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Dissatisfaction expressed by occupants with winter indoor thermal environment in the non-district heating zone based on the social listening method

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Abstract: With the development of the social economy, people in the non-district heating zone have growing demands to deal with the harsh winter indoor environments and yearn for a comfortable indoor environment in the winter. Relevant studies on heating demand and behavior are based on questionnaire surveys whose options are subjectively made by researchers. That would lead to biased results for occupants who can only show complaints following the researcher's thinking. Apart from that, the options that researchers designed were also not abundant enough. The social listening method is applied in this study that reviews relevant discussions on heating issues based on the community social questions and answers. The method collects 21 653 pieces of data in the form of answers and comments expressed spontaneously by different users. It also focuses on the 3.19% dissatisfaction within the indoor environment of the five categories and found that complaints during winter are much more trivial than researchers had thought before. At the same time, online users tend to describe equipment service time as actions-activated. That will provide a reference for designing questions and options to the questionnaire in related research supplementing the traditional passive questionnaire survey.

Keywords: heating; non-district heating zone; social listening; indoor thermal environment; questionnaire

运用社会化聆听方法的非集中供暖区住户对冬季室内热环境不满的分析

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摘 要:随着社会经济的发展,居住在非集中供暖区的居民对改善严酷冬季室内热环境的需求越发高涨,希望能在冬季拥有舒适的室内环境。有关于采暖需求和采暖行为的相关文献大多使用问卷调研进行研究,而问卷中的问题和选项又多是研究者主观制定,在这种情况下,居民只能顺着研究者的思路表达他们的不满,这将导致调研结果产生偏差;此外,研究者设计的问卷选项在丰度上也有欠缺。基于社会化聆听的方法,回顾了网络问答社区上有关供暖的讨论,收集了 21 653 条网络

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用户自发表达的有关供暖的回答和评论，着重研究了其中3.19%的5项关于室内热环境营造的不满。研究结果表明，相比传统问卷调研，网络用户有关冬季室内热环境的抱怨类型更加丰富、内容更加细碎；此外，网络用户更倾向于使用特定动作描述采暖设备的开启，这将对后续相关研究中问卷调研问题和选项的设置提供参考，成为传统被动式问卷调研的补充。

关键词：采暖；非集中供暖区；社会化聆听；室内热环境；问卷调研

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1 Introduction

China uses the Qinling to Huai River as a boundary that divides the country into a district heating zone in the north and a non-district heating zone in the south. Under this policy, different climate zones in China present different characteristics in winter indoor temperature conditions. Some literature has summarized the winter indoor temperature conditions in different climate zones[1-2]. It has been shown that the severe cold within the cold region that have district heating exhibit high indoor temperatures of 19-24 ℃, which maintain relatively mild indoor environments. While the hot summer and cold winter regions without district heating have relatively harsh indoor temperature conditions of 8-14℃, under this circumstance, people who live in the hot summer and cold winter regions have heating demands to possess a comfortable winter indoor life. The demands have multiplied rapidly in recent years. The topics of heating in the non-district zone in China have been read more than 480 million times and have over 320 000 pieces of discussion on Weibo's social platform, and the answers under the topic of "heating in South China" have reached more than 4 000 with countless comments.

In addition to the heating policies, the buildings' thermal performance and outdoor climate conditions in each of China's climate zones are distinct from each other. Even if the same equipment and systems are used for heating, the effects can not be compared equally. Moreover, due to related reasons such as energy conservation and emission reduction plans, hot summer and cold winter areas are more suitable for distributed heating[3]. Besides, occupants in this area have unique winter heating devices and heating behavior characteristics.

The current indoor situations, heating demands, heating devices, clothing insulation, equipment service time, triggering temperature, energy consumption, dissatisfactions, and other aspects of the non-district heating zones have been studied by related literature[4-9]. Socio-demographic factors that affect habits of heating[6, 10-11] has been discussed in detail. A literature review has been done by searching the keywords "heating dissatisfaction" and "winter thermal discomfort" through the Web of Science[4, 7, 12-28]. Most of the literature was researched using questionnaires, while some were done by interviewing[20, 26]. Temperature and humidity preference can be easily thought of as dissatisfaction about the indoor thermal environment and are widely evaluated by literature. Thermal sensation vote, thermal comfort vote, and the thermal preference vote are standard measurement metrics used during experiments. Most of the literature shows that the temperature is too low during winter for occupants in China's non-district heating zones. Moreover, local thermal discomfort is another aspect studied by various researchers[12, 28]. According to some researchers, heating demands for the lower body including the feet are eager. Some physical discomfort[20-21, 23-24] can be caused by thermal discomfort such as eye dryness, dizziness, and sore throat. Some equipment may have functional problems that occupants may complain

about[12, 17-18, 20, 26], and all of those covered complaints about the slow response of the heating system. Another aspect occupants are not satisfied with is the air-conditioner's uneven temperature distribution[12, 17, 28]. Furthermore, extensive research also collected data on adaptive behaviors[15-20, 22-23, 25-27] and equipment using habits [7, 13, 26] such as service time and set-point using questionnaires. Adaptive behaviors can be seen as actions that happened after the thermal discomfort appeared. The equipment's service time reflects urgent demand on a time scale; when the demands arise, dissatisfactions emerge.

A questionnaire survey is a standard research method to analyze residents' demands and behaviors in the studies mentioned above. Mora and Simone[29] have summarized the relevant characteristics of questionnaires such as sample size, sample structure, collection method, and data processing. The preparation and management of a questionnaire are very complicated and need a specific aim and require a trained researchers' experience and competence. Questions and options need to be carefully formulated if multiple-choice questions are to be used in questionnaires. As for questionnaire that investigates thermal environment demand in winter, the options are often fixed under questions like local thermal discomfort, adaptive behaviors, thermal environment evaluation, or as a blank to fill in[12, 14, 16-17, 19, 22, 24-25]. When researchers design questions and options for the questionnaire, they may contain bias from leading questions[30] since they have little contact with the subjects, leading to a misunderstanding of some of the questions and options[31]. That is the disadvantage when the questions are answered with alternations. Suppose the questions are answered by filling in the blanks like dissatisfactions about the indoor environment in winter or heating devices, in that case many subjects will feel it is inconvenient to answer. The answers which were obtained through the questionnaire on the internet may be shorter than those obtained through paper questionnaires or face-to-face interviews and may lead to information loss to some extent[32]. Another possibility is that people may provide wrong information through questionnaires on the internet [29]. Researchers cannot check each person's option, whether true or not, in a real life situation. Furthermore, when research is studied via an interview, it is more detailed, but useless information is also enriched[20, 26]. It is also challenging to do a large-scale face-to-face interview in real life. To solve the problems mentioned above, social listening through the internet might be an excellent way to learn about dissatisfaction within the indoor environment during winter.

Using online social networking platforms, researchers can also selectively obtain different opinions from a multitude of online users rather than actively designing questionnaires and distributing them to sample populations. Moreover, the questionnaire survey can be thought of as a passive method. If researchers do not solicit the questionnaire they designed, these occupants may not have access to or be aware of the opportunity to report their dissatisfactions. Unsolicited building reviews are used in a former study to explore indoor environmental quality through Airbnb[30] and Ctrip.com[33]. Researchers used text mining to analyze online travel websites' comments to do IEQ evaluations of hotels and focus on customer complaints. There are many benefits to this kind of new method:

1) Because researchers did not deliberately set options, the information is provided by online users spontaneously avoiding bias from researchers.

2) There is no need to employ a lot of personnel for the distribution and recovery of questionnaires.

3) The sample background is not limited, whereas the majority of online users are often young and middle-aged.

Social listening is also referred to as social media monitoring, which means to monitor and analyze the information posted on social media networks around specific topics[34]. This study will adopt this social listening method. Answers from different users on heating related questions as well as the comments below the answers have been collected on the Chinese social question and answer (SQA) community. Zhihu (https://www.zhihu.com/) is an online SQA community that connects users from all walks of life and allows them to share each other's knowledge, experience, and insights. The community is like a forum where users engage in relevant discussions around a certain topic of interest on their own initiative. Former researches whose topics range from games[35], celebirties[36] and health[37] are studied based upon the Zhihu.com platform. The characteristics of the users in Zhihu.com have also been investigated in depth[38-39]. The users are a group of experts and students with high educational qualification that help to provide a professional atmosphere. Unlike Airbnb and Ctrip.com's comments, the way users describe their opinions on Zhihu.com is more full of life atmosphere. Airbnb and Ctrip.com's comments are similar to POE where the users are asked to rate the service after they have completed the short-term accommodation orders. The answers and comments from Zhihu.com are more similar to the results given during a formal interview, as observed in the literature[20, 26]. Users from Zhihu.com show their true feelings about their long-term accommodations; this is the most signifigant difference from the research that is based on Airbnb and Ctrip.com's answers and comments. That is also why the complaints are not as numerous as they are in Airbnb and Ctrip.com's comment and answer section. Based on the review done above, information has been collected about users' views on the indoor environment, as well as their heating behavior such as using time and set-point, dissatisfaction with local thermal and physical discomfort, complaints about devices' operation, and other complaints of how to improve the indoor winter environment in southern China, especially in the non-district heating zone. Discussions have been made about whether there are differences between demands collected through traditional questionnaires and social-listening.

In this study, discussions have been made about:

1) Whether the way users online described their demands is distinct from how researchers designed the options?

2) Whether the complaints that users online reported are more detailed or more superfical than what researchers have found through the traditional questionnaire survey?

3) Whether the extra information users online said they were dissatisfied with is meaningful for the design of the questionnaire?

2 Methodology

The methods used in this paper consists of four phases: questions chosen, key phrases chosen, text refinement, information input and export. The answer and comment texts were sifted through in detail. Several questions have been chosen under the topic of heating. The sum of answers under these questions is 2 701, and the sum of comments under these answers totals 18 952. The specific operation process is shown in Fig. 1.

2.1 Key phrases chosen

Based on the literature review in the introduction, thermal dissatisfaction can be devided into five categories: dissatisfaction about the indoor environment, dissatisfaction about local thermal discomfort, dissatisfaction about physical discomfort, dissatisfaction about devices' operation, and dissatisfaction about others. Simultaneously, the details of thermal adaptive behaviors and equipment service time are collected.

The results after classification from literature are shown in Fig. 2. The options of each category are selected based on the literature and provide a reference when refining the raw text of online answers and comments.

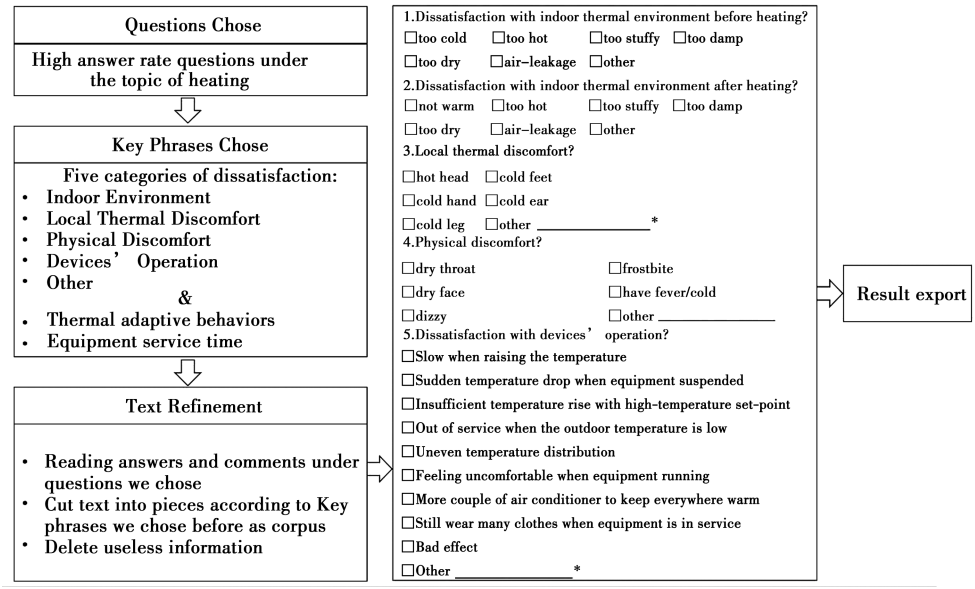


Fig. 1 Operation process

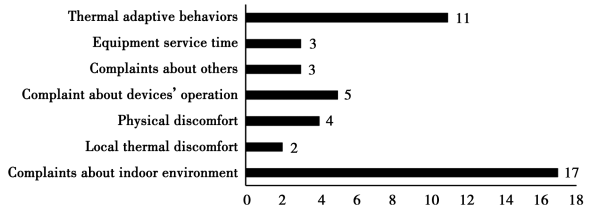


Fig. 2 Discomfort category and other information from literatures

2.2 Text refinement

Answers and comments do not always contain the required information, they jest or be argumentative about the topic that can be excluded. Furthermore, users may use different descriptions to describe the same means. The text needs to be refined following the key phrases chosen based on the literature. The refinement contains two steps. First, turned the raw answers and comments into text which only contains information related to heating. Second, cut the text into pieces according to the key phrases as the five categories of dissatisfaction and other information mentioned in Fig. 1.

The example is shown in Fig. 3. The example text is the information that has been extracted from raw answers and comments.

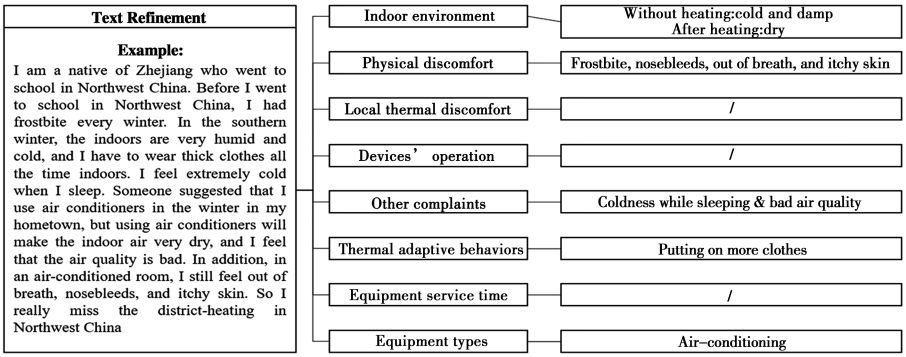


Fig. 3 An example of text refinement

2.3 Information input and export

One thousand two hundred twenty-eight items of a complaint from 658 users have been collected from the indoor environment platform before and

after they used the heating equipment, local thermal discomfort, physical discomfort, complaints with device operation, as well as other complaints. A corpus has been built based on the collected dissatisfaction about heating. These complaints are extracted from 21 653 pieces of answers and comments, and showed a complaint rate of 3.19%. As shown in Fig. 1, a questionary has been made based on the phrases and corpus of the dissatisfaction and has been filled in by each answer and comment received from the internet. Table 1 shows detailed information on counts of complaints. Besides, information about the service time of heating equipment for 58 items, information about thermal adaptive behavior for 163 items, information about heating devices for 593 items, and other information about setting temperature, hometown, inhabitant now have been gathered. The specific statistics about each type of complaint will be shown in the results.

Table 1 Types of complaining

Categories	Items
Complaints about the indoor environment before heating	283
Complaints about the indoor environment after heating	184
Complaints about local body discomfort	146
Complaints about physical discomfort	76
Complaints about devices' operation	347
Other complaints	191

3 Results and discussion

3.1 Indoor thermal environment

The indoor thermal environment is the foundation on which to discuss the question of complaints. When there are no heating devices or the heating devices are not in operation, occupants showed complaints about the damp and cold indoor air at 77.2% and 68.3%, and the portion of the complaints about damp and cold in the meantime reached 50.3%. The rates at which the occupants only complain about damp or cold air are 25.1% and 15.0%, respectively. This shows that before heating, the main dissatisfaction with the indoor environment is temperature and humidity.

After using heating devices, the damp air complaints are reversed, and dry air complaints increase to 56.5%. The heating devices do not work for 60 out of the 161 users, showing their dissatisfaction about indoor temperature. The rates that occupants only complain about dry or cold air are 43.5% and 26.7%, respectively. Before heating, occupants complained about both damp and cold. Unlike the complaints before heating, the main dissatisfaction turns to one type, dry or cold. Moreover, the stuffy conditions remain both with and without heat but are more severe when using heat.

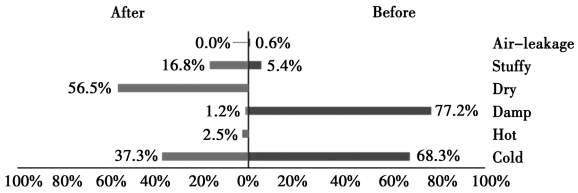


Fig. 4 Complaints about the indoor environment before and after heating

Twenty-four items in 263 users complained about the low-temperature elevation with a high-temperature set-point at the devices' operation. Moreover, 24 in 26 users whose information contained the air-conditioner's set-point in winter showed that they set the temperature above 25 ℃ and 15 of them even set the temperature above 30 ℃. It's not strange that occupants complained about the coldness during winter. Compared to the 8-14 ℃ indoor temperature in the hot summer and cold winter zone in China[40], the set-point is undoubtedly high showing the eager change of indoor temperature. The high-temperature set-point is also observed by other research. The average temperature set-point has been shown to be above 26 ℃ in all family structures [7].

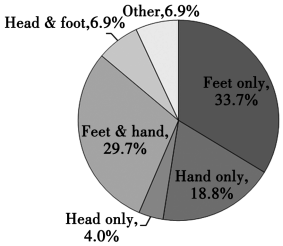
To reduce dryness sensation, 13 of 91 users who complained about the dryness after using heating devices said that they use a humidifier in combination when they use a heating devices. Furthermore, 13 in 38 users who complained about

stuffy air said that they or their family members open windows during winter, disregarding the operation of the heating device as well as the outdoor temperature. Moreover, some users even reported that they prefer coldness to stuffiness during the online investigation.

3.2 Discomfort

Regarding local thermal discomfort, the result is similar to former studies showing that hands and feet are parts of the body they want to keep warm. 53 and 75 of 146 users complained about cold hands and feet respectively, while the number reflected cold hand and cold foot meanwhile is 31. The users that complained about cold legs, feet, hands and a hot head are 1.98%, 33.66%, 18.81%, and 3.96%, respectively.

Apart from that, there's a small portion of cold ear and leg complaints. As a discomfort due to uneven temperature distribution, the hot head is reported as a thermal discomfort of 13 in 101 users. From the literature reviewed, the body part occupants want to warm up the most is their feet and lower body[12, 28]. There're also complaints of cold hands & head[12], but they were not concerned that the local thermal discomfort may happen when hot air floats to the top of the room. Another discovery is that the body part occupants wanted to be warm is simpler, they just want to warm one or two part. Some literature[28] cut the local thermal discomfort into more than 7 parts, but occupants online only show complaints for 5 body parts in this study.



Note: Other contains cold legs only/cold feet & legs/ cold hands & leg/ hot head & cold hean/ cold ears & hands & legs.

Fig. 5 Complaints about local thermal discomfort

The types of physical discomfort are varied, and are shown in Fig. 6, the details of body part affected and aligment are shown in Table 2. Users reported that most of these symptoms are positively related to dryness after using the heating devices like the dry sensation of throat, face, nose lips, and skins. Moreover, occupants may have a headache or feel dizzy, these two symptoms were categorized into the head label; others have sleepiness symptoms. Another kind of symptom is the effect of coldness, 36.4% of users said that they suffered from frostbite indoors and 10.6% said that they had a fever or caught a cold during the winter in southern China. To learn more about physical discomfort, Xiong et al.'s questionary[24] is percise and covers numerous physical discomforts. His questionary reported 35 different kinds of unique discomforts stemming from temperature-related discomfort.

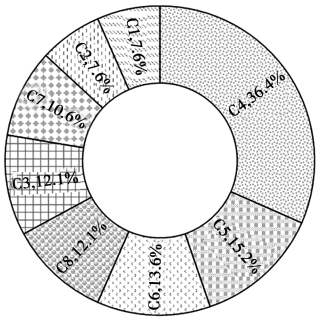


Fig. 6 Complaints about physical discomfort

Table 2 Details of labels about physical discomfort

Lable	Details
C1	Throat
C2	Face
C3	Head
C4	Frostbite
C5	Nose
C6	Sensation of asphyxia
C7	Have fever/cold
C8	Other

Apart from the types of dissatisfaction summarized above, other complaints are shown in Fig. 7. The details of each label are shown in Table 3. 48.9% of users think the price of electricity the equipment consumes is too high, especially

compared to district-heating fees in northern China. Eighty-one out of 176 users reported the phenomenon of "Feels hard to get up in the morning", "Freezing at midnight or in the morning" and "Feels cold when sleeping". These are complaints about the whole procedure of sleeping. It shows that people cared about their sleeping thermal comfort a lot. Furthermore, there are severe dissatisfactions that happened when occupants take shower or go to the bathroom at midnight. The air quality is also a concern by the occupants.

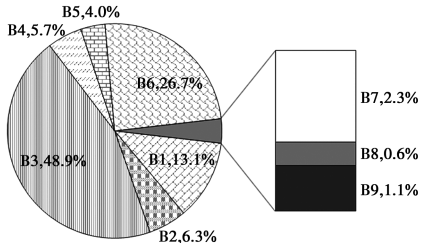


Fig. 7 Other complaints

Table 3 Details of labels about other complaints

Label	Details
B1	Feels hard to get up in the morning
B2	Freezing at midnight or in the morning
B3	The cost of electricity the equipment consumed is too high
B4	Feels cold during and after taking a shower
B5	Feels cold when going to the toilet at midnight
B6	Feels cold when sleeping
B7	Poor air quality
B8	Go moldy
B9	Can not dry clothes

The information on equipment service time was collected from 50 users on the forum, and 36 of them described the heating equipment's service time as activated by specific motions. Others were described as time scales as usual studies did. The service time related to sleeping ("before sleep", "before getting up", and "while a sleep") counts for up to 55.6%. Some studies[41-42] have discussed these phenomena, and are related to the discomfort of sleeping. Moreover, the shower is an action that will lead people to complain about the coldness and may activate the operation of heating devices.

3.3 Demand for heating devices

Fig. 8 shows complaints about device operation. Each labels details are in Table 4. One hundred-two of the 263 users complained about the harmful effect of heating devices, and 15 of the 102 users complained that they did not feel warm. Sixty-six in 263 users said they felt uncomfortable when using heating devices, and 25 of the 66 users described it in detail in categories of local thermal discomfort and physical discomfort. Other comments which are quite conmen are "Out of service when the outdoor temperature is low" (10.3%), "Uneven temperature distribution" (16.0%), and "The occupants still wear many layers of clothes when equipment is in service"(14.8%).

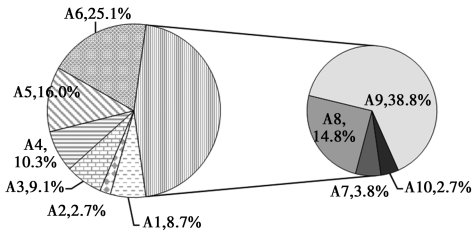


Fig. 8 Complaint about devices' operation

Table 4 Details of labels about complaints about devices' operation

Label	Details
A1	Slow when raising the temperature
A2	Sudden temperature drop when equipment suspended
A3	Insufficient temperature rise with high-temperature set-point
A4	Out of service when the outdoor temperature is low
A5	Uneven temperature distribution
A6	Feeling uncomfortable when equipment running
A7	More couple of air conditioner to keep everywhere warm
A8	The occupants still wear many layers of clothes when equipment is in service
A9	Bad effect
A10	Other(noisy, cold airflow, burning clothes, and lack of heating function)

The reason why users complain about "Sudden temperature drops when the equipment is suspended" and or "Out of service when the outdoor temperature is low" may be due to the

defrost process. When the air conditioner is operating in a low temperature and high humidity area, the external unit is prone to frost. Hence, the air conditioner needs to suspend the heating phase and turn on the defrost every time the air conditioner passes. Therefore, frequent starts and stops, may explain why users complain about the temperature drop after the air conditioner is suspended. In more extreme cases, air conditioners cannot defrost well; this causes the air-conditioner to fail to perform normal heating cycles. Researchers have come up with new defrost methods[43] and calculated predicted mean vote (PMV) as well as predicted percent dissatisfied (PPD) to evaluate the thermal comfort of occupants indoors while the air-conditioner is in operation[44].

As the heated air rises to the top of the room, it is not uncommon that there is dissatisfaction about uneven temperature distribution. Furthermore, the uneven temperature distribution complaint also concludes the situation that users feel cold when they're far away from the devices. The discomfort that they feel too warm when facing the wuiipment directly while their backsides still felt cold was information that was extracted directly from online sources. The non-uniform temperature distribution can be shown by Computational Fluid Dynamics software [45], and is the main reason that lead to localized thermal discomfort. In that case, many personalized heating methods and thermal comfort models have been designed to study how to improve total thermal comfort[46-48].

There is still a complaint about "The occupants still wear many layers of clothes when equipment is in service". One hundred and sixty-three items of thermal adaptive behaviors have been summarized from 143 users. The details are shown in Fig. 9.

The most general thermal adaptive behavior is putting on more clothes from the answers

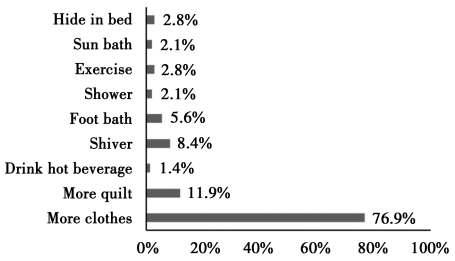
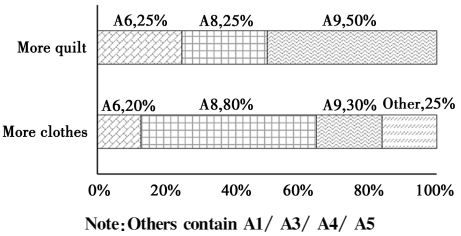


Fig. 9 Thermal adaptive behaviors

collected. Hiding in bed and putting on more quilts show that the bed is where occupants are getting through harsh winters. Drinking hot beverages and foot bath showers are adaptive behavior relating to hot water. Other ways include shivering, exercising, and sunbathing.

For occupants who put on more clothes to compensate for the discomfort of coldness, they are dissatisfied that they cannot reduce clothing layers when the heating devices are in operation, as Fig. 10 shows. The labels have the same meaning in Table 4. They also complained about the harmful effect of heating devices; this shows their expectation with heating. They want to wear less in a warmer indoor environment.



Note: Others contain A1/ A3/ A4/ A5

Fig. 10 Correlation between thermal adaptive behaviors & complaints of device operation

To sum up, former studies[12, 17-18, 20, 26, 28] whose occupants complained about devices' operation did not evaluate it systematically; they just picked one or two complaints. The occupants' demand can be summarized in the following:

1) They want the temperature to acclimate quickly as well as have an equal distribution.

2) They hope that the devices' operation can be continuous and reliable in any outdoor condition so that they can wear less to be free indoors.

3) They don't want that the use of heating devices to bring them any physical discomfort.

4 Analysis and Discussion

The questionnaires investigated from the literature are quite different from the answers gathered from the internet, for the questionnaires can inquiry complete information and eliminate incomplete replies. The correlations between each question can be evaluated using a statistical method, but the answers accumulated in this study are quite independent. One dissatisfaction may be extracted from one answer, while another answer yields several dissatisfactions.

Users who answered questions or discussed with others about heating are occupants who actively care about the indoor environment signifigantly. This kind of group is distinct from subjects that traditional questionnaire researchers has investigated. For subjects in the questionnaire survey passively concerned about the indoor environment and may not have access to or be aware of the opportunity to report their dissatisfactions without researchers delivering questionnaire to them.

Here are results that address the questions brought up in the introduction.

1) Whether the way users online described their demands is distinct from how researchers designed the options?

When talking about the equipment service time, some research concludes the open and the close by actions or feelings like "feeling cold", "sleeping", "feeling good" or uses in and off to show occupied conditions[13]. Others from the literature [7, 13, 49-50] were often shown in timescale (e. g., from 18:00 to 6:00) or just mentioned "service time 8 hours". However, the corpus summarized in this study shows that the equipment service time was described more as an action activated by specific behaviors like "before getting up", "before showering", and so on. Some studies[41-42] have discussed it as an event trigger, while this research would say that occupants prefer these kinds of event-triggers as ways to describe the time they use the heating devices.

2) Whether the complaints that online users reported are more vivid or simpler than those that researchers have found through the traditional questionnaire survey?

Other dissatisfactions collected from the literature are complaints about noise[12, 14], air quality[12], personal control[12, 17], have trouble falling asleep[23], unpleasant to get up[23, 26], cold when taking a shower/going to bed[26], or cold when coming back home[26]. Compared with the corpus summarized based on social listening, occupants complained more about the coldness during taking a shower, going to bed, and falling asleep to getting up in the morning. Sleeping may become an important part of dissatisfaction during winter, and there is much research focused on thermal comfort during sleep[51-53].

Moreover, dissatisfaction with the devices' operation reflects the demand for properly working heating devices; the main complaint in literature is the slow response of the heating system[12, 17-18, 20, 26] and the uneven temperature distribution caused by the air-conditioner [12, 17, 28]. While these works of literature did not classify the uneven distribution condition at the horizontial, vertical, front or back. During this investigation, occupants mentioned that online users distinguish the uneven temperature distribution in three dimensions: horizontal, vertical, and the front and back of the body. While in the corpus summarized online, the types of complaints about the devices' operation are more variable and specific for more than 10 kinds of complaints.

As for the local thermal and physical discomfort, the classifications that this study analyzed and concluded are similar to the literature reviewed above. The differences are that the local thermal discomforts the literature is concerned with are the results of coldness. Researchers may ignore the discomfort caused by the warm air in the upper space of the room. Apart from that, former studies cannot show whether the local thermal discomfort appears just in one area or several areas simultaneously[12, 28]. Moreover, the complaint

rates of feet and hands in Lin's study[28] are around 17% and 13%, respectively, in 97 subjects. The rates are close to each other, but in our study, among 101 users, the demand that feet want to be warmed seems more urgent than hands. The body parts occupants want to be warm is much simpler than previous literature has shown. Many physical discomforts are caused by air dryness or warmness such as dryness of skin, throat, nose, and eyes. Frostbite caused by coldness and dampness was not mentioned by the studies we reviewed.

3) Whether the extra information online users said they were dissatisfied with is meaningful for the design of the questionnaire?

Many studies have not evaluated and discussed temperature, humidity, and air movement [15-16, 18-19, 22, 24-25]. Some even mention temperature preference and put the dissatisfaction of air-dryness and stuffy air as other aspects of discomfort[12, 17]. While in this research, occupants care mainly about the temperature, humidity, and the air-movement indoors. When the indoor thermal environment in winter is evaluated, especially in the non-district heating zone, these three parts should be investigated systematically as some researchers did[14, 28]. Nevertheless, there is a difference between this research and the former study by Guo et al.[13]. Guo et al. found that in China's non-district heating zone, 45% of occupants want to improve only the temperature, while 16% of them want to improve only the humidity conditions among nearly 1 800 families. The priority is inversed in this research. It may need further study in the future. Another essential element in this study is that many occupants reported that they use a humidifier to reduce dryness, many studies did not mention the use of a humidifier through a traditional questionnaire survey. Another aspect is occupants may open the window while the heating devices are in service[7, 13, 22]. Research needs to study the window using behavior to deal with the discomfort brought on by stuffiness. The adaptive behaviors gotten from literature can be sought by Fig. 11. Through social-listening, except for the coldness and stuffiness, occupants can use devices or ventilation to deal with the problem of humidity, questionnaires can seldom investigate that kind of correlation. In that case, thermal adaptive behavior can not be restricted to temperature and air movement. Adaptive behavior should contain actions that deal with dampness and dryness.

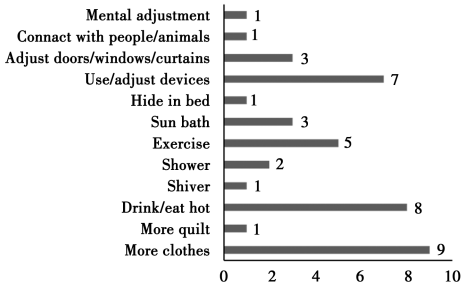


Fig. 11 Adaptive behaviors from literature

The dissatisfactions about devices' operation show that occupants have three main requirements of heating devices:

1) Sufficient effect to ensure fast and adequate temperature elevation;

2) Stable operation to keep running no matter how harsh the outside environment is and avoid sudden temperature drops caused by a halt.

3) Uniform temperature and air-flow distribution to keep overall thermal comfort.

The dissatisfaction with the devices' operation may need to be evaluated more systematically in a further study.

To sum up, through social-listening, there are four points distinct from literature. First, a correlation was found that people use equipment or ventilation to reduce the discomforting sense of humid or stuffy air. Second, thermal comfort during sleeping can be an independent part when investigating discomfort in winter. Third, occupants prefer to describe their device's service time as motion-activated by specific behavior like sleeping, shower, and getting up. Fourth, the evaluation of the devices' operation can be more systematic.

5 Conclusions

Data was extracted from 21 653 pieces of answers and comments on an online SQA community about dissatisfaction with winter heating behaviors through social listening. A corpus has been built, which is classified as complaints about the indoor environment before and after heating, local thermal discomfort, physical discomfort, other discomforts, and complaints about the devices' operation. In the meantime, information about equipment service time, thermal adaptive behaviors, and heating appliances occupants possess have been collected. The complaint rate is 3.19%. The group of users that have been investigated are people who are proactively concerned with their indoor environment.

The primary outcomes of the survey can be summarized as follows:

1) Temperature and humidity are two aspects occupants want to improve before heating, while the dryness becomes the main complaint after heating, which is different from literature.

2) Extremities, including feet and hands, are two concerns of occupants who want to be warm. The priority of feet is higher than the hand.

3) Frostbite needs to be a concern when making a questionary about physical discomfort during winter.

4) Dissatisfactions with devices' operation and other aspects are more trivial through social listening. Occupants concern about their comfort all the time and everywhere at home, for they want to keep warm of almost all the body parts in every room and every time they stay at home.

5) Occupants prefer to describe their device's service time as motion-activated.

The disadvantage is that the analysis and integration methods of fragmented information need to be upgraded. This study only displays the basic situation of the obtained information through pie and bar charts. What's more, the correlation between each item is not analyzed in-depth, such as not analyzing each heating method of whether it makes a difference in how people feel about indoor temperature and humidity.

This research may contribute to the questionary survey in residential buildings and provide reference alternations when scholars design their questionnaries.

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