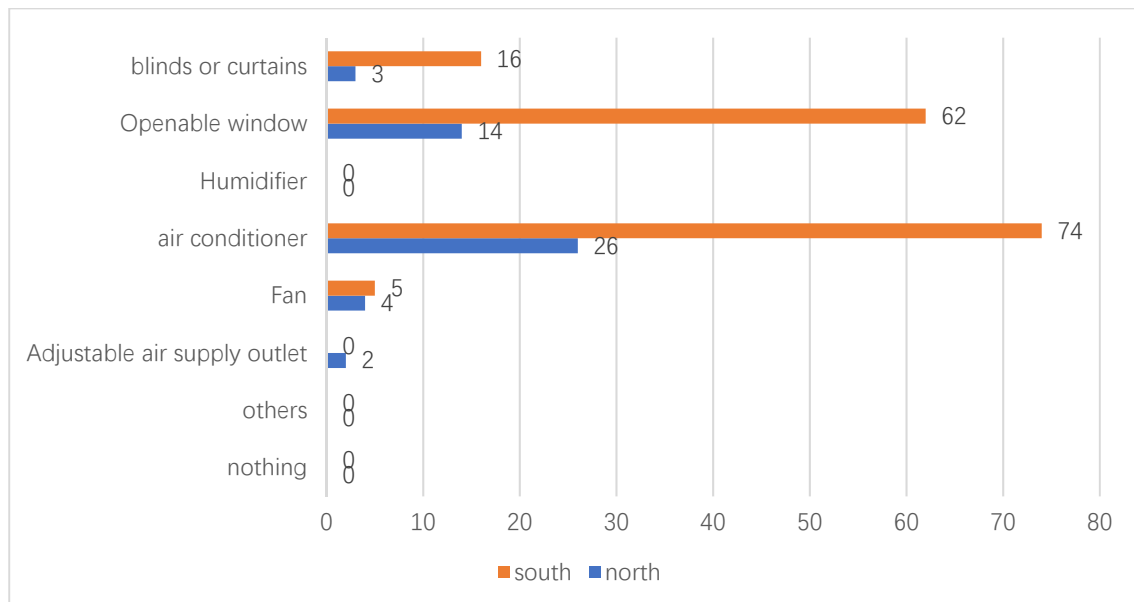


Figure 21. Voting distribution of indoor thermal comfort regulation improvement behavior

4. Conclusion

1. In the evaluation of indoor thermal comfort of Longji minority dwellings (homestays), most of them have good evaluations. People with heat experience in the south have higher sensitivity to the thermal environment, while people with heat experience in the north have worse heat resistance. Therefore, similar to Guilin, where the summer temperature is hot in summer and cold in winter, building cooling measures should be taken, and good energy-saving materials should be a good choice to isolate the external high temperature and lower the indoor temperature.

2. Among the four meteorological factors, subjects' average satisfaction with solar radiation is the lowest, but the expected change of meteorological factors is the most expected change of wind speed, and solar radiation is the least important meteorological factor in Longji indoor thermal environment. Optimizing the indoor thermal environment in northern Guangxi can start with the expected direction of meteorological factors.

3. The indoor relative humidity of Longji is relatively high. Although the average satisfaction of relative humidity is relatively high, the people have a strong desire to reduce the indoor relative humidity, especially the people who have experienced heat in the north. Therefore, the damp-proof design can be carried out for the homestay-style renewed dwellings through the integration of new technologies and new materials.

4. Building orientation affects the wind speed of indoor thermal environment in Longji. Longji belongs to the area with hot summer and cold winter, with long summer and short

winter. Southeast wind and south wind prevail in summer, so it is advisable to open windows to the south of the building.

5. For Longji minority dwellings (homestays), dry-column buildings are adopted, which have no air-conditioning equipment and can be called free-running buildings. To some extent, it has a very objective reference value for the study of human physiological regulation, psychological expectation and adaptive means.

References

- [1] Li Guangying. Research on indoor thermal comfort of people in different areas under non-air-conditioned environment [D]. Hainan University, 2018.
- [2] Gong Zhi, Zhao Wei, Jia Chenyang. Field study on indoor thermal environment and thermal comfort of multi-storey residential buildings in Guilin karst area in summer [J]. Journal of Wuhan University of Technology, 2020,42(12):34-40.
- [3] Zheng Wenqian. Research on human thermal adaptability of non-heating and air-conditioning buildings in hot summer and cold winter areas [D]. Chongqing University, 2011.
- [4] Li Junge. Research on climate adaptation model of human thermal comfort in hot summer and cold winter area [D]. Xi'an University of Architecture and Technology, 2006.
- [5] Liu Jing. Study on indoor thermal environment and human thermal comfort of naturally ventilated buildings in hot summer and cold winter areas [D]. Chongqing University, 2007.
- [6] Yang Wei. Research on the thermal comfort and adaptability of residential buildings in hot summer and cold winter areas [D]. Hunan University, 2007.