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Innovative Evaluation Techniques for Hanok Sustainability Based on Integrative Comfort Indices

Mi-Hyang Lee [1] and Seung-Hoon Han [2,*]

[1] Industry Liaison Office, Chonnam National University, Gwangju 61186, Korea; dahyeon01@jnu.ac.kr
[2] School of Architecture, Chonnam National University, Gwangju 61186, Korea
* Correspondence: hshoon@jnu.ac.kr; Tel.: +82-62-530-1646

Abstract: This study aims to present integrative evaluation techniques that can assess spatial comfort reflecting the unique value of a vernacular building type in Korea called Hanok. For this purpose, current evaluation indices and methods of official standards for normal building performance were analyzed through previous studies, since any certified tools for Hanok evaluation do not exist. This situation has made relevant markets to be deactivated, although Hanok has valuable meanings as the traditional architecture to be succeeded to the next generation in Korea. Accordingly, specific assessment indices were derived to evaluate the Hanok sustainability especially focused on spatial comfort by using a qualitative field surveys with combined quantitative references. Then, actual resident data were collected from a series of Hanok testbeds for specific time-points including summer and winter solstices on the lunar-year system. As a result, resident data could be employed to reveal the characteristics of comfort performance from those target specimens, and show the tendency of the Hanok comfort by suggested innovative criteria for the market as a clue for its commercial potentials. Accordingly, it was concluded that the proposed techniques and indices could be certified for the Hanok evaluation and applied to the field of associated industries to show its specific values and advantages.

Keywords: Hanok; comfort performance; integrative evaluation; Korean traditional architecture; residential sustainability; assessment techniques; open innovation

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1. Introduction

Today, interest in indigenous cultures is increasing in all countries and regions in an era of globalization that demands recognition of the value of individualization, and there has also been a movement to restore cultural identity by newly understanding and interpreting the ethnic values of a nation. Therefore, it is necessary to find a new alternative that reflects regional uniqueness and specificity in a sustainable way [1]. A vernacular style is created according to the daily lifestyle and natural needs of the local people, and has become an important resource for contemporary architecture [2].

In this sense, Paul Oliver defined vernacular housing as a form of dwelling made by traditional techniques and resources produced in a specific environment by local people or communities [3]. It is the most widespread form of the most regional architecture that refers to informal construction supported by a structure in a traditional way, without using the services of practical or commercial architects [4,5]. Architects have realized the significance of intrinsic, ecological principals incorporated in the vernacular form of architecture, in Korea for example the Hanok, and tried to adapt it through the modernized consensus of some factors. In particular, it can be a true example of sustainable architecture that is now considered in various locations worldwide [6,7].

Hanok as Korean vernacular housing is a house form with structure built in traditional architecture style by the cutting, trimming, and assembly of timber without nails, as shown in Figure 1. The walls of the traditional Hanok used natural materials, such as soil, stone,

and lime, and its roof was topped with weaving rice straw for the first stage, but then used earth-baked tiles step-by-step. In addition, under the roof tiles, a thick layer of ocher was applied to give it a thermal effect. Most Hanok were composed of single-story building units facing south, and open spaces were used openly between them to provide better lighting and ventilation in preparation for heat and cold [8–10]. However, the popular form of housing in Korea has gradually changed to high-rise apartments, and the Hanok is quickly disappearing in the face of modern industrialization and urbanization.

Figure 1. Hanok as Korean vernacular housing.

Recently, Hanok research has been actively underway in the process of discovering the possibility of contemporary forms and spatial adjustment through the combination of a new understanding of local architectural methods. The public perception of Hanok in Korea is changing positively compared to the past, but the demand for Hanok is slower than the tendencies in which interest increases. In general, it is well recognized that the Hanok is an eco-friendly and healthy house, but there are difficulties in objective verification and policy applications as the performance of the Hanok has not been fully evaluated.

Most indoor climate technologies, such as air conditioning, mechanical ventilation, and heating units, however, tend to minimize the interaction between the system and people, and in many cases, limit to the button similar to a default on/off switch. Therefore, the amount of adaptation acceptable to comfort range might be limited, if quantitative indices such as temperature, humidity, lighting, and noise levels remain at an optimal level instead of providing options and diversities without considering the possibility of changes in blankets, cups of tea, and clothes that are regarded as qualitative sensory factors [11]. Nevertheless, in the form of technology, people normally use other senses such as touch, sight, and hearing to experience how their levels of warmth, coolness, air quality and noise are gradually changed, recognize how their actions affect the environment, and/or adapt themselves to their daily situations.

A study performed by Luis Godoy-Vaca et al. exemplified a customized evaluation technique based on specific climate conditions and building materials that determine a vernacular sustainability in social houses in Ecuador. A new concept of PCM (phase change materials), in addition, has been involved into the process of evaluating spatial comfort and energy efficiency for a very hot-humid climate [12]. Another research by David Beltrán et al. also insisted an importance of an optimized evaluation method to reveal an effectiveness of PCM performances toward the reduction of greenhouse gas emissions and energy consumption [13].

Existing evaluation methods for building performance focus on the structural and energy aspects, so there have been limits to evaluating the performance of Hanok with those normal standards, since Hanok is considered to be complex in construction procedure, expensive for its building materials, and vulnerable to low temperature; these considerations offset the psychological advantages of Hanok, such as beauty, comfort, and peace. Therefore, it is necessary to evaluate the psychological factors from actual users or residents living there, and to simultaneously find a unique performance evaluation method that is suitable for Hanok.

Amos Rapoport claimed that vernacular housing determined the form of human lifestyle and space due to the influence of climate, and adapted to its changes, resulting in the formation or structure of housing [14]. In other words, it is necessary to try to understand the mental state of human beings living in such housing, not just to see the dwelling as a structure. This is because housing is a place that controls both the physical environment and the psychological state of residents and/or users, and in this respect, it is necessary to evaluate not only the numerical interpretation by legal standards, but also the psychology of the people living there.

For the ultimate goal of developing an integrated performance evaluation model for Hanok, this paper presents a method to assess the psychological state of users on the physical perceptual elements of indoor space using a questionnaire. In addition, quantitative figures and questionnaire data were collected and analyzed through a long-term monitoring process targeting the actual Hanok that were used or lived in. If the unique evaluation model of the Hanok is presented through this cross-validation process, it will be possible to explore the architectural role of the Hanok with cultural identity, while securing the function of modern buildings. In addition, as such research continues, it is expected that it will be able to contribute to the housing welfare of people by gaining momentum in the dissemination and popularization of Hanok that have advantages as vernacular housing.

2. Materials and Methods

2.1. Criteria forEevaluating the Quality of Housing

The quality of housing is difficult to grasp only through physical values, such as indoor temperature, humidity, illuminance, and airflow, and the measured values are not accurate. However, the quality of most houses is currently judged by comparing the values measured according to a standardized test method with the criteria presented. In its 1961 report, the WHO (World Health Organization) set safety, health, convenience, and amenity as four qualitative goals for healthy living standards to enjoy a human life [15]. Thus, the quantitative performance of the building, as well as the qualitative elements, should be addressed in the factors that evaluate the quality of housing. The qualitative indicators of housing are classified into contents related to the surrounding environment, along with the physical elements inside the living space. Evaluation items consist of matters directly related to health, such as basically securing necessary space, supply of electricity and water, indoor toilets, kitchen facilities, as well as the quality of building materials, efficient use of indoor air, moisture, mold, and noise exposure.

The importance of the quality of housing has been recognized as a natural task, especially in developed countries, such as Europe, the United States, Japan, and Canada. Each country proposes standards and regulations related to building performance evaluation, as shown in Figure 2, to save energy and improve the residential environment by reflecting the climatic characteristics. In 2011, the OECD (Organization for Economic Cooperation and Development) proposed new regulations at the international level to improve the quality of housing [16]. In the case of the housing code in San Francisco, United States, detailed regulations, such as securing a window area of more than 10 ft^2 or 1/12 of the room and floor area in relation to lighting and ventilation, are presented and managed [17].

In this regard, Korea also enacted Korean Standard (KS) A 6300 by the National Institute of Technology and Standards in 2017 as a test method for Hanok [18]. It was created in consideration of the unique characteristics of Hanok, as vernacular housing that is different from the modern Westernized house. Based on the recognition of the performance of general modern housing, evaluation items were selected to reflect the actual value of Hanok, and the test methods and procedures were suggested to be used in connection with the existing building performance-related certification system. Figure 3 shows that KS A 6300 is organized around fourteen items of the comfort performance of Hanok, and these are divided into nine items of physical perceptive factors and five items

of psychological cognitive factors in detail, consisting of terms for each, citation of existing standards, and explanations of test methods.

Figure 2. Technical standards by country.

Evaluation Item		Citation Standard	Evaluation Contents
Physical Perceptive Factors	Humidity Control	KSF 2611 KSF 2295	Ability to control the indoor air of *Hanok* space so that it is not too dry or humid
	Airtightness (Air Permeability)	KS L ISO 9972	A feeling of ventilation transmitted from the outside to the inside due to the characteristics of t he wooden structure of *Hanok*
	Air Cleanness	KS I ISO 16000-6 KS I ISO 16000-3	Air quality that allows users of *Hanok* to breathe comfortably in the space
	Condensation	KS L 9016 KS F 2295 KS L ISO 8301 ISO 15099	The degree of condensation of water droplets that may appear on the walls, junctions and the interior surface of *Hanok*due to the temperature difference between indoors and outdoors
	Insulation	KS F 2277 KS F 2278	A sense of warmth in the room through the heat-blocking performance of the materials that m ake up *Hanok*
	Solar Radiation	ISO 15099	The degree of sunlight entering the indoor space of *Hanok*
	Thermal Comfort	KS A ISO 7730	The thermal comfort of an indoor space where *Hanok* users can live comfortably
	Sound Insulation	KSF 2810 KSF 2862 KSF 2863	The degree of noise entering the interior from the outside that may be offensive to the ears of *Hanok* users
	Solar Lighting	KS A 3011 ISO 15099	The brightness of the indoor space of *Hanok* where sunlight comes through the windows and doors
Psychological Cognitive Factors	Scenery	KS A ISO 10551 KS I ISO 4869-1 KS Q ISO 13302 KS A ISO 20462-1	Analysis using subjective judgment scale by questionnaire Sensory test for food Psychophysical method for image quality evaluation
	Beauty		
	Deodorization		
	Usability		
	Health		

Figure 3. KS A 6300: Examination methods for Hanok.

As part of a step-by-step study to develop an integrated performance evaluation model of Hanok, the authors focused on the five psychological cognitive factors in Figure 3 in the preceding study entitled '*A Technical Assessment of Comfort Performance of Hanok Using Comparative Field Surveys between Experts and Users*' to adjust a gap between on-site monitoring results measured by instruments and sensory estimation data from users and/or residents [19], while this study has further focused on the improved innovative process based on certified standards for such a specific building type. For this, questionnaires of

experts and users were collected and compared, and as a result, the subjects generally responded that they were comfortable, although there were slight differences in psychological cognitive factors per season. In particular, it was found that environmental factors, such as the natural environment and location, along with the formative beauty of the Hanok, are the main variables that affect satisfaction. This study is different from previous research in that it collected and analyzed information through a questionnaire survey on the emotions and psychology that users feel about nine items of physical perceptive factors, i.e., items that can be measured numerically.

2.2. Evaluation of the Comfort Performance of Hanok

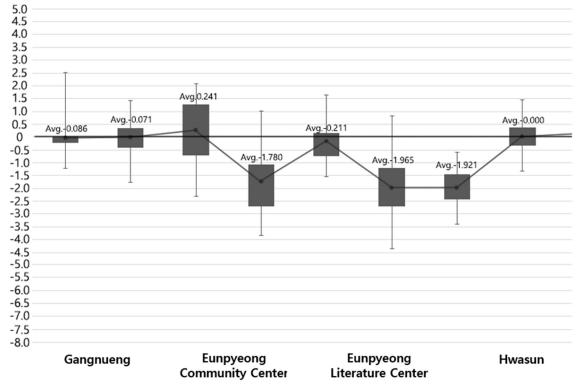
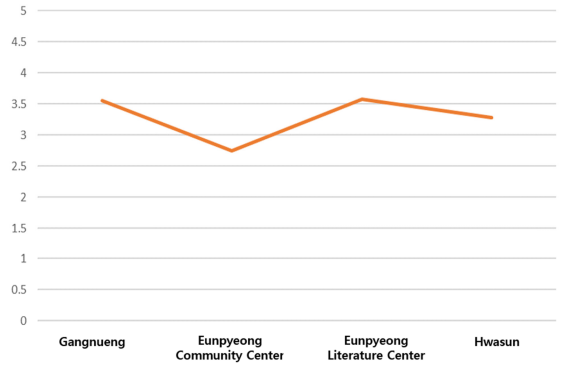
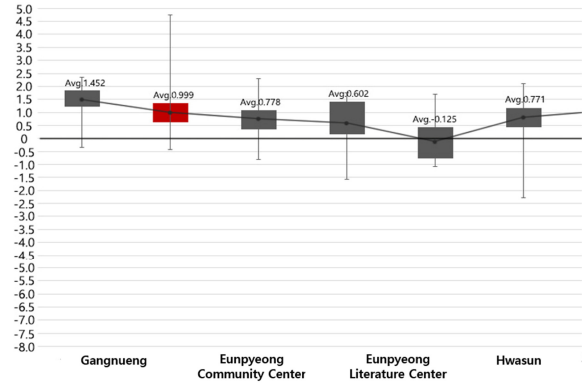
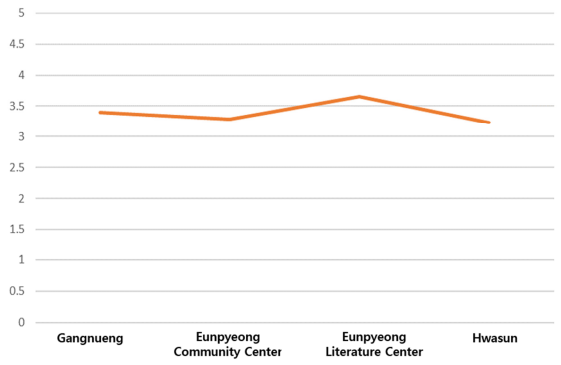
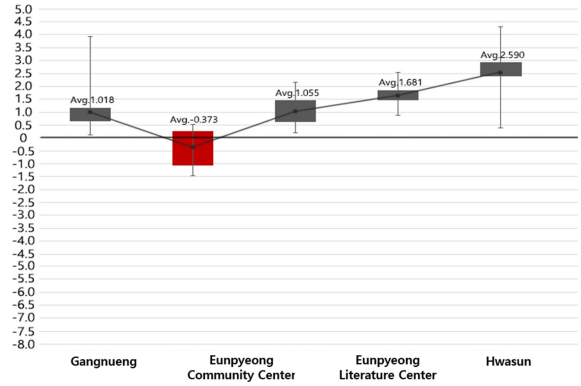
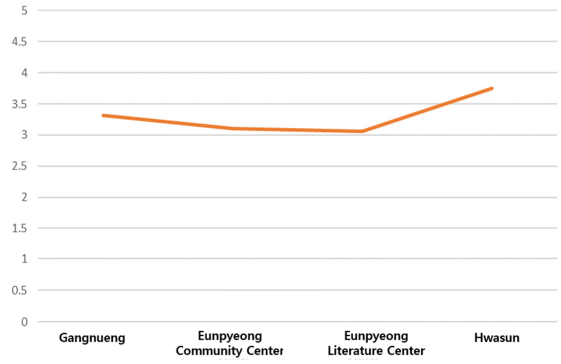
Among the comfort performances of Hanok, physical perceptive factors can be measured numerically through objective and reliable experiments, unlike psychological cognitive factors. In the actual KS, as shown in Figure 3, an objective and reliable test method was suggested by citing the method of the current standard, and a commentary was attached so that it could be applied to the Hanok. However, as in vernacular housing, unlike modern buildings, it is difficult to categorize the form of Hanok, and as Hanok of various forms and configurations were derived, there were limitations in applying them in a consistent way. There were cases in which it was difficult to control variables of the measurement environment of the target Hanok, or the test was only suitable for the laboratory environment, and did not provide a clear numerical standard. In this case, it was selectively applied mutatis mutandis compared to foreign technical standards, such as ISO (Organization for Economic Cooperation and Development) and ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), and measured by a method available in the field.

In accordance with previous research of the authors, on-site field measurements were performed on nine physical perceptive factors of the target Hanok for each evaluation period. At the same time, a questionnaire about the emotional and psychological changes for users was conducted through an in-depth interview. Thereafter, the quantitative measurement results and the information collected by the qualitative method were compared with each other to analyze the trends of the user's sensory and psychological changes according to season. Throughout the year, the process of verifying the evaluation method and the framework of analysis was repeated through continuous monitoring and feedback. Based on the information accumulated through the research process, a follow-up study will be conducted in the near future to develop an integrated performance evaluation model for Hanok.

In this paper, statistical analysis methods were basically used with references to the above case, and especially, employed a process to test a hypothesis using significance probability through correlation analysis between two variables. For instance, it is considered 'statistically significant,' if p-value in terms of the significance probability is less than 5% (0.05). This is so meaningful that it cannot be regarded as mere coincidence from a probabilistic point of view [20]. In the case of humidity among physical perception factors, the absolute humidity value (g/kg DA) could be compared, in this sense, instead of the relative one greatly affected by the temperature to evaluate whether the indoor humidity was controlled. After measuring the absolute humidity from the inside and the outside target Hanok, the degree of change by season was checked. These were compared with the average response rate in the results of the user satisfaction survey.

As shown in Table 1, it was confirmed that there was a certain trend between two variables: the absolute humidity difference and the survey satisfaction response ratio. As a result of correlation analysis between those, a regression equation with a p-value of less than 0.05 was derived, especially in the summer season.

Table 1. A comparative case of humidity of physical perceptive factors.

Evaluation Period	A Comparative Case	
	Difference of Humidity	Difference of Survey
Summer		
Inter-season		
Winter		

- Absolute Humidity Difference = 0.33 − 0.239 × Summer Season Survey Average Score (p-value < 0.001)
- Absolute Humidity Difference = 1.128 − 1.215 × Survey Average Score (p-value < 0.001)

In the case of thermal insulation among physical perception factors, the degree to which heat transfer is properly maintained through the mixture of materials constituting the target Hanok was evaluated. After calculating the thermal transmission rate of each component and the satisfaction rate of the total thermal resistance (%) by region, a comparative study was performed with the average response rate in the results of the user satisfaction survey.

As shown in Table 2, the thermal insulation is a constant value regardless of seasonal changes by calculating the heat resistance and heat transmission rate of each material shown in the detailed drawings, but it can be confirmed that a constant trend appears when

compared with the user survey satisfaction response rate. As a result of the correlation analysis between two variables, a regression equation with a p-value of less than 0.05 was derived for the thermal resistance satisfaction rate when the living room floor on the lowest floor faces outdoor air indirectly.

- Thermal Resistance Satisfaction Rate by Region (%) = 69.7 + 2.154 × Survey Average Score (p-value < 0.001)

On the other hand, it was impossible to verify the hypothesis through correlation analysis for all the physical perception factors of Hanok. Since solar radiation and solar lighting factors are calculated by inputting EPW (EnergyPlus Weather) data received from the DOE (Department of Energy) which is open access, into a computer simulation program, there may be slight differences from measured climate records of the day. In addition, it may be difficult to accurately reflect the physiological variation of the measurement day, since the thermal comfort factor utilizes the predicated mean vote (PMV) range normally used as an international standard for the degree of indoor thermal comfort. Despite these limitations, this paper was written with the intention of overcoming the ambiguity of the concept and increasing objectivity of the relationship between quantitative measurements and sensorial evaluation by using a statistical analysis method.

Table 2. A comparative case of thermal insulation of physical perceptive factors.

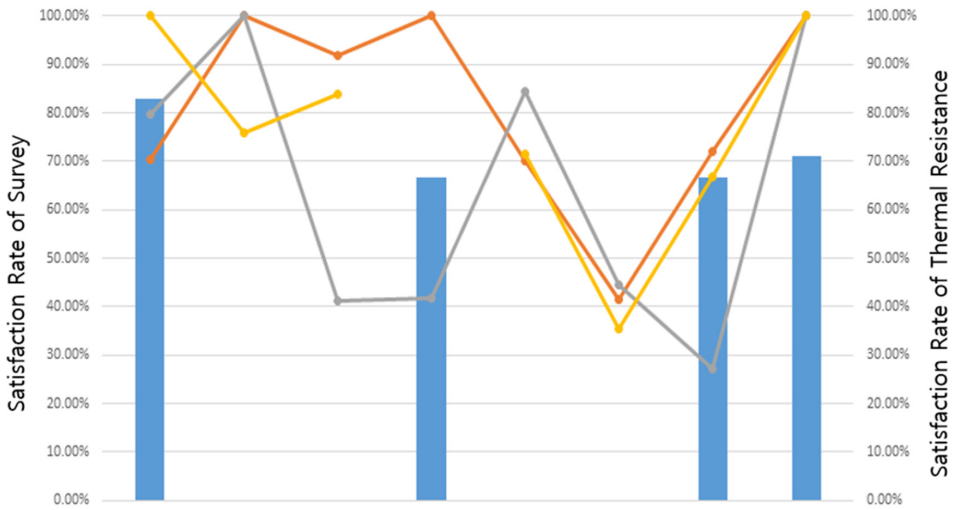
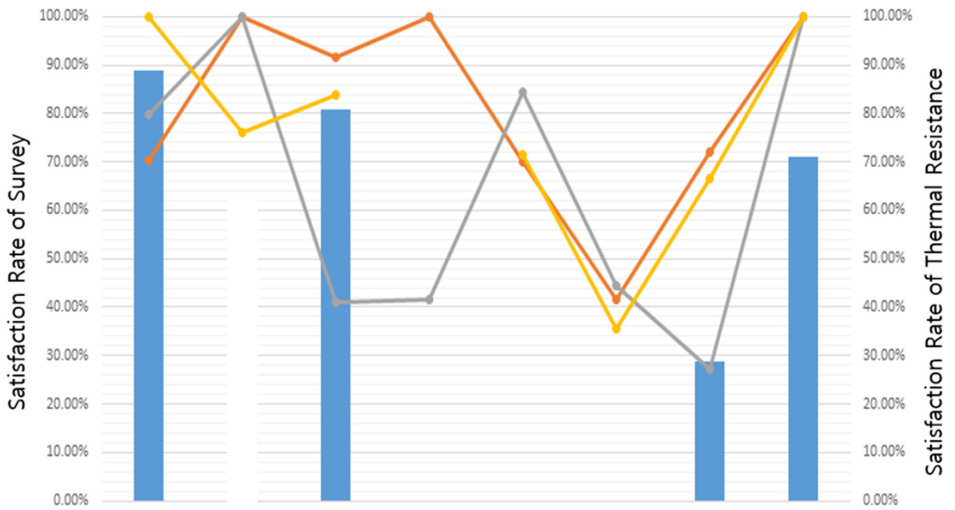
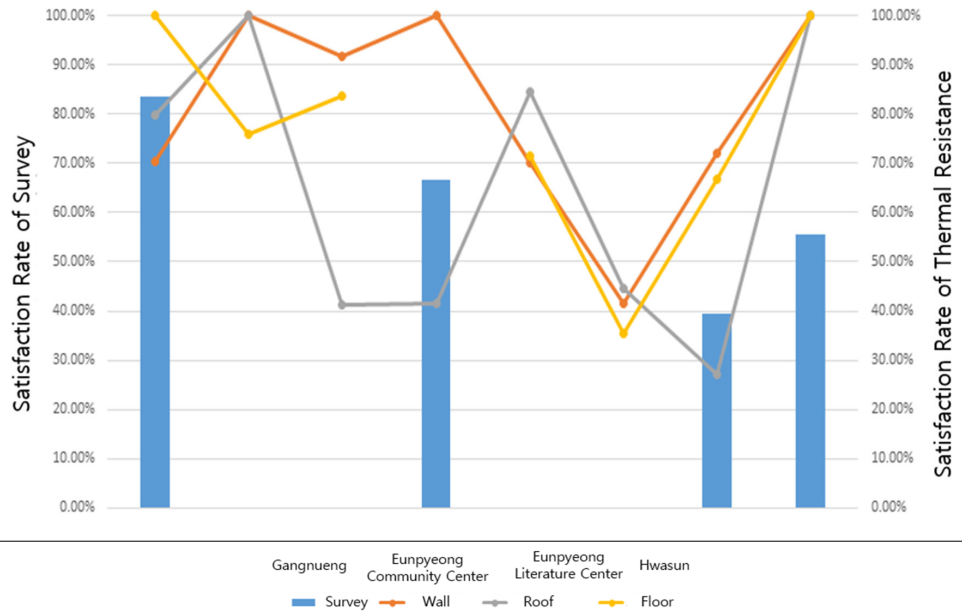
Evaluation Period	Satisfaction Rate of Thermal Resistance and Survey
Summer	
Inter-season	

Table 2. *Cont.*

Evaluation Period	Satisfaction Rate of Thermal Resistance and Survey
Winter	

2.3. Questionnaire Composition

Conducting a survey is one of the quick and easy ways to obtain data about users. Depending on which evaluation method and scale is used, different types of data can be calculated, and the statistical analysis method for them varies. Therefore, it must be carefully written in many ways to obtain reliable results. In general, sensory evaluation is used as a method of assessing the human sense of various qualities in industrial sites [21]. This means that when objective measurement is difficult, for example, when it involves complex senses and comprehensive judgments, such as taste of food, quality of sound devices, or softness of sheet, humans themselves play the role of measuring equipment. If the human sense measurement process is compared to the analysis process of a measurement device, the human sense is an input device that measures and collects values in the measurement device, while the brain processes the input information. In the central processing unit (CPU), it can be said that indicating an evaluation result or responding to a questionnaire corresponds to an output device. The characteristics sensed by the sensory organs are expressed in words or numbers through a sensory process and a cognitive process in the brain as shown on Figure 4 [21–23]. Through this process, quantitative data on human senses can be calculated, and statistical analysis is possible.

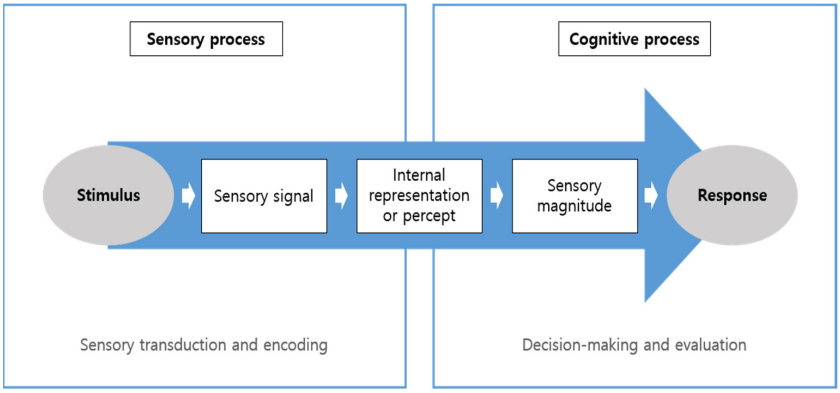


Figure 4. Sensory Stimulus ↔ Response Process.

In this paper, based on these principles, a questionnaire suitable for each item's evaluation was created for the nine items of physical perceptive factors among the comfort performance of Hanok, such as temperature, humidity, wind strength, and solar radiation, which are external stimuli. The purpose of this study is to evaluate the level of comfort they feel indoors for those who live in, or use, Hanok. Therefore, the intention of the questionnaire survey was to understand how Hanok users experience their current indoor environment. User surveys are widely used to evaluate user reactions and responses to indoor environments. Such surveys are a powerful tool in research [24–26].

The questionnaire was organized according to the following basic principles:

- Short and concise questions;
- Avoiding the use of academic jargon or difficult words;
- Avoiding duplicate responses;
- Preventing respondents from being bored;
- Arranging questions logically and probably;
- Intuitive response induction;
- Quantification of data that could be used statistically.

There are two types of questions in the survey: closed and open. First, closed-ended questions provide respondents with a fixed number of responses to choose from, such as yes/no, multiple choice, and classification of scales. These have the advantage that they are easy to analyze statistically due to the high response rate, so they are effective when collecting quantitative data. The other is open-ended questions that the respondents can answer in any way they see fit. In this case, respondents can write their own opinions or answers to questions, and present examples and explanations of them, which is an effective technique when conducting qualitative research [27–29].

In this paper, the questionnaire is aimed at the general public who actually live in or use a Hanok, and with the purpose of evaluating the intuitive psychology they feel indoors. Therefore, it is necessary to keep the language simple so that they can understand it, and to organize the content of the question clearly and concisely. In addition, respondents should be allowed to promptly choose how they feel, without using terminology or abbreviations that confuse them. To this end, closed-ended questions were constructed and evaluated using the most widely used categorical scale in sensory testing [30–32]. To calculate quantitative data using a categorical scale, the terms 'strong', 'weak', and 'very good', which are terms indicating scale, should be accepted as the same meaning by all survey participants; and the psychological response to each term should show a normal distribution [33–35]. To this end, questionnaires were collected through face-to-face in-depth interviews in a one-to-one format or a small group each time.

Among the scales used for sensory testing, the nine-point scale, which is the most widely known, was introduced and widely used by experimental psychologists Peyram and Girardot in 1952. They analyzed the psychological gap between each score on a nine-point scale in about 900 participants using a list of 51 intensity adjectives, and proved that the psychological distances between sequential scores were not the same [23].

Therefore, some scholars argue that the data obtained using the categorical scale should be treated as ranking data, not equivalent data, and analyzed by non-parametric statistical methods, rather than the conventionally used parametric statistical methods. However, when the results are analyzed by t-test or ANOVA (analysis of variance) by treating them as equivalent data, industry and academia tend to accept the existing research methods, because the results explain the phenomenon relatively well [36–38]. In the case of the categorical scale, the higher the scale is, the more meticulous the selection that is possible, however, there is the disadvantage in that this can cause confusion among survey participants. In this paper, a five-point categorical hedonic scale was used, considering that the subject of the questionnaire was the general public. Furthermore, to compose the questionnaire in a way that minimizes the number of people who leave, three questions were prepared for each item as a funnel structure as expressed by Figure 5.

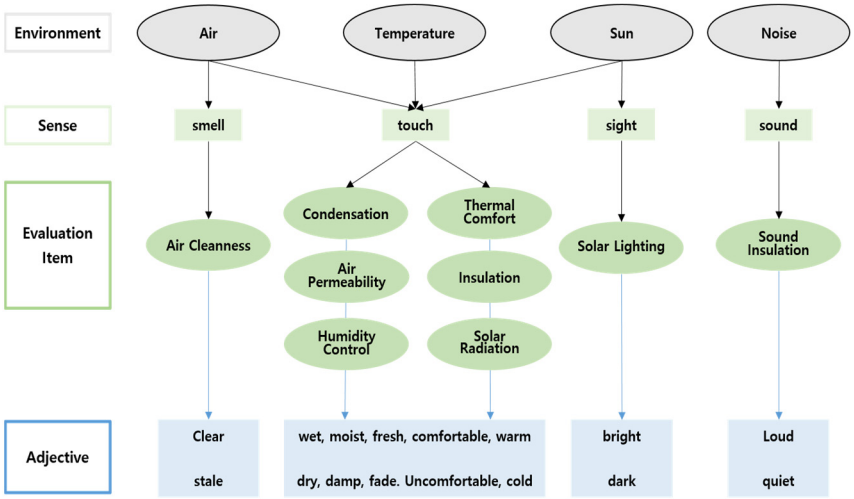


Figure 5. Classification of senses using adjectives.

This is a method of first asking a broad, foundational question; in the middle, a more focused question; and then finishing with a very specific question. The psychological state that humans living indoors experience with external stimuli was selected from the questionnaire using the word 'adjective', and this was used as quantitative numerical information. Commonly, semantic analysis has been mainly used as an effective method to psychologically measure and analyze human emotions. The semantic analysis method can be said to be a method of analyzing the difference in meaning. When evaluating an object, a pair of adjectives with opposite meanings is used as an evaluation item, and the degree to which it fits is divided into a step-by-step scale, and evaluated [39].

The influence of climate determines human lifestyles and forms of space, and as the form and structure of dwellings is completed, the impact of weather on human psychology is great. There is a life weather index that express the effect of weather on our lives in an easy-to-understand manner, such as the sensory temperature and the discomfort index. The sensory temperature indicates the degree to which a person actually feels hot or cold depending on the strength of the wind, humidity, and the degree of sunlight, while the discomfort index indicates that a person feels good or bad according to the temperature and humidity. Thus, it is necessary to construct a question using sensory adjectives for external stimuli, and to quantify the degree of sensation that humans feel in connection with a quantitative measurement value. Figure 5 shows the process of judging the comfort level of Hanok by using adjectival vocabulary that represents the inner state of human beings for warmth, noise, and brightness corresponding to temperature, illumination, noise, and air, which is the main stimulus environment for physical perceptive factors.

However, there is still no clear definition and distinction in relation to human emotions regarding the physical perceptive factors of Hanok. In addition, the terms or vocabulary reflect social and cultural aspects, and the nuances are slightly different between countries or regions, so it is not possible to accurately respond to a single term or vocabulary on a one-to-one basis. Moreover, in the process of cognitive processing, humans not only evaluate the information itself, that is, sensory input, collected when processing sensory information, but utilize the surrounding environment and previously formed experience or knowledge [40,41].

In this study, the degree to which humans feel comfortable in a Hanok interior was divided into senses, sensory images, and adjectives representing the degree of comfort, and questions were written for each item. Of course, this is insufficient to describe the degree of comfort using adjectival words for abstract concepts that cannot be evaluated quantitatively. However, it was created with the intention of overcoming the ambiguity of the concept and increasing objectivity by extracting the lower image constituting the sense

of comfort, and expressing the relationship between the lower image and the sensuous image in the form of a question as summarized by Figure 6.

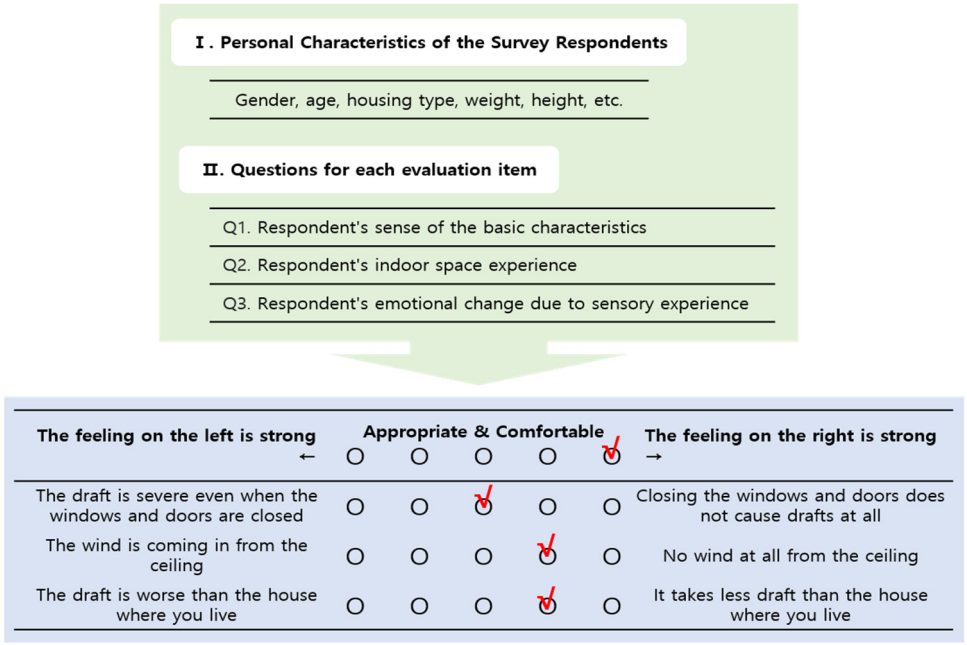


Figure 6. The basic structure of the questionnaire.

Among the target Hanok, a pilot test was conducted in April at Gangneung and Eunpyeong to verify the suitability and validity of the evaluation questionnaire, and the questionnaire was finally completed by supplementing the necessary information, form, order, and individual items. The questionnaire first arranged questions on personal characteristics, such as gender, age, type of residence, and whether the subjects feel comfort or discomfort in the indoor space of Hanok, and the causes of such comfort or discomfort. Next, three questions were written for each item for the subjects to respond to: the basic characteristics of the evaluation item, the degree of personal experience, and the change in personal sense.

2.4. On-Site Evaluation

In the field test, a user survey was conducted simultaneously with quantitative measurements. Measurements were made using the final test method after revising the evaluation method item-by-item as described in Table 3 through a pilot test. Temperature, humidity, and airflow information were collected through constant monitoring sensors installed inside and outside the target Hanok, which were used for analysis as shown on Figure 7. Through each in-depth interview, each item was explained so that the intention of the question could be understood, and the atmosphere was induced to freely present opinions. The psychological responses to each question were selected among the range of five categories using adjective vocabulary expressing human sensibility, and questionnaires were collected after sufficient time.

Table 3. Final test method for each evaluation item of physical perceptive factors.

Evaluation Item	Physical Perceptive Factors
	Measure Value through Final Test Method
Humidity Control	The difference in average absolute humidity between indoor and outdoor air (g/kg DA)
Air Permeability	Average airflow speed (m/s)
Air Cleanness	Average HCHO concentration in air ($\mu g/m^3$)
Condensation	Temperature difference ratio (TDR)
Insulation	Heat transmission rate (W/m^2 k)
Solar Radiation	Average inflow insolation (Wh/m^2)
Thermal Comfort	Average PMV value based on clo 0.7, met 1.2
Sound Insulation	Average noise by distance with window closure (dB A)
Solar Lighting	Satisfaction area ratio according to LEED v.4 standard (%)

Figure 7. Field measurements and survey photos.

3. Results

3.1. Physical Measurements

Measured values for each item were calculated through on-site measurements for the target Hanok, and a total of 793 valid questionnaire responses were collected through user surveys. Among all the collected data, the trends according to seasonal changes were analyzed by comparing them with each other, limited to Gangneung and Hwasun Hanok for residential use.

Gangneung Hanok is currently managed by local government, and is operated as a lodging facility used by unspecified people, so it was a place where universal and diverse parameters could be secured. In comparison, Hwasun Hanok is a place where real owners live, and it is meaningful in that it is a place where the trend of sensory change of specific respondents can be secured. Gangneung is located on the northeast coast of Korea, while Hwasun is located on the southwestern inland of Korea. Gangneung is an area where there is a lot of wind in spring, cooler in summer than other regions, and enjoys a lot of snow in winter. Hwasun is an area where there are many mountains and rivers, so the temperature is not high in summer, there is a lot of fog, and there is not much snow in winter. Table 4 shows that the two regions exhibited generally similar climate characteristics in terms of monthly average temperature and daylight hours, except for the temperature difference of 2–3 °C in summer.

Table 4. On-site measurements result (excluding unit) in Gangneung and Hwasun Hanok.

Evaluation Item	Physical Perceptive-Factors					
	Gangneung			Hwasun		
	Summer	Inter-Season	Winter	Summer	Inter-Season	Winter
Humidity Control	−3.9317	1.4235	1.0847	−0.5891	0.7560	1.3941
Air Permeability	0.09	0.02	0.02	0.07	0.03	0.03
Air Cleanness	0.0637	0	0	0.185	0.007	0
Condensation	-	0.18	0.19	0.26	0.29	0.29
Insulation	Wall 0.341, Roof 0.188, Floor 0.164			Wall 0.443, Roof 0.662, Floor 0.464		
Solar Radiation	66.07	174.79	85.31	71.52	297.06	262.24
Thermal Comfort	0.1	−0.73	−0.23	1.24	0.21	−1.31
Sound Insulation	-	35	35.65	-	32.85	30.975
Solar Lighting	55.7	48.26	42.7	44.88	48.37	36.77

Table 4 summarizes the on-site measurements for each item of the physical perceptive factors of Gangneung and Hwasun Hanok. Among the nine items, insulation is the performance of evaluating satisfaction by comparing the calculated values of the heat resistance and heat transmission rate of the wall, roof, and floor layers shown in the detailed drawings with regional standards, and the measured value was constant, regardless of seasonal changes. In spite of the geographic differences between Gangneung and Hwasun Hanok, similar climate characteristics were observed in the annual average temperature and daylight hours [42]. This trend was also confirmed by changes in the on-site measurements of Gangneung and Hwasun Hanok according to seasonal changes.

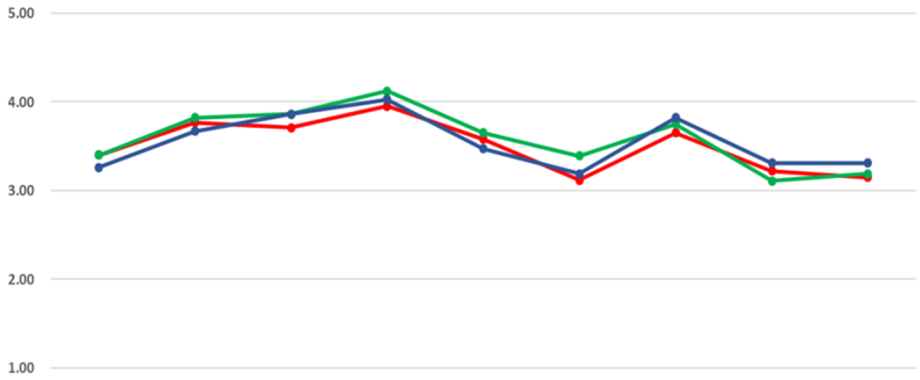
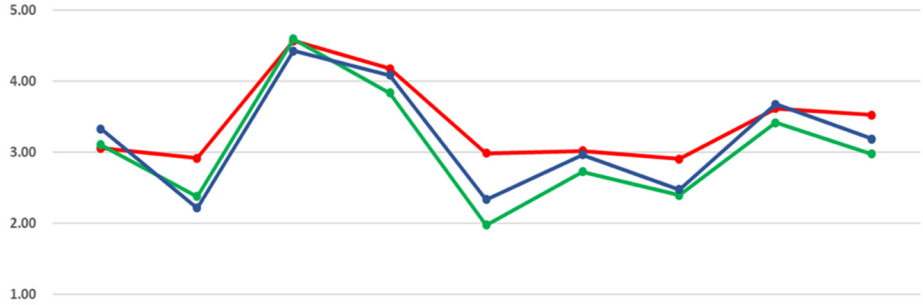
However, in the case of thermal comfort, there was a clear difference. Predicated mean vote (PMV), a traditional scientific evaluation method of comfort, was measured by quantitative analysis with physical data collection in relation to human comfort, such as clothing (CLO), metabolic rate (MET), and actual environmental clues monitored by sensing devices installed in Hanok. PMV comes from the balance of thermal equilibrium, which is a measure of physical health, and represents the average opinion of respondents on warm and cold sensations [43,44]. According to the international standard ISO 7730, it represents a pleasant state within the range (0.5 ± 0.5) [45]. In the case of Gangneung Hanok, it is generally included in the comfort range, because it is used as an accommodation facility that maintains mechanical cooling and heating. However, Hwasun Hanok appeared to feel a little hot or cold, except during the inter-season when mild weather was maintained.

3.2. Sensory Evaluation

Gangnung Hanok, based on the technology developed in the state-led R&D (research and development) project, was created with most of the characteristics of traditional Hanok, using locally produced materials and ingredients to add style and appearance. In addition, it was made to inform and experience the beauty of Hanok and traditional Korean culture to the public who long for life in Hanok. The building is located on flat land surrounded by mountains, and it faces a famous tourist attraction nearby, so it is a place with many users, and many respondents actively participated.

Hwasun Hanok was created as a new town construction project to attract people migrating from urban to rural areas by local government, and a traditional Hanok and a modern townhouse were built together. The building was located on the slope of a mountain 256 m above sea level, and responses to questionnaires were repeatedly obtained for each season from the actual residents. Table 5 shows the changes in user responses by season in Gangneung and Hwasun Hanok.

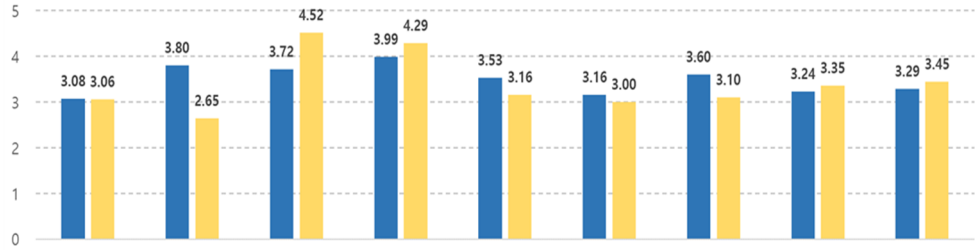
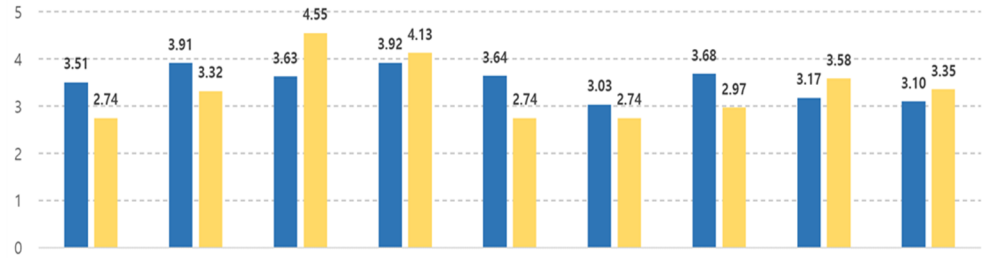
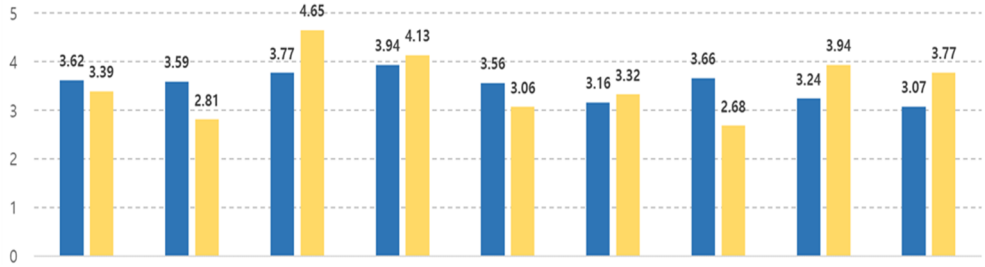
Table 5. Result of seasonal survey at Gangneung and Hwasun Hanok.

Target Hanok	Result of Seasonal Survey
Gangneung	
Hwasun	

In the case of Gangneung Hanok, almost similar responses were identified in each item, regardless of seasonal changes. There were many reactions to the effect that it was comfortable in all items during the inter-season, when the humidity in the air was lowered, and the sunny and refreshing weather was maintained. In the case of Hwasun Hanok, there were many responses to the effect that it was comfortable in all items in summer compared to other seasons, and this was meaningful in that it was a response to the building's performance without a separate mechanical device. In the inter-season and winter, which are the seasons that require heating, the response reactions were almost similar for each item. In particular, it was confirmed that the users' comfort responses were low in air permeability, insulation, and thermal comfort.

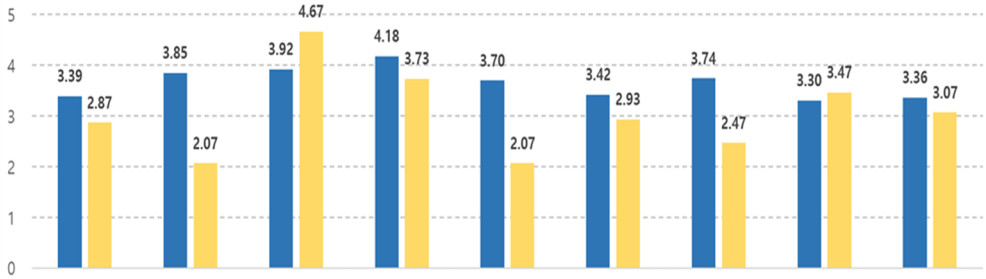
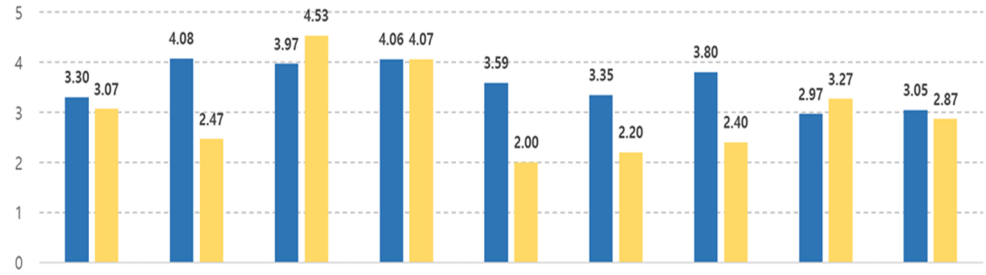
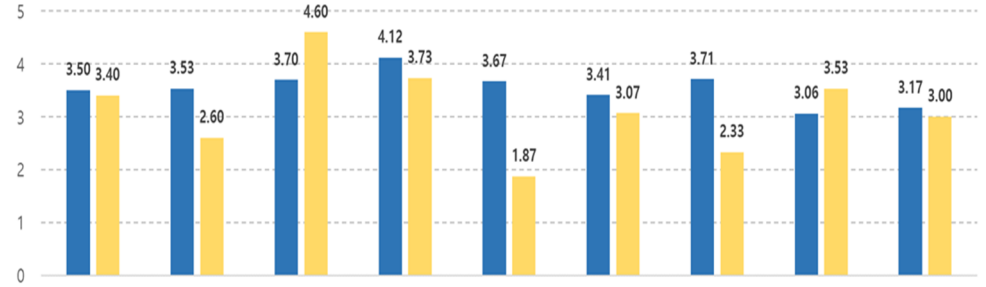
The majority of respondents evaluated the physical performance of Hanok as generally comfortable. In particular, in air cleanness, sound insulation, and solar lighting, it was evaluated that it was comfortable throughout the year, regardless of seasonal changes. However, in inter-season and winter, when there is a large temperature difference between day and night, there was a big difference between Hwasun and Gangneung Hanok in their ratings for air permeability, insulation, and thermal comfort. For Gangneung and Hwasun Hanok, the changes in user responses by questionnaire questions were classified by season, and examined. Table 6 summarizes the survey results of the summer.

Table 6. Survey results in summer at Gangneung and Hwasun Hanoks.

Number	Survey Results in Summer
Q1	
Q2	
Q3	

As a result of the survey, Hwasun scored higher than Gangneung in air cleanness, condensation, sound insulation, and solar lighting among the nine physical perceptive factors. In the case of air cleanness, Hwasun Hanok received a high rating of 4.5 or higher in all three questions, because the surrounding air was cleaner than Gangneung, which is located in the downtown area, because it is located under the mountain. In the case of condensation, Hwasun Hanok was evaluated as being comfortable compared to other seasons, because it is mostly living with windows open in summer, and Gangneung Hanok was evaluated relatively low, in that the temperature was controlled by air conditioner due to the surrounding conditions. In the case of sound insulation, Hwasun Hanok has a high sound insulation effect from adjacent buildings with a wide yard and fence, but Gangneung Hanok has a yard and a fence, but the difference in area and height affected the evaluation results. In the case of solar lighting, the daylight hours of Gangneung and Hwasun were almost the same, but it is judged that the results differ due to the influence of the eave length of Hwasun Hanok, and the sizes of windows and doors. Table 7 summarizes the inter-season survey results:

Table 7. Survey results in inter-season at Gangneung and Hwasun Hanoks.

Number	Survey Results in Summer
Q1	
Q2	
Q3	

Inter-season is a time when it is clear during the day, and the temperature drops at night, so the daily temperature difference between morning and evening is large. Therefore, it is easy to receive frost. Due to these climate characteristics, Gangneung Hanok was evaluated as relatively more comfortable than Hwasun in all items except air cleanness and sound insulation. With regards to insulation, it is judged that the discomfort reaction of respondents to the temperature influenced the results. Table 8 summarizes the winter survey results:

Table 8. Survey results in winter at Gangneung and Hwasun Hanoks.

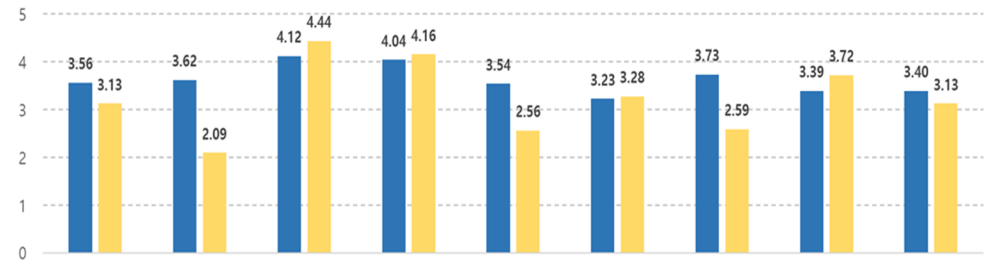
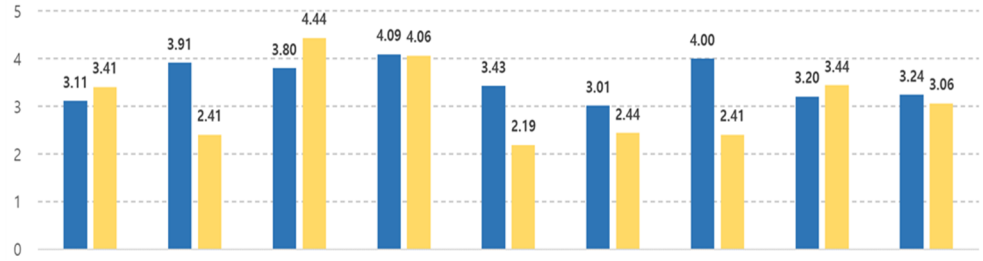
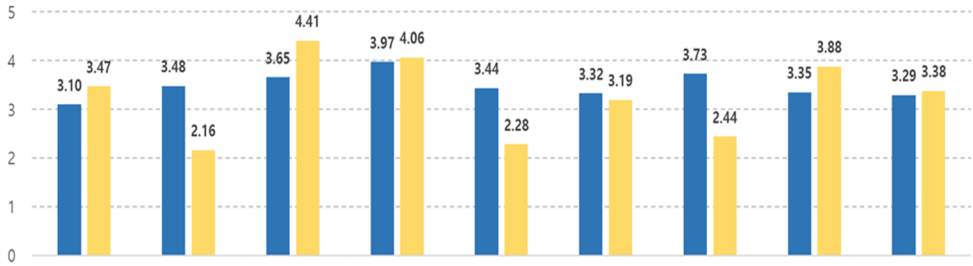
Number	Survey Results in Summer
Q1	

Table 8. *Cont.*

Number	Survey Results in Summer
Q2	
Q3	

In winter, the temperature difference between the inside and outside was large, showing a marked difference in air permeability, insulation, and thermal comfort. There is a common perception that Hanok is generally cold. However, for Gangneung Hanok, which was made as a result of R&D, participants responded that it was more comfortable compared to Hwasun, because it has supplemented these shortcomings by introducing a modernized wooden structure joining methods and adding more insulation.

3.3. Comparisions

Compared with Gangneung Hanok, which can secure universal and various parameters, Hwasun Hanok was able to secure repeated survey results by specific respondents. This was advantageous for comparing physical measurements and sensory evaluation results with each other. In this paper, the trends of changes in on-site measurements and questionnaires according to seasonal changes in Hwasun Hanok were compared. However, it is impossible to compare the measured values for each item on the nine items of physical perceptive factors and the results of the user survey in a one-to-one correspondence, because the units and variables for each item are all different. In addition, Insulation was excluded as having a constant value regardless of seasonal changes by calculating the heat resistance and heat transmission rate of each material shown in the detailed drawings. Sound insulation is a performance that is blocked by the external and internal structures in which noise enters, and it is a value that changes according to the site situation on the day of measurement, so only the user responses were compared as follows.

First of all, humidity control is a measure of the difference in the average absolute humidity of indoor and outdoor air collected through a constant monitoring sensor installed inside and outside the target Hanok. In summer, the difference in humidity was not large. However, as the outside temperature went down in winter, the indoor humidity rapidly changed and gradually increased. In comparison, the average value of the user's questionnaire was 3.06→3.11→3.33, with little difference in change. This is because the user operates heating devices according to the change of indoor humidity while living in

real life, so it is evident that the evaluation by the user's sense is prioritized, rather than the direct evaluation of the humidity control performance of the Hanok itself.

Air permeability is a measure of the amount of outside air flowing into the room, and the fluctuation of indoor airflow was affected by the change of external wind speed, and at this time, the user's senses were also affected at 2.92 → 2.38 → 2.22. Further, air cleanness is a measure of the concentration of formaldehyde (HCHO) in indoor air, and it did not affect the user's sensory evaluation in a fine amount below the standard value (0.17 ppm). Condensation judges the possibility of water droplets forming on the indoor surface in contact with the outside due to the temperature difference between the inside and outside, but the measurement space was limited to the living room, so condensation did not affect the user's sensory evaluation.

Solar radiation is a measure of the amount of radiant heat energy per unit area entering the room through simulation evaluation by a ray-tracing algorithm program. As the sun went from summer to winter, its altitude decreased, and the amount of direct solar radiation entering the room increased. The eaves that make up the facade of the Hanok and the Korean-style wooden floor acted as a buffer to control the amount of solar radiation entering the room, so the solar radiation did not affect the user's sensory evaluation. On the other hand, thermal comfort is a measure of the degree of thermal comfort in the room, and in ISO 7730, an international standard, PMV is evaluated as a comfortable state within the range (0.5 ± 0.5) [46].

PMV is quantified using integrated indicators that consider the parameters of the climate environment, MET, and CLO for work. This is used as an index that most accurately reflects the influence of physiological variables related to thermal comfort. The measured PMV of Hwasun Hanok changed from 1.24 → 0.21 → −1.31 when going from summer to winter. This effect was from Hwasun Hanok being located under a mountain, so the daily temperature difference was large compared to a flat region, so the users felt a little warm or a little cool. Even in an optimized thermal environment (PMV = 0), for a single thermal condition, 5% of users can be expected to be dissatisfied with the thermal environment. This is because the personal temperament and preferences of individuals vary. Therefore, the only way to further reduce PPD (predicted percentage of dissatisfied) is to individually control the thermal environment.

Sound insulation is a measure of the amount of noise entering the room from the outside. This was influenced by the external environment on the day of measurement rather than seasonal change, and did not affect user surveys. Solar lighting is a measure of the brightness of an indoor space caused by light entering through the windows. It was confirmed that the user's comfortable response also decreased as the illuminance decreased of the light flowing into the living room, which is the room mainly used.

The physical measurement values differed slightly according to the seasonal change, but accordingly, the user operated the indoor cooling and heating device and adjusted it to a certain level or higher, affecting the user's sensory evaluation, indicating that it was comfortable on average. In addition, the average value of the questionnaire was slightly different for each question, and the Q1 response to the sensory attribute showed a similar tendency, but the responses of Q2 and Q3 to the individual's experience and emotional change showed a difference from the measured value. Apart from the physical measurement, it was judged that humans' personal temperament and preferences were different, and personal experiences were accumulated to influence the evaluation.

4. Discussion; Innovation in Hanok, and Open Innovation

As stated in the previous research by Lee, unlike contemporary houses, where functionality for open innovation is often important, Hanok was formed by staying in one place, forming a village, and living together. In addition, the residents themselves have adjusted the space to fit their lifestyle and have maintained it efficiently. Therefore, Hanok is a space of life that contains a human-centric system of consciousness and thought, and it is an experiential space, not merely visual and formative [46]. Compared with previous studies,

this study is meaningful in that quantitative data were secured through a questionnaire on the psychological comfort of respondents according to seasonal changes. However, there is a limit to comparing the relationship between physical perceptive factors and sensory images on the same scale. The environmental variables for each item were different, and there were differences in the response of the respondents according to the weather changes on the measurement day, seasonal climate characteristics, and the questionnaire items.

In this regard, in evaluating Hanok, it is necessary to evaluate it comprehensively in consideration of history, tradition, place, image, memory, and symbolism. In other words, it is necessary to establish a multi-dimensional evaluation model in order to preserve the strengths, values, and performance factors of Hanok. Previous studies, however, show that there is a lack of complex interest in the integrated evaluation system and detailed guidelines in terms of sustainability toward open innovation including the spatial comfort. Lee and Park, in this sense, raised some critical issues for Hanok have emerged, such as narrow space dimensions and the layout for a modern lifestyle, poor insulation, weak fire resistance, expensive construction costs and so on, in comparison to contemporary buildings [47,48].

Jeong, Cheon and Han, on the other hand, raised another issue in maintenance and sustainability as a main factor of the traditional habitability, especially for Hanok. They emphasized that architecture has a duty in societies to preserve the past, provide the possibility of retaining the present on the strength of culture and tradition, and keep the performance by sufficient monitoring to see whether Hanok maintains its functions in the open dynamics accordingly [49]. Han, Lee, and Cheon also said that Hanok is a settlement space built according to the customs of residents who have lived in the local community from the past, and it is necessary to consider it by expanding its meaning to not only visual and physical characteristics, but also psychological and intrinsic space derived from them [50].

In comparison, this paper attempted to clarify the correlation between the quantitative values of the indoor environment and the human comfort satisfaction questionnaire in the process of finding a way to evaluate the comfort performance of Hanok. There was also a limit to comparing the relationship with quantitative measurements to the same scale. Despite these limitations, this paper is meaningful as an attempt to overcome the ambiguity of the concept and increase objectivity in which it secured a survey on the psychological comfort of respondents according to seasonal changes compared to previous studies for open innovation. It could also be contributive that the proposed methodology of the Hanok comfort evaluation has been proved to perform as an objective testing system associated with advanced certain indices for assessing Korean traditional buildings, based on official data collected over a long period of time targeted to representative specimens throughout the country.

In this regard, the results revealed through the evaluation using the proposed questionnaire may not actually reflect the intensity of the trait perceived by residents. There could be controversy, of course, among scholars, as to date, and this has not been fully verified through experiments and remained as an ongoing investigation for open dynamics [51,52]. In the future, factors that could affect the feeling of warmth, such as radiant heat and air currents, and quantification of the degree of clean air, will be developed into a more practical evaluation model with joint research with scholars and newly developed equipment, such as an emotion simulator. Continuous follow-up research is needed to develop an integrated performance evaluation model of Hanok based on the information accumulated through the research process of this paper.

5. Conclusions

Since evaluation using a questionnaire seems simpler than a measurement method using device analysis, it is frequently performed immediately after a short training process. However, the results calculated using the scale may not actually reflect the intensity of the trait perceived by humans. It is not an easy task for humans to detect and quantify

stimuli such as warmth and brightness, rather than clear visual and physical stimuli, such as length and thickness. There is controversy among scholars, as to date, this has not been fully verified through experiments.

To construct a system that creates a pleasant environment, it is necessary to grasp and apply the individual's senses and patterns according to the daily indoor environment conditions. In addition, effective and objective various approaches are needed to grasp complex human emotions. However, despite efforts to realize a comfortable indoor environment, there are many difficulties in evaluating human emotions individually and quantitatively. Human sensibility is determined by the relationship with the environment surrounding humans, and it is necessary to comprehensively evaluate emotional value through the accumulation of data on psychological satisfaction and establishment of quantitative evaluation methods in consideration of human individuality. Therefore, to correctly interpret the collected information, it is necessary to use the measurement method specified in KS to compare and analyze the physical numerical results.

In this paper, a method of verifying the hypothesis through correlation analysis was used in order to understand some relations between quantitative measurement and sensorial evaluation. However, statistical significance does not always indicate practical importance meaning the results cannot be applied to real situations. In addition, statistical significance might be misinterpreted when researchers do not use language carefully in reporting their results. That is, a strong correlation with one another does not imply a situation of the causation with just two collected data sets. In this point of view, statistical significance can help discern whether one evaluation model is better than another. Of course, it is necessary to expand to different contexts and to groups of volunteers characterized by other age demographics, geographic distributions, or background skills for more reliable experimental surveys. It should continue to be conducted by using a more detailed questionnaire about user senses for each factor. In other words, it is required to build a larger database and further analyze more target Hanoks. Thus, it would be desirable to determine whether the same pattern continues to appear, and to develop a simple tool for evaluating Hanok performance based on statistical ratios and characteristics.

This study was conducted as a process of efforts to discover the possibility of modern form and spatial coordination of Hanok as an eco-friendly and sustainable building as a form of vernacular housing in Korea. A home is a place that controls the physical environment and subjective psychological state at the same time, and it is necessary to comprehensively evaluate the psychology of the residents living there, as well as the quantitative evaluation by measurement. This paper presented a method to assess the psychological state of users there on physical perceptual elements of the indoor space using a questionnaire. In addition, quantitative figures and questionnaire data were collected and analyzed through a long-term monitoring process targeting the actual Hanok that current residents used or lived in. In other words, this research tried to find a more complete and holistic evaluation method using both quantitative measurements of the property and qualitative interviews with users.

Continuous follow-up research studies are definitely needed to develop an integrated performance evaluation model of Hanok based on the information accumulated through the research process suggested by this paper. In the future, comfort factors affecting the feeling of warmth, such as radiant heat and air currents, and quantification of the degree of clean air, will be employed into a more practical evaluation model with joint research with scholars and newly developed equipment, such as an emotion simulator. If the unique evaluation model of the Hanok is presented through this cross-validation process, it will be possible to explore the architectural role of the Hanok with cultural identity, while securing the function of modern buildings. In addition, as such research continues, it is expected that it will be able to contribute to the housing welfare of people by gaining momentum in the dissemination and popularization of Hanok that have advantages as vernacular housing.

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References

1. Kwon, Y.-G. Discussion of Globalization and Cultural Identity. *Ind. Des.* **1995**, *138*, 2–8.
2. Kim, Y.-G. *The Theory of the Native Design*; Design Net: Gyeonggi-do, Korea, 2000.
3. Oliver, P. *Built to Meet Needs: Cultural Issues in Vernacular Architecture*; Architectural Press: Oxford, UK, 2006.
4. Ghisleni, C. Examples of Vernacular Housing. Available online: https://www.archdaily.com/951667/what-is-vernacular-architecture (accessed on 3 October 2021).
5. Rodofsky, B. *Architecture without Architects*; University of New Mexico Press: Santa Fe, NM, USA, 1964.
6. Nash, C. *Contemporary Vernacular Design: How British Housing Can Rediscover Its Soul*; RIBA Publishing: London, UK, 2016.
7. Atroshenko, V.I.; Grundy, M. *Mediterranean Vernacular: A Vanishing Architectural Tradition*; Rizzoli: New York, NY, USA, 1991.
8. Jeong, Y.-B. *Understanding Hanok and Its Story*; Munundang: Seoul, Korea, 2016.
9. Hanok Space Research Association. *Space Culture of Hanok*; Kyomunsa: Seoul, Korea, 2004.
10. Park, M.-D. *Hanok*; Salim: Seoul, Korea, 2005.
11. Jaffari, S.D.; Matthews, B. From occupying to inhabiting—A change in conceptualizing comfort. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2009. Available online: http://iopscience.iop.org (accessed on 28 September 2021).
12. Godoy-Vaca, L.; Vallejo-Coral, E.C.; Martínez-Gómez, J.; Orozco, M.; Villacreses, G. Predicted Medium Vote Thermal Comfort Analysis Applying Energy Simulations with Phase Change Materials for Very Hot-Humid Climates in Social Housing in Ecuador. *Sustainability* **2021**, *13*, 1257. [CrossRef]
13. Beltrán, R.D.; Martínez-Gómez, J. Analysis of Phase Change Materials (PCM) for Building Wallboards Based on the Effect of Environment. *J. Build. Eng.* **2019**, *24*, 1–7. [CrossRef]
14. Raporort, A. *House Form and Culture*; Prentice-Hall Inc.: Englewood Cliffs, NJ, USA, 1969.
15. World Health Organization. *The Work of WHO, 1961: Annual Report of the Director-General to the World Health Assembly and to the United Nations Covering the Period 1 October–31 December 1961*; World Health Organization: Geneva, Switzerland, 1962.
16. Organization for Economic Cooperation and Development. Compendium of OECD Well-Being Indicators: Housing 2011. Available online: https://www.oecd.org/sdd/47918045.pdf (accessed on 18 March 2021).
17. The City and County of San Francisco. *Housing Code 2019 Edition*; American Legal Publishing Corporation: Cincinnati, OH, USA, 2020.
18. Korean Agency for Technology and Standards. Korean Industrial Standards. Available online: https://www.standard.go.kr/KSCI/ (accessed on 18 March 2021).
19. Lee, M.-H.; Cheon, D.-Y.; Han, S.-H. A Technical Assessment of Comfort Performance of Hanok Using Comparative Field Surveys between Experts and Users. *Sustainability* **2020**, *12*, 10315. [CrossRef]
20. Baron, R.M.; Kenny, D.A. The Moderator–Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *J. Personal. Soc. Psychol.* **1986**, *51*, 1173–1182. [CrossRef]
21. Jones, L.V.; Peryam, D.R.; Thurstone, L.L. Development of a Scale for Measuring Soldier's Food Preferences. *J. Food Sci.* **1955**, *20*, 512–520. [CrossRef]
22. Lim, J. Hedonic Scaling: A Review of Methods and Theory. *Food Qual. Prefer.* **2011**, *22*, 733–747. [CrossRef]
23. Lawless, H.T.; Heymann, H. *Sensory Evaluation of Food: Principles and Practices*; Springer: Berlin/Heidelberg, Germany, 2010.

24. Newsham, G.; Veitch, J. *Cost-Effective Open-Plan Environments Project (COPE)*; National Research Council (NRC): Ottawa, ON, Canada, 2009.
25. Preiser, W. *Learning from Our Buildings: A State-of-the-Practice Summary of Post-Occupancy Evaluation*; National Academies Press: Ottawa, ON, Canada, 2002; Volume 145.
26. Choi, J.-H.; Loftness, V.; Aziz, A. Post-occupancy Evaluation of 20 Office Buildings as Basis for Future IEQ Standards and Guidelines. *Energy Build.* **2012**, *46*, 167–175. [CrossRef]
27. Creswell, J.W. *Research Design: Qualitative. Quantitative, and Mixed Methods Approaches*; SAGE Publications: New York, NY, USA, 2013.
28. Michell, J. *An Introduction to the Logic of Psychological Measurement*; Lawrence Erlbaum Associates Inc.: Mahwah, NJ, USA, 1990.
29. Bartlett, R.J. Measurement in Psychology. *Adv. Sci.* **1940**, *1*, 422–441. [CrossRef]
30. Stevens, S.S. On the Theory of Scales of Measurement. *Science* **1946**, *103*, 677–680. [CrossRef]
31. Knapp, T.R. Treating Ordinal Scales as Interval Scales: An Attempt to Resolve the Controversy. *Nurs. Res.* **1990**, *39*, 121–123. [CrossRef]
32. Peeters, M.J. Measuring Rater Judgments within Learning Assessments, Part 1: Why the Number of Categories Matter in a Rating Scale. *Curr. Pharm. Teach. Learn.* **2015**, *7*, 656–661. [CrossRef]
33. Borg, G. *A Category Scale with Ratio Properties for Intermodal and Inter-Individual Comparisons: Psychophysical Judgment and the Process of Perception*; North-Holland Publishing Company: Amsterdam, The Netherlands, 1982; pp. 25–34.
34. Luce, R.D.; Krumhansl, C.L. *Measurement, Scaling, and Psychophysics: Steven's Handbook of Experimental Psychology*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 1988; pp. 3–73.
35. Lawless, H.T. Contextual Effect in Category Ratings. *J. Test. Eval.* **1983**, *11*, 346–349.
36. Frank, R.A.; Klaauw, N.J.; Schifferstein, H.N. Both Perceptual and Conceptual Factors Influence Taste-Odor and Taste-Taste Interactions. *Percept. Psychophys.* **1984**, *54*, 343–353. [CrossRef]
37. Diamond, J.; Lawless, H.T. Context Effects and Reference Standards with Magnitude Estimation and the Labeled Magnitude Scale. *J. Sens. Stud.* **2001**, *16*, 1–10. [CrossRef]
38. DeVellis, R.F. *Scale Development: Theory and Applications*; SAGE Publications: New York, NY, USA, 2003.
39. Philipp, D. Semantic Network Analysis as a Method for Visual Text Analytics. *Procedia Soc. Behav. Sci.* **2013**, *79*, 4–17.
40. Nagamachi, M. Kansei Engineering: A New Ergonomic Consumer-Oriented Technology for Product Development. *Int. J. Ind. Ergon.* **1995**, *15*, 3–11. [CrossRef]
41. Kiyoshi, F.; Hiroshi, K.; Yoshihisa, F.; Hirokazu, G. Human Sensory Perception Oriented Image Processing in a Color Copy System. *Int. J. Ind. Ergon.* **1995**, *15*, 63–74.
42. National Centers for Environmental Information. Assessing the Global Climate in October 2021. Available online: https://www.ncei.noaa.gov/news/global-climate-202110 (accessed on 22 March 2021).
43. Fanger, P.O. *Thermal Comfort: Analysis and Applications in Environmental Engineering*; Danish Technical Press: Copenhagen, Denmark, 1970.
44. Kim, J.; Cho, A. Analysis of a structure between comfort feeling and sensibility in indoor environment by using fuzzy inference. In Proceedings of the Korean Society for Emotion and Sensibility Conference, Incheon, Korea, 11 April 1998; Korean Society for Emotion and Sensibility: Daejeon, Korea, 1998; pp. 121–126.
45. International Standard Organization. *Moderate Thermal Environments: Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort*; International Organization for Standardization: Geneva, Switzerland, 1984.
46. Lee, M.H. Implementation of an Evaluation Model for the Habitability Performance of Hanok. Ph.D. Thesis, Chonnam National University, Kwangju, Korea, April 2019.
47. Lee, J.; Park, J. Phase Change Material (PCM) Application in a Modernized Korean Traditional House (Hanok). *Sustainability* **2018**, *10*, 948. [CrossRef]
48. Kim, G.-E.; Lee, J.-R. The Impact of Historic Building Preservation in Urban Economics: Focusing on Accommodation Prices in Jeonju Hanok Village, South Korea. *Sustainability* **2020**, *12*, 5005. [CrossRef]
49. Jeong, J.-H.; Cheon, D.-Y.; Han, S.-H. A Better Maintenance Strategy, a More Sustainable Hanok: Towards Korean Traditional Public Facilities. *Buildings* **2019**, *9*, 11. [CrossRef]
50. Han, S.-H.; Lee, M.-H.; Cheon, D.-Y. Assessment Indexes for Habitability Performances Applicable to Hanok Focused on Household Types. *KIEAE J.* **2018**, *18*, 5–14.
51. Robbins, P. From Design Thinking to Art Thinking with an Open Innovation Perspective—A Case Study of How Art Thinking Rescued a Cultural Institution in Dublin. *J. Open Innov. Technol. Mark. Complex.* **2018**, *4*, 57. [CrossRef]
52. Ryu, D.; Baek, K.H.; Yoon, J. Open Innovation with Relational Capital, Technological Innovation Capital, and International Performance in SMEs. *Sustainability* **2021**, *13*, 3418. [CrossRef]