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Field Study on Nationality Differences in Thermal Comfort of University Students in Dormitories during Winter in Japan

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Abstract: Comfort in university dormitory buildings in Japan is under-investigated as compared to offices and residences. A winter field survey conducted in two university dormitories in Central Japan aimed at investigating the differences in thermal responses of occupants relative to nationality and; to estimate their neutral and comfortable temperature under identical climatic conditions. Acceptability of the indoor environment was invariably high. While evaluation and preference votes depended on nationality; thermal sensation vote did not. Both Japanese and non-Japanese subjects voted neutral at a mean indoor temperature of 22 °C. The estimated probability of voting neutral for Japanese subjects was highest (65%) from 19 °C to 22 °C, while for non-Japanese subjects it was highest (75%) at a wider range: From 19 °C to 24 °C. Japanese students were more sensitive of and more critical about their indoor environment as opposed to the internationals (adjusted regression coefficients 0.55/K and 0.20/K). Griffiths' model estimated the comfortable temperature for non-Japanese subjects at a 2 °C wider range and at a 2 °C higher average than for Japanese subject. Neutral and comfortable temperatures observed and estimated in the study were split above and below the recommended temperature threshold of 20 °C for Japan in winter.

Keywords: dormitory buildings; field survey; winter season; neutrality; comfort

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1. Introduction

Buildings' energy consumption increases in contemporary society with the increasing demand for comfort and the affordability of air-conditioning. With people spending over 80% of their time indoors, providing quality indoor environment becomes essential for maintaining health and productivity. The concept of providing thermal comfort has been approached differently by scientists leading to the establishment of the two main models—the static and the adaptive. Initially considered irreconcilable, they have been proven to complement each other in understanding human comfort. While static model focuses on physics and physiology and is founded on the theory of thermal balance between a body and its environment, the adaptive model accounts for the psychological and behavioral aspects as well. The static model was defined in the 70 s [1,2], and it assumes the occupant is mostly passive to the indoor environment; that the comfortable conditions are the same irrespective of building type, climate or location; that they are fixed within a narrow band of temperature and they should be provided to the occupant by all technological means available for environmental control. Thus, the static model might recommend unnecessarily excessive energy consumption and ignore personal preferences and more energy-conserving building solutions. The need for energy conservation and efficient energy use, however, has become unquestionable, as well as the certainty that it should not be achieved at the expense of progress or quality of living. Japan's energy demand depends on more than 80% on import. Under the concept of the adaptive model more diverse energy-conserving building, solutions can be implemented as the model acknowledges that comfort can be achieved under variable conditions, in a much wider range of temperature; that it depends on cultural, climatic and social factors and it allows for personal control. The development of the model started in the 30 s even though its formal definition was coined in the 70 s [3,4]. It states that "given the opportunity, the occupants will make themselves comfortable" by being active to the indoor environment and adapting—either behaviorally, physiologically or psychologically [5,6].

In the globalized world, it becomes common for people to live outside of their native countries under new cultural and climatic conditions but with their native expectations and habits. The phenomenon can be broadly observed in Japan. It is challenging the existing and the newly designed buildings for multi-national occupancy, which now must provide for a diverse subjective understanding of comfort and still maintain low energy consumption. To tackle the issue, it is necessary to determine what does comfort mean in terms of the temperature range for non-Japanese people and what are the differences.

Buildings for temporary occupancy as dormitories in Japan are likely to demonstrate the actual preference of their occupants as: (1) Students live in private rooms where immediate social restraints are practically non-existent with the exception for the habitual or culturally predetermined ones; (2) the rooms are relatively small so no matter the energy consumption, the final financial burden cannot get excessive; and (3) the occupants are young and assumingly still developing their finance managing attitude, so their indoor environment setting is expected to represent more genuinely their subjective preference. Dormitories in Japan will keep increasing the number of their non-Japanese occupants relative to Japan's aim of internationalization of the universities [7]. However, dormitories can never be as flexible as necessary to accommodate the ever-changing residents. In dormitories in Japan, non-Japanese students live less than a year, sometimes even only several months and their prior climate history is from all around the world. Air-conditioning can provide a solution, however, at the cost of high energy consumption and subsequently CO_2 emissions. Japan's strong resolution towards energy efficiency and conservation, as well as its determination to increase the number of international students, poses the question of how to simultaneously address both issues. As a result, a study on neutral and comfortable indoor conditions for Japanese and non-Japanese students in dormitories seems relevant and timely.

The adaptive comfort studies in Japan are extensive. Mainly, researchers investigated the comfort in Japanese offices [8–11] in summer, because the hot and humid summers in Japan present a challenge regarding achieving thermal comfort. More limited is the research in residential buildings [12–14], or throughout several seasons [12–17]. The subjects of the studies are usually Japanese [10,11,13,15,17], and comparison relative to nationality under the same climatic conditions is difficult. Indraganti et al. [9] used a limited number of non-Japanese votes as part of their dataset, but did not focus on the differences relative to nationality. Nakano et al. [16] investigated the difference based on nationality, but the survey was conducted in an office building. Dormitory buildings present an interesting combination of a residence and office where the neutrality and comfort might be different; and being occupied by many international students, the differences based on nationality can be observed. A type of housing similar to a dormitory are temporary houses, where Shinohara et al. [18] investigated thermal comfort and air quality for three seasons, however, among Japanese subjects only. Dormitory buildings in Japan have come into the focus of the research of Schweiker and Shukuya who investigated the potential for energy saving in building envelope improvements as compared to change in occupants' behavioral pattern [19]; the effectiveness of various methods of stimulating an informed change in occupants behavior [20], as well as the occupant-window interaction and its effect on exergy consumption rate [21]. However, dormitories and the effect of nationality on neutral and comfortable temperatures there, have remained off the main focus of the researchers in Japan.

On the contrary, in China, dormitory buildings have been intensively investigated in summer, in winter and throughout an entire year [22–26]. It is worth reciprocating similar research in Japan as well.

2. Methodology

2.1. Location and Climate

Toyohashi is located in the southeastern part of Aichi Prefecture (central part of the main Honshu island, on the Pacific Ocean side). The climate is classified as Cfa by the Köppen-Geiger climate classification system [27,28]. It is mild, generally warm and temperate. There is limited to no snowfall during the winter season. The data used for winter 2017–2018 was provided by the Japan Meteorological Data Agency (JMA) from WMO ID:47654 (weather meteorological observation point) [29]. This WMO is located 35 km to the northeast of Toyohashi at a similar distance from the Pacific coastline. The mean monthly outside temperature reached its minimum in January ($T_{avg.}$ = 5.5 °C; $T_{min.}$ = 1.7 °C; $T_{max.}$ = 9.7 °C). The mean relative humidity reached its minimum of 51% in February (Figure 1).

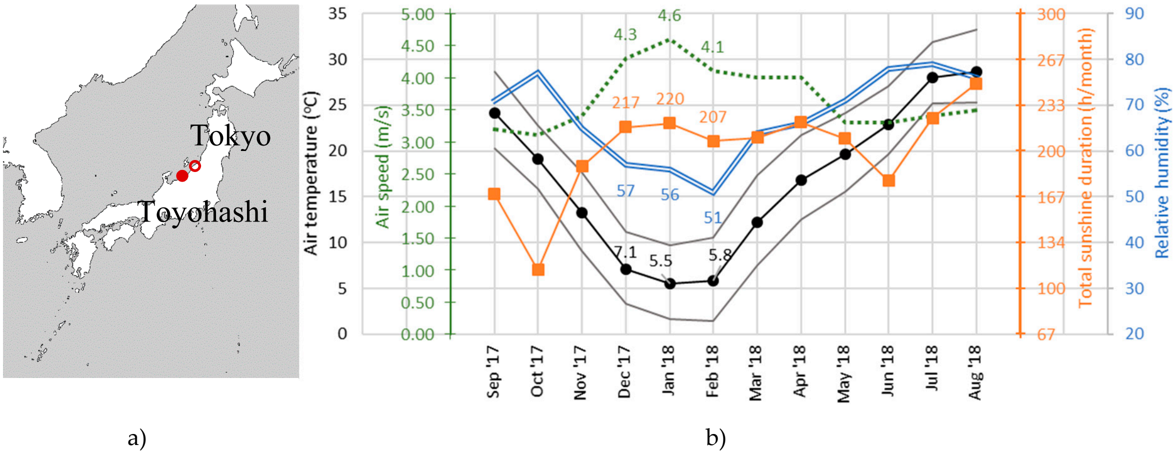


Figure 1. Toyohashi, Japan. (**a**) Location; (**b**) climate. Data from JMA WMO ID: 47654—min, max and mean air temperature and relative humidity for winter season 2017–2018.

2.2. Measuring Period

In Toyohashi, the residents experience two opposing climate conditions within a year—peak humidity and temperature in summer and their lowest values in winter. The survey was conducted in both periods, and the current paper presents the winter findings. The winter stage of the field survey was conducted in 2017 and 2018 (from December 5, 2017, to February 2, 2018). The targeted period was the winter. The period was divided into three sub-periods. Each sub-period consisted of two weeks of measurements (sub-period 1: 12/5~12/15; sub-period 2: 12/18~1/19; sub-period 3: 1/22~2/2). The weeks of the survey were not sequential to better adjust to the academic calendar and students' lifestyle. Within each week, the measurements were taken during the normal working days, from Monday to Friday (Section 2.4).

2.3. Dormitory Buildings and Sample Selection

The survey was conducted in two dormitory buildings: International dormitory (Kaikan) and the newly built dormitory for Japanese and international students (GSD—Global students' dormitory) in Toyohashi University of Technology, Japan (TUT) [30]. The population of interest was represented by a sample from the international students currently residing in Kaikan and in GSD. In both dormitories, the students were living in private rooms. The heating source was separate for each room air conditioner, split system, with heating, cooling and dehumidifying operation modes. The inner body was installed at 2.0–2.2 m from the floor.

The subjects sample consisted of Japanese and non-Japanese students currently residing in the two dormitories. We targeted the same number of participants from both buildings (sample stratified by residence). However, within each building, we worked with volunteering students (convenient sample) [31]. As a limitation to the study should be noted that there was a quota of a maximum ten participants from a dormitory.

2.4. Field Survey, Data Collection and Analysis

The field survey was designed as a longitudinal (repeated sampling of a limited number of subjects). The time difference between answers collected was usually more than 3–4 h, and often 6–10 h. Because of that sizeable time-difference, the data was analyzed as from cross-sectional research (singular sampling of many subjects). This approach has been used before in previous studies [26].

At the beginning of each measuring week, a set of paper questionnaires was provided to each volunteer in their preferred language—Japanese or English. The general questionnaire (2 in Figure 2) collected information about the country of origin, sex, age, and past climate history. It was to be completed at the beginning of the first measuring week. Description of the information from the general questionnaire is presented in Figure 3. The subjects were asked to fill in the indoor environment questionnaire several times per day—mandatory at waking up and at bedtime (3 in Figure 2); and optional at breakfast, at noon and at dinnertime (3* in Figure 2).

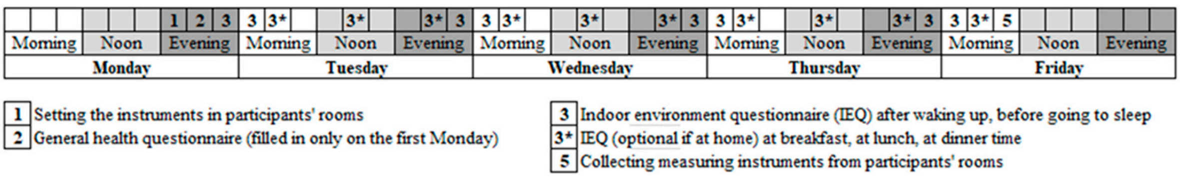


Figure 2. Week 1—Events schedule (**Each volunteer participated three non-sequential weeks).

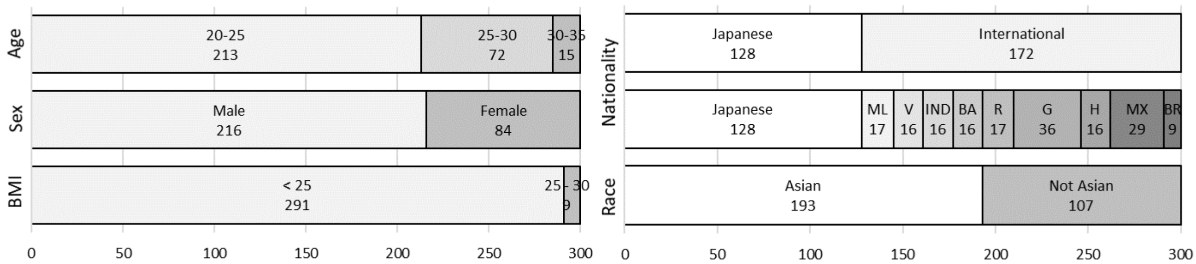


Figure 3. Population sample—Number of votes: Distribution relative to age, sex, nationality, race and BMI. ** ML (Malaysian); V (Vietnamese); IND (Indonesian); BA (Bangladeshi); MX (Mexican); G (German); BR (Brazilian); H (Hungarian); R (Russian).

The subjective thermal votes were collected using the recommended scales and wording of the questions in ISO 10551: 2003 (E) for assessment of thermal environment using subjective, judgmental scales [32], and in ANSI/ASHRAE 55 [33]. The associated questions were:

- TSV (thermal sensation vote): "How do you feel about thermal environment at this precise moment in your room?"
- TC (thermal comfort/evaluation vote): "How do you find the thermal environment in your room?"
- TP (thermal preference vote): "Please, state how would you prefer to be now?"
- TA (thermal acceptability vote): "How do you judge the thermal environment?"

The wording for each point on the scale of the thermal responses is presented in Table 4.

The subjects were asked to state their activity and clothing at the time of each vote. A list of reference clothing and physical activity was provided to facilitate the description (see Appendices A and B). The participants were advised to fill in the indoor environmental questionnaire after spending at least thirty minutes indoors for proper acclimation. The current study highly depended on the subjects' responsibility as they were to complete the questionnaires unattended at their own convenient time. However, test markers were included to ensure quality of the votes—for example, some typical outdoor activities. This way, the small percentage of votes stating less than twenty minutes spent indoors prior to voting were excluded. Occupant behavior was marked by the participants on a list provided and recorded in binary form.

Measurements of the indoor and outdoor air temperature and relative humidity were continuous at one-minute intervals from Monday to Friday (measuring devices listed in Table 1). Globe temperature was not measured, and it is considered as a limitation to the current study. However, the correlation between the indoor air temperature and globe temperature is invariably very strong, as reported by other researchers in various buildings [10,13,15]. Furthermore, it has been stated that simple air temperature can be used in long term measurements provided that there are no large hot/ cold surfaces [34]. The measuring devices were placed in each individual room at the desk at height, assuming sedentary activity. The height of the data loggers was within the acceptable range of 0.6~1.1 m above the floor in the living room [35]. The air velocity was measured close to the bed. However, almost all of air velocity measurements observed at the time of the valid votes were close to 0.0 m/s—suggesting still air. A value of 0.1 m/s for the air velocity was used to conduct all necessary calculations.

Table 1. Measuring devices.

Name	**Type**	**Parameter**	**Range and Accuracy**	**Image**	**Notes**
Thermo-hygrometer	TR-74Ui ISA-3151 sensor THA-3151 sensor	Air temperature Relative humidity Illuminance	0–55 °C (±0.5 °C) 10–95 %RH (±5%) 0–130klx (±5%)		Continuous measurement (1-min interval)
Air Flow Transducer	6332D (KANOMAX probe/VR-71 data logger)	Air Speed	0.1~25.0 m/s (±3%)		Continuous measurement (1-min interval)

The collected data was analyzed using Microsoft Excel and its add-in tool Data Analysis, as well as the add-in application XLstat, developed by Addinsoft (https://www.xlstat.com/en/company/about-us). The algorithm for analysis and calculations followed the explanation by Humphreys et al. [4].

2.5. Analysis Sequence

The structure of the analysis conducted, was as follows: First, indoor conditions defined as "neutral" were analyzed in relation to the outdoor conditions. The set of four subjective thermal responses (TSV, TC, TP, and TA) was listed, distributed and correlated to outdoor conditions, to one another, as well as to indoor conditions. The logistic regression of sensation vote and indoor air temperature was conducted to obtain a range of temperature within which the expected probability of voting neutral was the highest. The linear regression of sensation vote and indoor air temperature was conducted to obtain a single value for neutral temperature. The influence on TSV of other factors, such as humidity, clothing and activity was checked using multiple regression. Finally, the Griffiths method was used to calculate the comfortable temperature, which was then compared to the values of actually voted comfortable temperature. The results from our study were corelated to international standards and previous research in the field.

3. Results and Discussion

3.1. Participants

In the winter stage of the survey, 19 healthy, Japanese and international students from 20 to 30 years of age volunteered to participate (males: M = 24.6, SD = 3.5; females: M = 22.2, SD = 1.5). More than 90% of the participants' body mass index (BMI) was in the normal zone (M = 22.2, SD = 2.0). The total number of volunteers, sex, age, nationality, race and BMI distribution is presented in Figure 3.

3.2. Indoor and Outdoor Environment during the Voting

The subjects were asked to mark the time of their vote. This time was then set to the closest fifteen minutes. The physical data about indoor and outdoor temperature (T_i, T_{out}) and relative humidity (RH_i, RH_o) was recorded every minute. To match both the subjective and objective data, the physical data was divided into fifteen-minute periods, the average values of each period were calculated, and the value from the matching time of vote was used. During the wintertime study, a total of 172 questionnaires in Kaikan and 152 questionnaires in GSD were collected. As valid are considered these votes, at which there was a physical record of temperature and humidity indoors and out, as well as the set of four votes (sensation, comfort, preference and acceptability). In addition, there were no outdoor activities stated, or there were, they were less than ten minutes within the last thirty minutes prior to voting. Considering the above, 300 valid votes were collected in winter.

The daily mean outdoor temperature (T_{od}) was provided online by JMA [29]. Exponentially weighted running mean of the daily outdoor temperature (T_{rm}) was calculated using the formula given by Humphreys and Nicol [36], and the EN 16798-1 [34].

$$T_{rm(t)} = (1 - \alpha)\left(T_{t-1} + \alpha T_{t-2} + \alpha^2 T_{t-2} + \ldots + \alpha^{n-1} T_{t-n}\right) \quad (1)$$

where $T_{rm\,(t)}$ is the running mean temperature at a certain time-period, currently a day (°C); α is 0.8 constant estimating the effect of past temperatures; T_{t-i} is the temperature i periods before the calculated one (°C); n is number of the periods back.

The questionnaires distributed to the subjects contained a short list of clothing and activities, and the subjects were asked to mark all the items they were wearing at the time of vote and the percentage of each activity within the last thirty minutes prior to voting. The I_{cl} and M values for clothing insulation and activity level were assigned according to ASHRAE [33], and presented in Appendix B (Tables A1 and A2). The numerical results at the times of vote are presented in Table 2. Variations in indoor temperature and absolute humidity were higher than outdoors, while for the relative humidity it was the opposite.

Table 2. Descriptive statistics of the collected data at times of vote.

	T_i (°C)	T_{out} (°C)	T_{od} (°C)	T_{rm} (°C)	RH_i (%)	RH_o (%)	V_a (m/s) **	AH_i (kg/kg_{DA})	AH_o (kg/kg_{DA})	I_{cl} (clo)	M (met)	BMI (kg/m^2)
Min	9.8	−2.9	−0.3	1.2	21	25	0.001	0.003	0.001	0.36	1.0	19.4
Max	33.7	14.8	10.8	7.9	98	100	0.425	0.011	0.009	2.11	2.7	27.8
Mean	19.6	4.2	4.7	4.4	47	66	0.032	0.007	0.003	0.63	1.3	22.2
St. D	4.7	3.7	2.6	1.5	14	18	0.063	0.002	0.001	0.23	0.4	2.0

NOTE: Number of observations N = 300; T_i: Indoor temperature (°C); T_{out}: Outdoor daily mean temperature (°C); T_{od}: Outdoor daily mean temperature (°C); T_{rm}: Outdoor daily running mean temperature (°C); RH_i: Indoor relative humidity (%); RH_o: Outdoor relative humidity (%); AH_i: Indoor absolute humidity (kg/kg_{DA}); AH_o: Outdoor absolute humidity (kg/kg_{DA}); V_a: air velocity (m/s); I_{cl}: clothing insulation (clo) where 1clo = 0.155 m^2K/W; M: activity level (met) where 1met = 58.2 W/m^2; BMI: Body mass index (kg/m^2) ** The observed values of air velocity were outside the measurement range, that is why they were set to 0.1 m/s.

Extended "neutral" is the parameter when the subjects voted TSV = −1, 0, +1. There was no significant correlation between the indoor neutral temperature (T_n) and the outdoor temperature (Table 3, Figure 4), irrespective of whether it was the measured outdoor value, the daily mean or the daily running mean. It was surprising to observe such disconnection from the local climate. It is foundational assumption in the adaptive model theory, and extensive studies have supported it. For example, in residential buildings in China, Li et al. [37] reported very strong sensitivity to climate in the zones with severe cold and cold winter (0.471/K, 0.660/K) and even stronger in the zones with hot summer and cold winter (0.748/K, 0.739/K). Similar are the results by Yan et al. [38].

Table 3. Correlation coefficients.

	All Data Points (N = 189)					Japanese (N = 75)					International (N = 114)				
	r	*a*	β	R^2	p	r	*a*	β	R^2	p	r	*a*	β	R^2	p
T_n: T_{out}	−0.04	−0.040	20.3	0.001	0.619	−0.02	−0.022	19.2	0.001	0.843	−0.09	−0.102	21.2	0.007	0.360
T_n: T_{od}	−0.07	−0.106	20.6	0.005	0.351	−0.14	−0.208	20.0	0.020	0.222	−0.12	−0.192	21.8	0.013	0.225
T_n: T_{rm}	0.07	0.189	19.2	0.004	0.370	0.40	1.169	14.4	0.163	**<0.001**	−0.13	−0.379	22.5	0.017	0.172
RH_n:RH_o	0.13	0.106	40.1	0.016	0.082	0.20	0.149	35.4	0.041	0.082	0.09	0.077	43.2	0.008	0.352
AH_n:AH_o	0.51	0.562	0.005	0.261	**<0.001**	0.37	0.414	0.005	0.139	**<0.001**	0.54	0.556	0.005	0.288	**<0.001**

NOTE: N: Number of observations at thermal sensation vote (TSV) (−1, 0, +1); r: Coefficient of correlation (Pierson's r); a: Slope of regression line; β: Intercept of regression line; R^2: Regression coefficient of determination; p: Confidence interval; T_n: Neutral indoor temperature (°C); T_{out}: Outdoor temperature (°C); T_{od}: Outdoor daily mean temperature (°C); T_{rm}: Outdoor daily running mean temperature (°C); RH_n: Neutral indoor relative humidity (%); RH_o: Outdoor relative humidity (%); AH_n: Neutral indoor absolute humidity (kg/kg_{DA}); AH_o: Outdoor absolute humidity (kg/kg_{DA}).

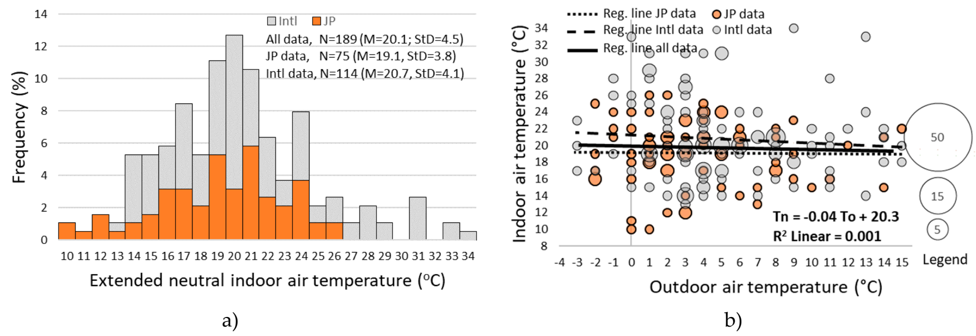


Figure 4. Indoor and outdoor temperature at TSV (−1, 0, +1): (**a**) Frequency percentage distribution of neutral indoor air temperature; (**b**) correlation between indoor and outdoor air temperature at the vote.

In our study, there was no correlation to relative humidity (RH_n) either irrespective of nationality. Only extended neutral absolute humidity indoors showed a significant correlation to its outdoor counterpart (Table 3, Figure 6). As seen in Figures 5 and 6, indoor humidity at extended "neutral" vote was low with mean RH_n of 47% (IQR from 38% to 58%) and AH_n of 0.007 kg/kg_{DA} (IQR from 0.006 to 0.008 kg/kg_{DA}). As mentioned in Section 2.4, the measured airspeed was very low, suggesting still air. Such low values were observed by Indraganti and Bousaa offices in Qatar in summer [37], as well as by Ning et al. in Chinese dormitories in winter [23]. In the current study, a standard value of 0.10 m/s airspeed was selected for any necessary further calculations.

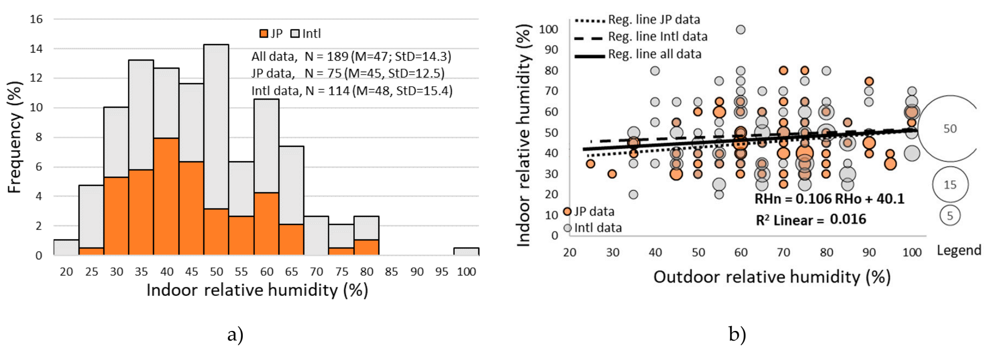


Figure 5. Indoor and outdoor relative humidity at TSV (−1, 0, +1): (**a**) Frequency percentage distribution of neutral indoor relative humidity; (**b**) correlation between indoor and outdoor relative humidity at the vote.

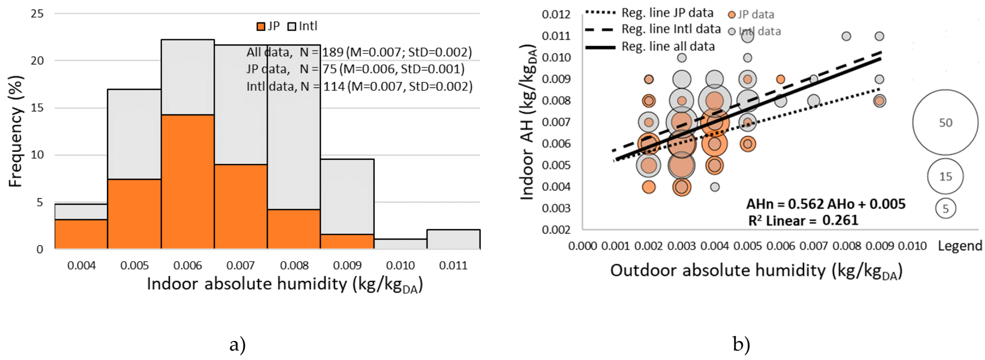


Figure 6. Indoor and outdoor absolute humidity at TSV (−1, 0, +1): (**a**) Frequency percentage distribution of neutral indoor absolute humidity; (**b**) correlation between indoor and outdoor absolute humidity at the vote.

3.3. Thermal Sensation, Comfort, Preference and Acceptability

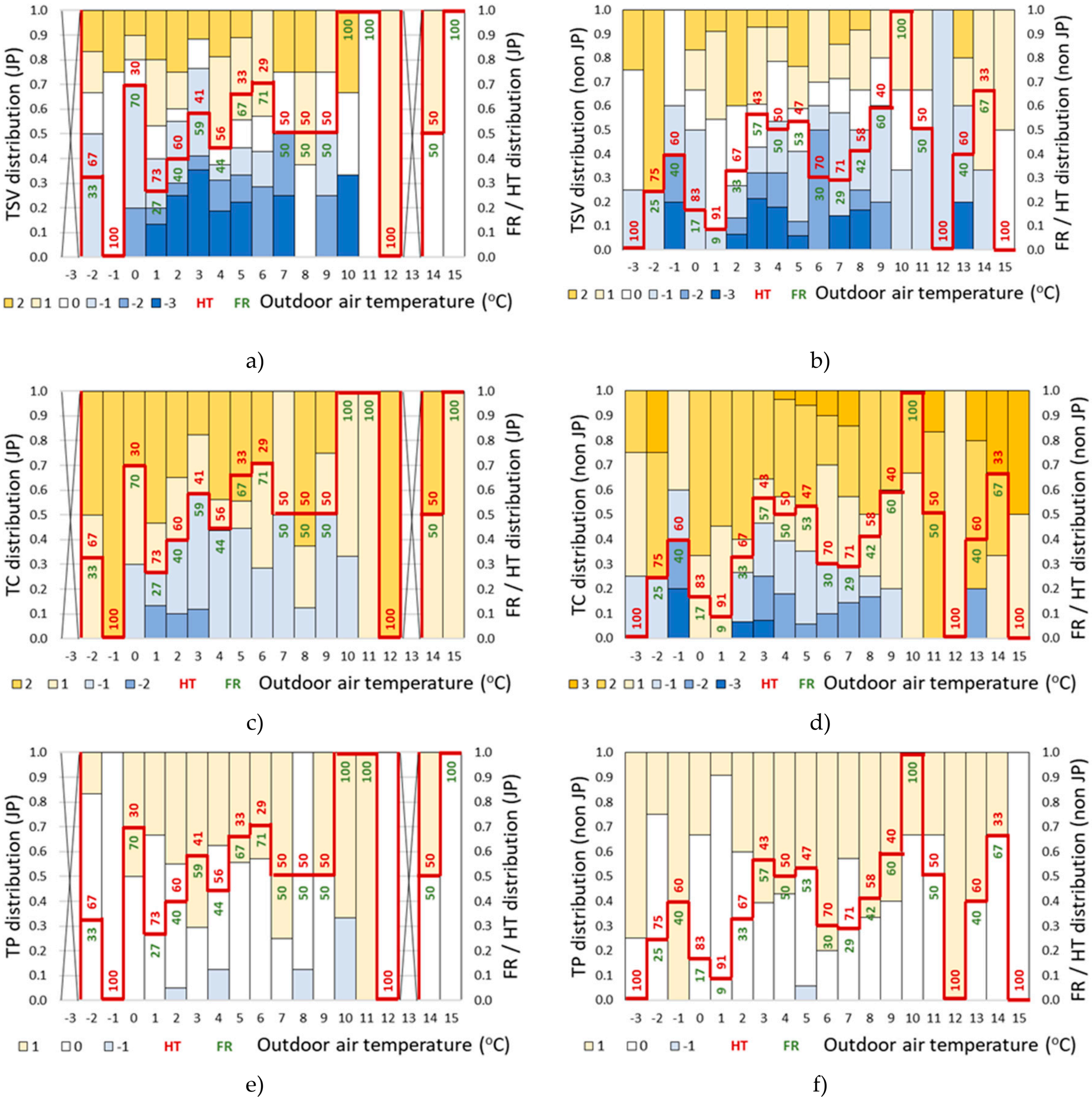
The distribution of TSV, TC, TP and TA relative to nationality is presented in Table 4. Less than one in every five Japanese students were feeling neutral (17%), while the percentage for the non-Japanese ones was slightly higher (22%). Although there were notable differences in the percentage of votes, at almost every point of the TSV scale, the differences both regarding mean and variance of the T_i of Japanese and non-Japanese dataset were insignificant. On the cold side of the scale were 44% of the non-Japanese votes and 46% of the Japanese. On the warm side of the scale—34% and 38%, respectively. As for the voted thermal comfort, 72% of the non-Japanese votes were on the comfortable side of the scale as compared to 66% of the Japanese votes. Only in the non-Japanese dataset, there were votes "very uncomfortable". However, the percentage was low (2%). The Japanese votes "prefer no change" were more than 50%, while more than half of the international votes were "prefer warmer". The acceptability for both was high—hovering slightly below and slightly above 90% (for non-Japanese and Japanese subjects, respectively).

Table 4. Percentage of thermal responses for each scale relative to nationality (Japanese: N = 128; international: N = 172).

Scale	Thermal Sensation (TSV) %			Thermal Comfort (TC) %			Thermal Preference (TP) %			Thermal Acceptability (TA)%		
		JP	Intl		JP	Intl		JP	Intl		JP	Intl
3	H	-	-	VCO	-	5.2						
2	W	16.4	13.4	CO	38.3	41.9						
1	SW	21.1	20.9	SCO	27.3	24.4	PW	42.2	51.7	UNC	8.6	11.6
0	N	17.2	22.1				PN	53.9	47.7	ACC	91.4	88.4
−1	SC	20.3	23.3	SUC	29.7	16.3	PC	3.9	0.6			
−2	C	9.4	9.9	UC	4.7	9.9						
−3	CC	15.6	10.5	VUC	-	2.3						

Note: H: Hot; W: Warm; SW: Slightly warm; N: Neutral; SC: Slightly cool; C: Cool; CC: Cold; VCO: Very comfortable; CO: Comfortable; SCO: Slightly comfortable; SUC: Slightly uncomfortable; UC: Uncomfortable; VUC: Very uncomfortable; PW: Prefer warmer; PN: Prefer no change; PC: Prefer cooler; UNC: Unacceptable; ACC: Acceptable.

The outdoor temperature measurements were grouped in 1 °C bins. Frequency distribution of the responses within each bin was graphed in Figure 7. The percentage of votes at heating mode (HT) and without the use of air conditioning (FR) were graphed and overlaid onto thermal responses. It is noticeable that a bigger percentage of Japanese students vote "very cold" at temperatures of 1~7 °C as compared to the non-Japanese ones. Overall the pattern of air conditioning use is similar in both groups—predominantly heating at temperatures below zero, balancing FR/HT in the central area and increased the percent of not using air conditioning with the increase of outdoor temperatures.



NOTE: The percentage of FR:HT was added in each 1oC temperature bin. Percentage of FR (without the use of air conditioning) is presented in green; Percentage of HT (air conditioning for heating) is presented in red.

Figure 7. Frequency distributions of thermal responses relative to outdoor temperature and the use of air-conditioning; (**a**) Japanese TSV: Tout; (**b**) Non-Japanese TSV: Tout; (**c**) Japanese TC: Tout; (**d**) Non-Japanese TC: Tout; (**e**) Japanese TP: Tout; (**f**) Non-Japanese TP: Tout.

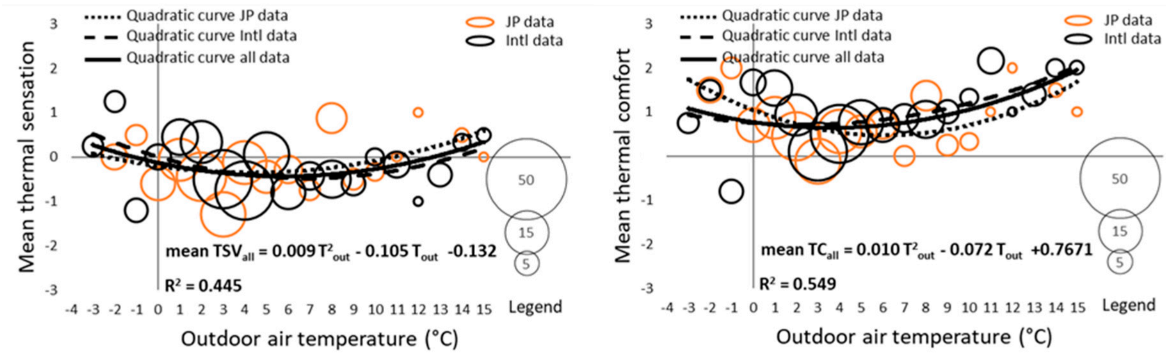
The subjective evaluation of comfort seems to follow the use of heating closely, and the vote "prefer to be warmer" is almost uniformly distributed throughout the observed range of outdoor temperatures.

Correlating the mean values of the thermal sensation votes within each bin to the outdoor temperatures showed there was no significant linear correlation (Table 5) However, the strong quadratic correlation could be observed for the subjective sensation and evaluation votes. Much weaker is the curve for preference and acceptability. Below zero, both TSV and TC decrease to about 4–5 °C outdoor temperature, after which the trends were upward (Figure 8).

Table 5. Correlation between mean thermal responses and outdoor temperature.

	All Data Points				Japanese				International			
	TSV$_{all}$	**TC$_{all}$**	**TP$_{all}$**	**TA$_{all}$**	**TSV$_{JP}$**	**TC$_{JP}$**	**TP$_{JP}$**	**TA$_{JP}$**	**TSV$_{all}$**	**TC$_{all}$**	**TP$_{all}$**	**TA$_{all}$**
r	0.06	0.52	−0.23	−0.23	0.31	0.07	0.04	−0.35	−0.17	0.48	−0.14	−0.19
p	−0.406	0.087	−0.618	−0.618	−0.201	−0.429	−0.451	−0.712	−0.577	<0.05	−0.556	−0.592
Quad.R$_2$	0.45	0.55	0.11	0.17	0.22	0.37	0.13	0.21	0.24	0.33	0.05	0.10

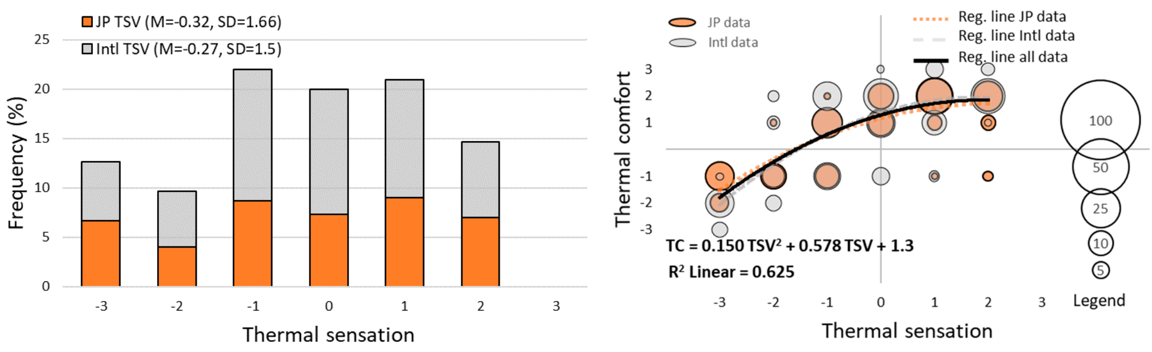
NOTE: T_{out}: Outdoor air temperature (°C); r: Coefficient of linear correlation (Pierson's r); p: Confidence interval for linear correlation; R^2: Regression coefficient of determination for the quadratic expression of the correlation; TSV: Mean thermal sensation vote; TC: Mean thermal comfort vote; TP: Mean thermal preference vote; TA: Mean thermal acceptability vote.



a) b)

Figure 8. Relationship between mean values of thermal responses to the outdoor temperature. (**a**) Mean TSV: T_{out}; (**b**) mean TC: T_{out}.

Thermal sensation had strong positive correlation with thermal comfort (r = 0.75, $p < 0.001$ (Figure 9) and strong negative correlation with thermal preference (r = −0.71, $p < 0.001$) (Figure 10) (Table 6). The hotter the subjects sensed their environment, the more comfortable they felt (Figure 11b), and their preference inclined from "prefer warmer" towards "prefer no change" without passing over the neutral line (Figure 11). The correlation between comfort and preference was also strong and negative (r = −0.60, $p < 0.001$). The more comfortable the subjects evaluated their indoor environment, the closer their preference vote was to "no change" (Figure 11). There was a significant correlation between TA and the other thermal responses; however, the coefficient of determination was relatively low ($R^2_{TSV:TA} = 0.253$; $R^2_{TC:TA} = 0.342$ and $R^2_{TP:TA} = 0.092$).



a) b)

Figure 9. The frequency distributions and correlation between thermal responses; (**a**) Distribution of TSV; (**b**) correlation TC: TSV.

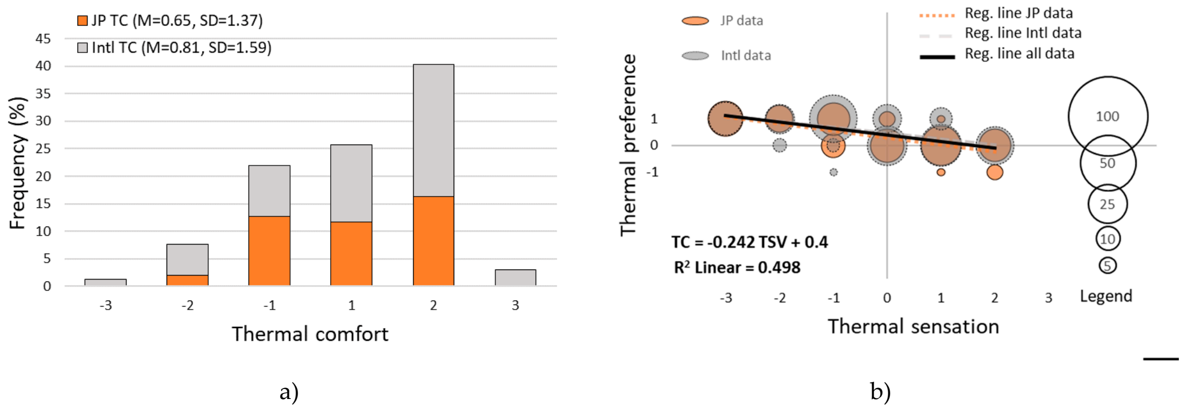


Figure 10. The frequency distributions and correlation between thermal responses; (**a**) Distribution of TC; (**b**) correlation TP: TSV.

Table 6. Correlation between thermal responses.

	All Data Points (N = 300)					Japanese (N = 128)					International (N = 172)				
	r	*a*	β	R^2	p	r	*a*	β	R^2	p	r	*a*	β	R^2	p
TC: TSV	0.75	0.718	0.9	0.565	<0.001	0.79	0.650	0.9	0.621	<0.001	0.74	0.778	1.0	0.542	<0.001
TP: TSV	−0.71	−0.242	0.4	0.498	<0.001	−0.78	−0.265	0.3	0.615	<0.001	−0.65	−0.222	0.5	0.421	<0.001
TA: TSV	−0.50	−0.098	0.1	0.253	<0.001	−0.36	−0.061	0.1	0.130	<0.001	−0.61	−0.131	0.1	0.376	<0.001
TP: TC	−0.60	−0.213	0.6	0.354	<0.001	−0.64	−0.262	0.6	0.409	<0.001	−0.59	−0.191	0.7	0.348	<0.001
TA:TC	−0.59	−0.119	0.2	0.342	<0.001	−0.45	−0.093	0.1	0.204	<0.001	−0.67	−0.135	0.2	0.444	<0.001
TA:TP	0.30	0.172	0.0	0.092	<0.001	0.23	0.119	0.0	0.057	<0.05	0.35	0.217	0.0	0.120	<0.001

NOTE: N: Number of observations; r: Coefficient of correlation (Pierson's r); *a*: Slope of regression line; β: Intercept of regression line; R^2: Regression coefficient of determination; p: Confidence interval.

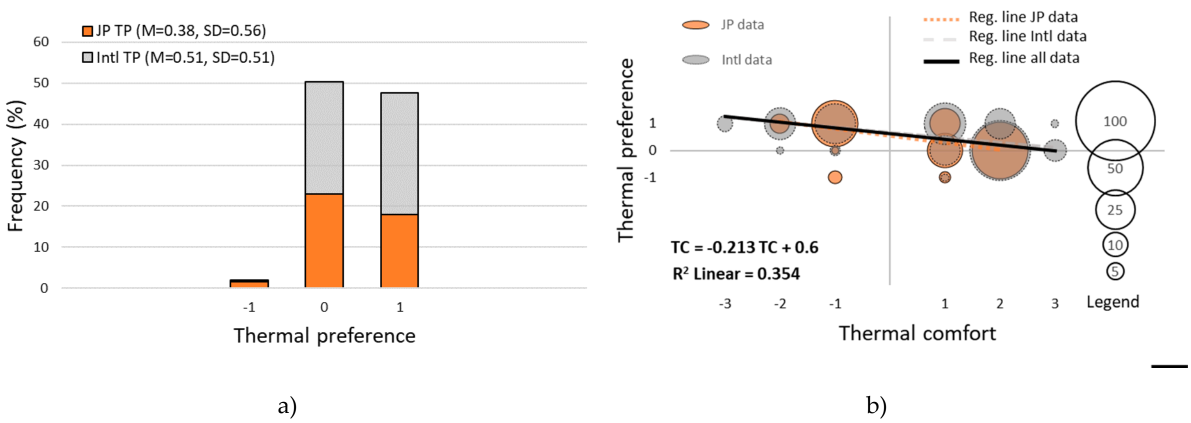


Figure 11. The frequency distributions and correlation between thermal responses; (**a**) Frequency distribution of TP; (**b**) correlation TP: TC.

The regression lines derived from all the data, from only the Japanese and only the international datasets were either very close (Figure 11b), or overlapping (Figure 11) revealing the same relationship between thermal responses irrespective of nationality.

It is a typical assumption that nationality affects subjective thermal responses. To investigate which factors indeed significantly affected the thermal responses in our survey, the votes TSV, TC, TP and TA were divided by time of the day, use of air-conditioning, dormitory building, sex and nationality, and tested for dependency on each of these factors through a chi-square test. The use of air conditioning affected three thermal responses (TSV, TC and TP). Dormitory building, sex and nationality affected two responses, while the time of day affected only one—only the thermal acceptability. The statistically significant results are presented in Table 7.

The test only partially confirmed the initial assumption. It was surprising that the nationality did not affect the thermal sensation vote. However, it affected the subjective comfort and the preference vote. The current paper explores the nationality factor. It was evident that a certain adaptation has taken place so to equalize the subjective thermal sensation votes of Japanese and non-Japanese subjects. Similar observations have marked the necessity of an adaptive approach to comfort from its very beginning [4] (p. 27). Investigating further what might have caused such equality in the neutral vote, the mean values and the variance for clothing insulation, activity level and BMI at each TSV scale point were compared. It seems that non-Japanese students voting on the warm side were predominantly larger by one point of BMI; when non-Japanese students were feeling cold their clothing varied more, and when Japanese students voted on the warm side, their activities inside their dormitory rooms varied more. In Chinese dormitories during winter, Ning et al. also observed that clothing adjustment is a main behavioral response [23]. The analysis focused on behavioral adaptation of students in dormitories will be presented separately in a following paper.

Table 7. Summary of Chi-square results: Dependence of TSV, TC, TP and TA on sub-divisions.

	Sub-Division	n	df	χ^2 Critical	χ^2	p	Estimated by Regression * (°C)		δT (°C)
TSV	AC on: AC off	165: 135	5	11.07	43.34	<0.001			
	Male: Female	216: 84			12.93	<0.05			
TC	AC on: AC off	165: 135	5	11.07	29.79	<0.001			
	GSD: Kaikan	147: 153			15.25	<0.001			
	Male: Female	216: 84			25.52	<0.001			
	Japanese: International	128: 172			18.73	<0.05	$T_{c\,JP} > 22.0$	$T_{c\,Intl} > 21.9$	0.1
TP	AC on: AC off	165: 135	2	5.99	15.75	<0.001			
	GSD: Kaikan	147: 153			8.41	<0.05			
	Japanese: International	128: 172			6.03	<0.05	$T_{p\,JP} = 27.0$	$T_{p\,Intl} = 33.2$	−6.2
TA	Day: Night	163: 137	1	3.84	7.43	<0.05			

Note: T_c Calculated values for temperature at TC = 1 (slightly comfortable). As values TC 2 and TC 3 are on the comfortable side of the scale, the results are given as an inequality; T_p Calculated temperature at TP = 0 (no change).

The linear regression conducted between the subjective votes and the measured air temperature estimated the neutral, comfortable and "prefer no change" temperature for Japanese and international subjects (Table 7). As the chi-square test showed that TSV was independent of nationality, the regression was run for all the data points together and estimated the neutral temperature T_n = 21.5 °C irrespective of nationality. Japanese subjects are expected to start feeling comfortable at a slightly higher temperature as compared to the international subjects (at 22.0 °C and 21.9 °C, respectively). However, the estimated comfortable temperature by regression is extremely close. Only in the preference vote, the estimated difference was notably sizable. The Japanese vote for "prefer no change" is expected at about 6 °C lower temperature than the international vote (at 27.0 °C and 33.2 °C, respectively).

3.4. Neutral and Comfortable Temperature

3.4.1. Logit Regression Analysis for Comfort Zone

Estimating the probability of getting a neutral Japanese and non-Japanese vote at a certain temperature, requires conducting a probability analysis of TSV with the indoor temperature. Using the XLstat add-in application for Microsoft Excel, an ordinal logistic regression analysis (probit model) was conducted. The resulting equations for six probit lines derived from our dataset are shown in Table 8.

The equations $P_{(\leq TSV)}$ represent the probability of voting the respective TSV vote or less—for example $P_{(\leq -1)}$ represents the probability of voting −1 or less than −1 (that is: From "slightly cool" down on the scale to "cold") [4,15,37]. The probit regression coefficient for Japanese university students is calculated to be −0.135/K and for international ones: −0.114/K. Mean temperature of the probit line is the absolute value of the result from dividing the y-intercept with the constant—for example |+1.4/−0.135| = |−10.4| = 10.4 °C. The SD is the absolute value of the inverse of the constant (SD = |1/−0.135| = |−7.42| = 7.42). Each equation was calculated for temperatures from 9 °C to 33 °C, which was the range of all the observed indoor temperature records (separately, the JP records were in a narrower range). For each result obtained, the cumulative normal distribution was calculated in MS Excel function NORM.S.DIST (z, cumulative). The six sigmoid curves of the probabilities were then plotted and presented in Figure 12.

Table 8. Probit analysis of thermal sensation and indoor temperature.

JP/Intl	TSV	Probit Regression Line	Mean Temperature (°C)	SD	N	R^2	SE	p
Japanese TSV	≤−3	$P_{(\leq -3)} = -0.135\ T_i + 1.4$	10.4	7.42	128	0.46	0.03	<0.001
	≤−2	$P_{(\leq -2)} = -0.135\ T_i + 1.8$	13.4					
	≤−1	$P_{(\leq -1)} = -0.135\ T_i + 2.4$	17.8					
	≤ 0	$P_{(\leq 0)} = -0.135\ T_i + 2.9$	21.5					
	≤1	$P_{(\leq 1)} = -0.135\ T_i + 3.7$	27.4					
	-	-	-					
International TSV	≤−3	$P_{(\leq -3)} = -0.114\ T_i + 0.8$	7.0	8.80	172	0.53	0.02	<0.001
	≤−2	$P_{(\leq -2)} = -0.114\ T_i + 1.3$	11.4					
	≤−1	$P_{(\leq -1)} = -0.114\ T_i + 2.1$	18.5					
	≤0	$P_{(\leq 0)} = -0.114\ T_i + 2.8$	24.6					
	≤1	$P_{(\leq 1)} = -0.114\ T_i + 3.6$	31.7					
	-	-	-					

Note: $P_{(\leq 1)}$ is the probability of voting 1 and less; $P_{(\leq 2)}$ is the probability of voting 2 and less and so on; SD: Standard deviation; N: Number of samples; R^2 (Cox and Snell): Coefficient of determination; SE: Standard error; significance $p < 0.001$.

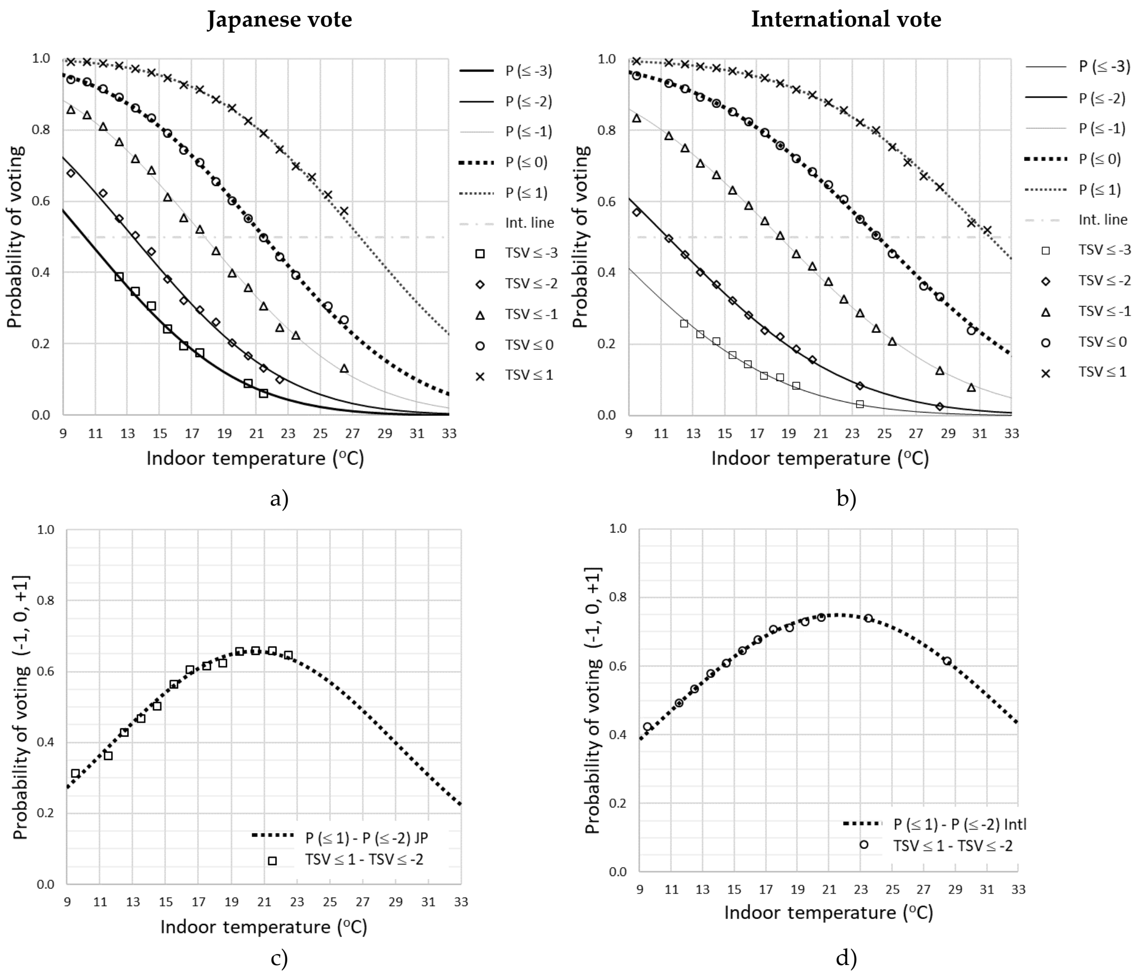


Figure 12. Graphical representation of probit analysis: (**a**) Probability of voting a certain TSV for Japanese subjects; (**b**) probability of voting a certain TSV for international subjects; (**c**) probability of voting within the "extended neutral range" of TSV scale—from −1 to +1 for Japanese subjects; (**d**) probability of voting within the "extended neutral range" of TSV scale—from −1 to +1 for international subjects. Note: Marker points represent the actual proportion of voting.

The curves help to estimate the probability of voting at a specific scale point or lower at all temperatures within the observed temperature range. As shown on Figure 12a, the probability of Japanese students voting neutral or less (dotted black line of $P_{(\leq 0)}$) at lower temperatures is high, while with the rise of temperatures, this probability decreases. And, at ~15.0 °C there is 80% probability of voting neutral or less. The explanation for all curves follows the same pattern.

When subtracting the probability of voting −2 from the probability of voting 1, the probability of voting within the extended neutral range (−1, 0 and 1) can be obtained. It was observed that within the range of 19 °C and 22 °C indoor temperature, the probability of Japanese students voting extended neutral is the highest. However, it is just slightly above 65% (Figure 12c). The peak of the graph for international subjects was within the interval from 19 °C to 24 °C. However, the expected percentage is higher—reaching 75%. Japanese students appear to be more critical to their indoor environment.

3.4.2. Linear Regression Method

Neutral is the temperature at TSV = 0, where the subjects felt neither cold nor warm. Using linear regression is a common method to derive the expected neutral temperature out of observed survey responses despite some downsides as observed by researchers previously. During winter stage, 59% of the Japanese TSV (N = 128, M = −0.32, SD = 1.66) were within the −1 to +1 segment of the scale, and the neutral votes were 17% (Table 4). As for the International TSVs (N = 172, M = −0.27, SD = 1.50), the respective percentages were 66% and 22%. When regressing the TSV and the measured indoor temperature, a strong positive correlation was observed, and based on the data collected, the neutral temperature relative to nationality could be estimated using the equations below:

$$TSV_{JP} = 0.195\ T_i - 4.0, \quad (2)$$

where N = 128; $p < 0.001$; $R^2 = 0.21$; S.E. = 1.48; F statistic = 33.8,

$$TSV_{Intl} = 0.146\ T_i - 3.2, \quad (3)$$

where N = 172; $p < 0.001$; $R^2 = 0.24$; S.E. = 1.31; F statistic = 54.7.

The calculated neutral temperature for Japanese subjects (${}_{JP}T_n$) using the Equation (2) is ${}_{JP}T_n$ = 20.6 °C. This is 1.3 °C higher than ${}_{voted\ JP}T_n$ = 19.3 °C—the mean indoor air temperature when the Japanese subjects voted "neutral". The calculated neutral temperature for international subjects (${}_{Intl}T_n$) using the Equation (3) is ${}_{Intl}T_n$ = 22.0 °C. This is 2.3 °C higher than ${}_{voted\ Intl}T_n$ = 19.7 °C—the mean indoor air temperature when the international subjects voted "neutral". The difference in slopes leads to thinking that Japanese subjects are more sensitive to their indoor environment, even though the difference in sensitivity appears to be small. This supports the outcome of the probit analysis in Section 3.4.1. Also, the slopes of the regression equations are comparable with the slopes derived from similar research: Rijal et al. estimated 0.183/K and 0.168/K for Japanese subjects in offices in FR mode throughout a year and in winter HT mode, respectively [15].

The linear regression defines a single value for the expected T_n. However, if using the assumptions in the PMV/PPD model and calculating for TSV = ±0.85 and for TSV = ±0.5, it is possible to derive the range of T_i corresponding to 80% and 90% acceptable thermal sensation, respectively [6]. In our survey, these ranges are from 16 °C to 25 °C (80%) and from 18 °C to 23 °C (90%) for the Japanese subjects, and from 16 °C to 29 °C (80%) and from 19 °C to 25 °C (90%) for the international subjects. The ranges are wider, but invariably include the range of 19 °C to 22 °C (and 19 °C to 24 °C, respectively) which was already observed in Section 3.4.1. However, the expected probability of voting neutral differed. Probit analysis showed that the probability of voting neutral never reaches 80% no matter how wide the temperature range.

To investigate which other variables affected the TSV together with T_i, a multiple regression analysis was conducted including T_i, RH_i, I_{cl} and M values. As both RH_i and AH_i were strongly correlated with T_i (${}_{JP}RH_i$: ${}_{JP}T_i$ r = −0.60, $p < 0.001$; ${}_{JP}AH_i$: ${}_{JP}T_i$ r = 0.40, $p < 0.001$; ${}_{Intl}RH_i$: ${}_{Intl}T_i$ r = −0.27,

$p < 0.001$; ${}_{Intl}AH_i$: ${}_{Intl}T_i$ $r = 0.27$, $p < 0.001$), these variables should be excluded from regressing in combination with T_i. The expectation was that clothing and activity level would significantly affect TSV for both Japanese and international students. However, this was not the case (see Equations (4) and (5)). Based on the Type III sum of squares, only the T_i brings significant information to explain the variability of TSV irrespective of nationality. The following analysis focused only on the temperature.

$$TSV_{JP} = 0.196\,T_i + 0.000\,RH_i + 0.331\,I_{cl} - 0.011\,M - 4.2 \quad (4)$$

where N = 128; significance of the effect of T_i: $p_1 < 0.001$; significance of the effect of RH_i: $p_2 = 0.979$; significance of the effect of I_{cl}: $p_3 = 0.727$; significance of the effect of M: $p_4 = 0.972$; $R^2_{adj.} = 0.19$; standard error for T_i: $S.E._1 = 0.045$; standard error for RH_i: $S.E._2 = 0.015$; standard error for I_{cl}: $S.E._3 = 0.946$; standard error for M: $S.E._4 = 0.314$; F statistic = 8.3

$$TSV_{Intl} = 0.160\,T_i + 0.008\,RH_i + 0.191\,I_{cl} - 0.268\,M - 3.7 \quad (5)$$

where N = 172; significance of the effect of T_i: $p_1 < 0.001$; significance of the effect of RH_i: $p_2 = 0.368$; significance of the effect of I_{cl}: $p_3 = 0.613$; significance of the effect of M: $p_4 = 0.312$; $R^2_{adj.} = 0.24$; standard error for T_i: $S.E._1 = 0.027$; standard error for RH_i: $S.E._2 = 0.009$; standard error for I_{cl}: $S.E._3 = 0.378$; standard error for M: $S.E._4 = 0.264$; F statistic = 14.2.

Linear regression is believed to have some major drawbacks when used for estimating the neutral temperature: (1) Majority of votes are clustered around the central point of the thermal sensation scale (Figure 13); as well as (2) the constant behavioral adaptation from the subjects that cannot be accounted for by this analysis as the vote remains constant especially because of the adaptive measures implemented [37]. In our analysis, the precision of the linear regression coefficient was improved following the usual analytical approach. Then, the comfortable temperature was estimated using the Griffiths' method.

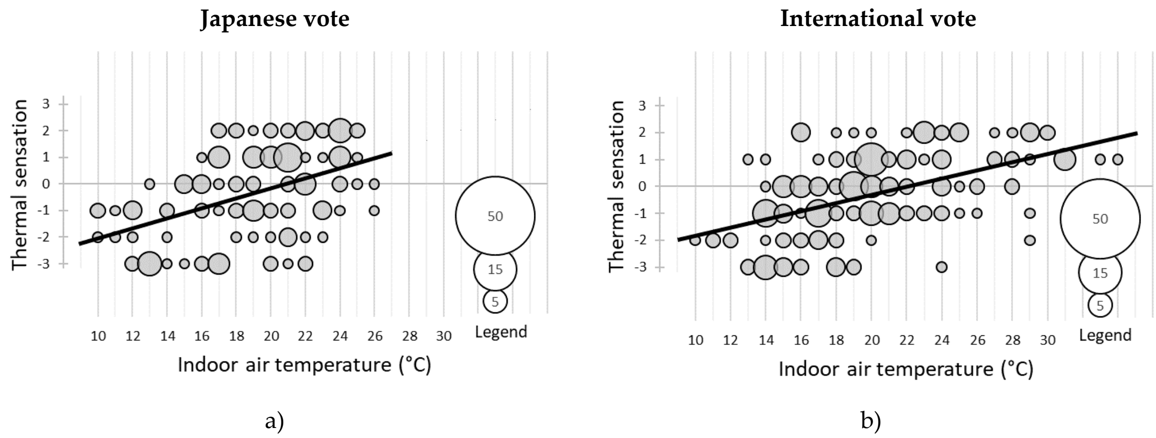


Figure 13. Thermal sensation votes: (**a**) The correlation between TSV and indoor air temperature at the vote for Japanese subjects; (**b**) the correlation between TSV and indoor air temperature at the vote for international subjects.

3.4.3. Improving the Precision of Linear Regression Coefficient

When considering the downsides of the regression method as mentioned above, it is necessary to improve its precision. The widely accepted method to do that is to analyze the within-day and within-room averages. That is to use the variability of the thermal sensation vote from its mean, and to correlate it to the variability of the indoor temperature from its mean [4,15,39].

In order to apply this method to our dataset, the mean thermal feeling (T_{fm}) and mean indoor temperature (T_{im}) were calculated for all the sets of data collected within a day in each of the 19 dormitory rooms for all the survey days within winter. These values were the room-wise day-survey averages.

The variability in thermal sensation is defined as $\delta T_f = T_f – T_{fm}$ (the mean of the thermal sensation/feeling vote within the day in a single room is subtracted from the actual thermal sensation/feeling vote). Similarly, the variability in indoor temperature is defined as $\delta T_i = T_i – T_{im}$ (the mean of the indoor temperature within the day from a single room is subtracted from the actual measured temperature at the vote). The data was then split relative to nationality. Irrespective of nationality, more than 50% of the variability in subjective sensation was zero. Zero variability means that within a single day a subject's mean vote was mostly equal to their actual vote of that day. If their average vote of the day was "neutral" the actual vote "neutral" frequented too.

The regression δT_f: δT_i from both Japanese and non-Japanese votes demonstrated that when there was low to no variability in the temperature, there was low to no variability in the sensation vote too (Figure 14). The relation was positive in both cases—however, it was much stronger for the Japanese dataset. That is, when the variability in temperature increases (bigger fluctuations from the mean), the sensation vote variability is also expected to increase, and the Japanese vote changes quicker than the non-Japanese. The linear regression equations are given below:

$$_{JP}\left(T_f - T_{fm}\right) = 0.506_{JP}(T_i - T_{im}) - 0.0 \quad (6)$$

where N = 128; $p < 0.001$; $R^2 = 0.32$; S.E. = 0.92; F statistic = 58.2

$$_{Intl}\left(T_f - T_{fm}\right) = 0.181\ _{Intl}(T_i - T_{im}) - 0.0 \quad (7)$$

where N = 172; $p < 0.001$; $R^2 = 0.22$; S.E.=0.79; F statistic = 49.0.

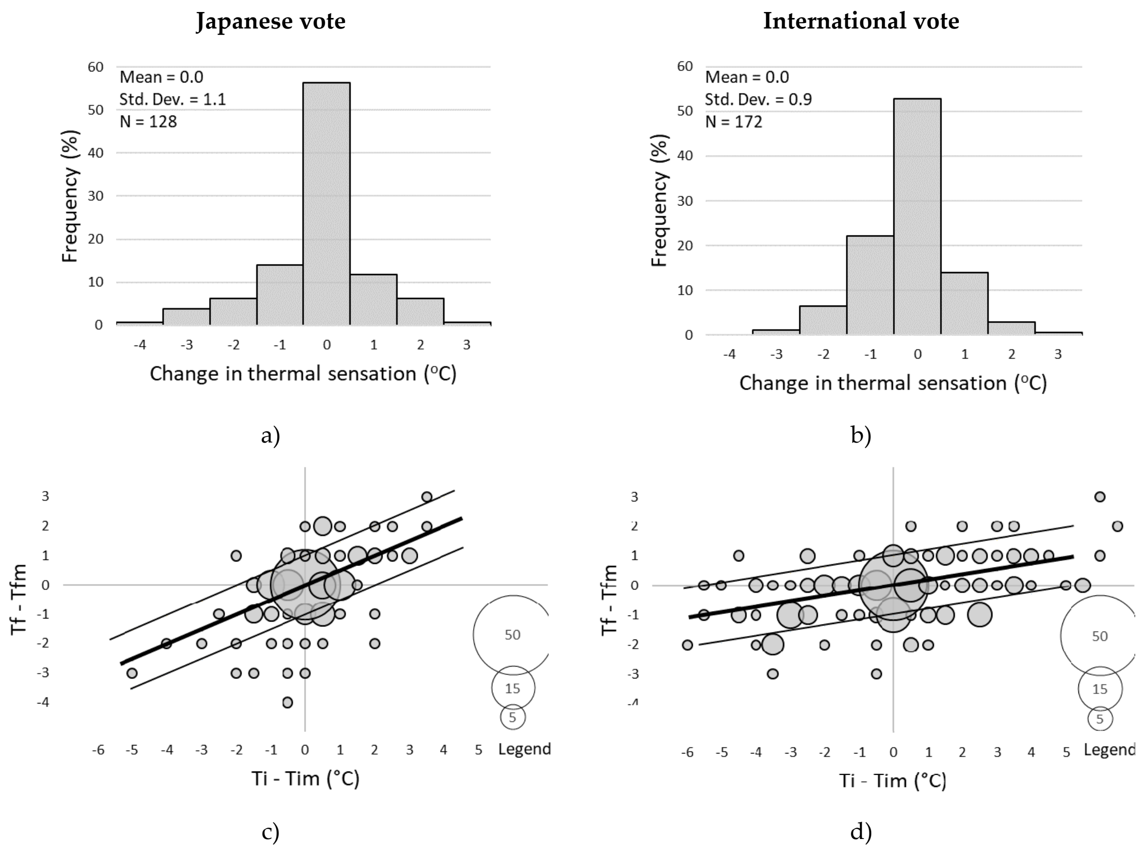


Figure 14. Room-wise day-survey averages (**a**) frequency distribution of the Japanese vote; (**b**) frequency distribution of international vote; (**c**) regression of the day surveys from the Japanese vote; (**d**) regression of the day surveys from the international vote. Note: Outer lines indicate the residual standard deviation.

From the linear regression δT_f: δT_i, the corrected value of the regression gradient was derived. It was 0.51/K for the Japanese vote, and 0.18/K for the international vote. It needs further adjustment as this value does not account for the possibility of measurement errors. The adjusted coefficient is calculated using the formula following below:

$$b_{adj.} = \frac{b(\sigma_{T_i}^2)}{\sigma_{T_i}^2 - \sigma_{err}^2}, \tag{8}$$

where b is the coefficient from δT_f: δT_i linear regression (0.51 for Japanese vote, and 0.18 for the international vote); $\sigma_{T_i}^2$ is the variance of δT_i; and σ_{err}^2 is the error variance of δT_i taken as the $\frac{\sigma_{T_i}^2}{\sqrt{N}}$—the variance of δT_i divided by the square root of the number of data points. Solving the equation provided us with an adjusted regression coefficient of ${}_{JP}b_{adj.}$ = 0.55/K and ${}_{Intl}b_{adj.}$ = 0.20/K. Similar values were derived from SCATs and ASHRAE databases [40]. The adjusted coefficient for Japanese data got closer to 0.5/K value that has been used in previous studies. The difference between b and $b_{adj.}$ is explained with the effect of the adaptive behavior people undertake in order to maintain their neutral sensation [4,15,37].

3.4.4. Griffiths' Method

Griffiths method estimates a temperature that is assumed comfortable based on the actual vote of neutral sensation and a regression coefficient. It is calculated by the equation following below:

$$_{G}T_c = T_i + \frac{0 - TSV}{a}, \tag{9}$$

where ${}_{G}T_c$ is Griffiths' comfortable temperature (°C); T_i is indoor temperature (°C); 0 is numeric code for "neutral" sensation vote based on the seven—point sensation scale used in this study; TSV is actual sensation vote using the same scale; a is Griffiths' regression coefficient.

Griffiths' coefficient accounts for the sensitivity to indoor temperature change and the value used predominantly is a = 0.5 [4,37]. However, previous research explores ${}_{G}T_c$ at two more values: a = 0.25, and a = 0.33 [13,38], as well as the value of the adjusted coefficient $b_{adj.}$ derived from room-wise day-survey analysis if conducted [37]. In the current study, ${}_{G}T_c$ was estimated using four values for the Griffiths' coefficient, and the results are presented below:

The current field survey directly asked about comfort. It made it possible to compare the calculated ${}_{G}T_c$ (Table 9) and the observed ${}_{voted}T_c$ (Table 10). For the Japanese dataset, there was no significant difference regarding means and variance of the calculated comfortable temperature at 0.55/K and its voted counterpart. At 0.55/K 80% of the ${}_{JP\,G}T_c$ fall within 15 °C and 25 °C. As for the international dataset, the calculated comfortable temperature at 0.20/K showed no significant difference in means, but a significant difference regarding variance. At 0.20/K 80% of the ${}_{Intl\,G}T_c$ fall within 14 °C and 30 °C, while the actual voted 80% of the ${}_{Intl\,voted}T_c$ fall within 15 °C and 29 °C (narrower range by 2 °C).

Table 9. Descriptive statistics of comfortable temperature calculated by Griffiths' method using different regression coefficients.

	Calculated Comfortable Temperature ${}_{G}T_c$ (°C)								
	Regression Coefficient (/K)	**N**	**Min**	**Q1**	**Median**	**Q3**	**Max**	**Mean**	**SD**
JP	0.55 (see Section 3.4.3)	128	11.6	17.0	19.3	22.1	27.9	19.5	3.7
	0.50		11.8	16.9	19.3	22.1	28.1	19.6	3.8
	0.33		10.9	16.3	18.9	23.3	31.0	19.9	4.8
	0.25		9.0	15.5	19.2	24.7	33.9	20.2	6.0
Intl.	0.50	172	11.2	17.8	20.0	23.5	35.1	20.7	4.5
	0.33		9.6	17.3	20.7	23.9	36.2	21.0	4.9
	0.25		7.6	16.9	20.9	25.4	37.1	21.2	5.6
	0.20 (see Section 3.4.3)		5.6	16.4	21.1	26.2	38.6	21.5	6.7

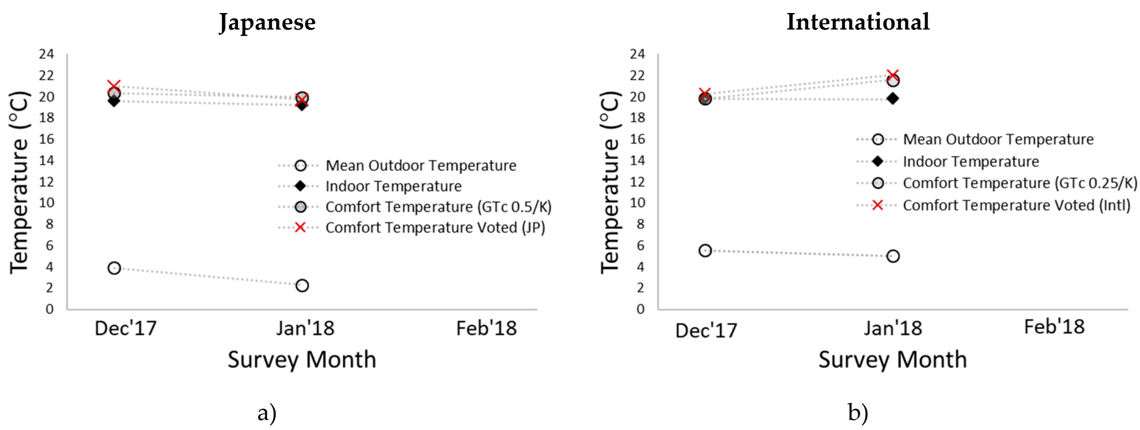
Note: Q1: The first quartile marks 25% of the data points; Median: Marks 50% of the data points; Q3: Marks 75% of the data points; (Q3–Q1): Marks the interquartile range—central 50% of the data points; Mean: Arithmetic average; SD: Standard deviation.

Table 10. Descriptive statistics of the actual temperature at TC +1, +2 and +3 (Comfortable side of the scale).

	Observed Comfortable Temperature T_c (°C)							
	N	**Min**	**Q1**	**Median**	**Q3**	**Max**	**Mean**	**SD**
JP TC votes "comfortable"	84	9.8	17.3	20.4	22.5	26.1	19.7	3.7
Intl TC votes "comfortable"	123	11.2	17.5	20.5	24.5	33.7	21.3	5.2

Note: Q1: First quartile marks 25% of the data points; Median: Marks 50% of the data points; Q3: Marks 75% of the data points; (Q3–Q1): Marks the interquartile range—central 50% of the data points; Mean: Arithmetic average; SD: Standard deviation.

Graphing the calculated and the voted mean comfortable temperature for each survey month (Figure 15) relative to nationality visually displayed the above—the non-Japanese subjects voted for a comfortable temperature close, and in the same relation to the calculated value (the voted comfortable temperature remained at about half degree higher). The comfortable temperature voted by Japanese subjects demonstrated change in relation to its calculated counterpart—its mean value was higher than the calculated comfort in December, and lower in January (Figure 15).



Note: There was only Japanese dataset for February (and only two days), that is why the February data was added to January data and analyzed together.

Figure 15. Comparing mean temperatures in each survey month (**a**) Japanese dataset; (**b**) international dataset.

To compare with the existing research, and to investigate whether the Griffiths model holds statistical significance with respect to our dataset, the analysis was continued. The ${}_{G}T_c$ at 0.5/K was used for the Japanese dataset and ${}_{G}T_c$ at 0.25/K for the international dataset. Frequency distributions of calculated comfortable temperature demonstrated a significant shift in the mean by 1.6 °C to the right in the non-Japanese dataset ($t(295) = -3.0$, $p < 0.05$). The range of comfortable temperatures for non-Japanese students was also significantly wider ($F(127,171) = 0.455$, $p < 0.001$) with 80% of the $_{G}T_{c}$ within 15–26 °C and 15–28 °C range for Japanese and non-Japanese subjects, respectively (Figure 16).

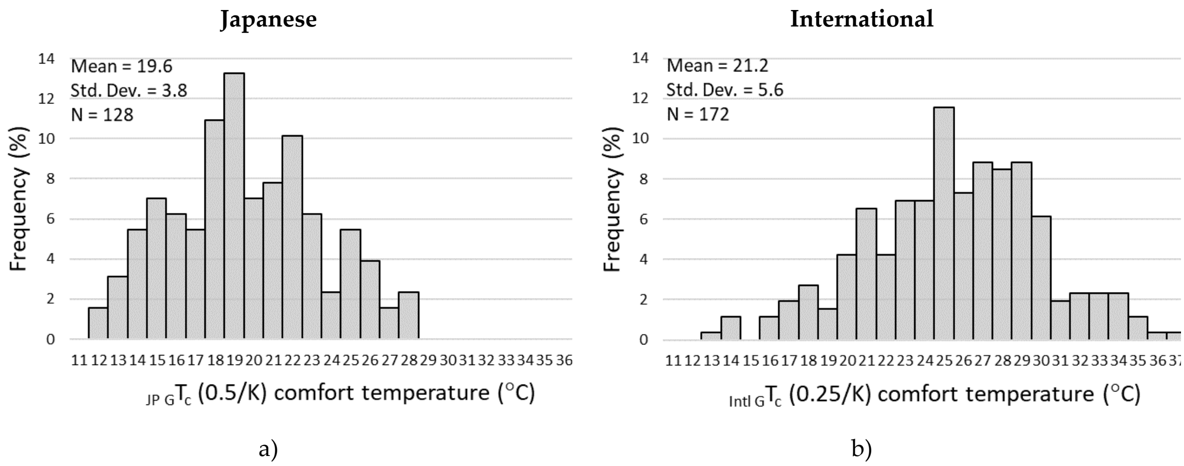


Figure 16. Griffiths comfortable temperature: (**a**) Frequency distribution of the calculated Japanese comfortable temperature; (**b**) frequency distribution of the calculated international comfortable temperature.

The calculated comfortable temperature in our survey was significantly correlated to the indoor air temperature; however, the relation was much stronger in the Japanese dataset (Equation (10) and Equation (11)).

One of the fundamental assumptions of the adaptive model is that the comfort indoor temperature would be in relation with the seasonal outdoor temperature provided that the outdoor conditions are not unpleasantly hot or unpleasantly cold [4] (p. 60). For both Japanese and non-Japanese dataset, there was significant correlation between the calculated comfortable temperature and the running mean outdoor temperature (Table 11, Equation (12) and Equation (13)). However, while $_{calc\ JP\ G}T_{c}$ varied in sympathy with the T_{rm}, the correlation $_{calc\ Intl\ G}T_{c}$: T_{rm} was inverse (Figure 17). Other researchers [4] have noted similar effect and have attributed it to unpleasantly cold outdoor conditions in which case the subjects tend to use mechanical means to assure comfort. The percentage of non-Japanese subjects using heating in winter did indeed differ from Japanese subjects (64% to 53%, respectively), and the TSV when using or not air-conditioning was indeed dependent on nationality ($\chi^2(5, N = 300) = 43.34$, $p < 0.001$). Further analysis about how using or not using air-conditioning affects the comfortable temperature in winter in dormitories will be the focus of a following paper.

$$_{JP\ G}T_{C} = 0.610\ T_{i} + 8.0, \tag{10}$$

where $N = 128$; $p < 0.001$; $R^2 = 0.40$; S.E. = 2.97; F statistic = 82.9,

$$_{Intl\ G}T_{C} = 0.418\ T_{i} + 12.8, \tag{11}$$

where $N = 172$; $p < 0.001$; $R^2 = 0.14$; S.E. = 5.24; F statistic = 28.1,

$$_{JP\ G}T_{C} = 1.275\ T_{rm} + 14.3, \tag{12}$$

where $N = 128$; $p < 0.001$; $R^2 = 0.17$; S.E. = 3.48; F statistic = 26.2,

$$_{Intl\ G}T_{C} = 0.650\ T_{rm} + 24.3, \tag{13}$$

where $N = 172$; $p < 0.05$; $R^2 = 0.03$; S.E. = 5.56; F statistic = 5.86.

Table 11. Correlation coefficients.

	All Data Points (N = 300)					Japanese (N = 128)					International (N = 172)				
	r	*a*	β	R^2	p	r	*a*	β	R^2	p	r	*a*	β	R^2	p
$_GT_C$: T_{rm}	0.00	0.009	20.6	0.000	0.969	0.41	1.275	14.3	0.172	**<0.001**	−0.18	−0.650	24.3	0.033	**<0.05**
$_GT_C$: T_{od}	0.00	−0.002	20.6	0.000	0.987	−0.07	−0.111	20.0	0.005	0.448	−0.04	−0.079	21.6	0.002	0.609

NOTE: N: Number of observations; r: Coefficient of correlation (Pierson's r); *a*: Slope of regression line; β: Intercept of regression line; R^2: Regression coefficient of determination; p: Confidence interval; T_{od}: Outdoor daily mean temperature (°C); T_{rm}: Outdoor daily running mean temperature (°C); $_GT_C$: Comfortable temperature as calculated using the Griffiths' method (°C).

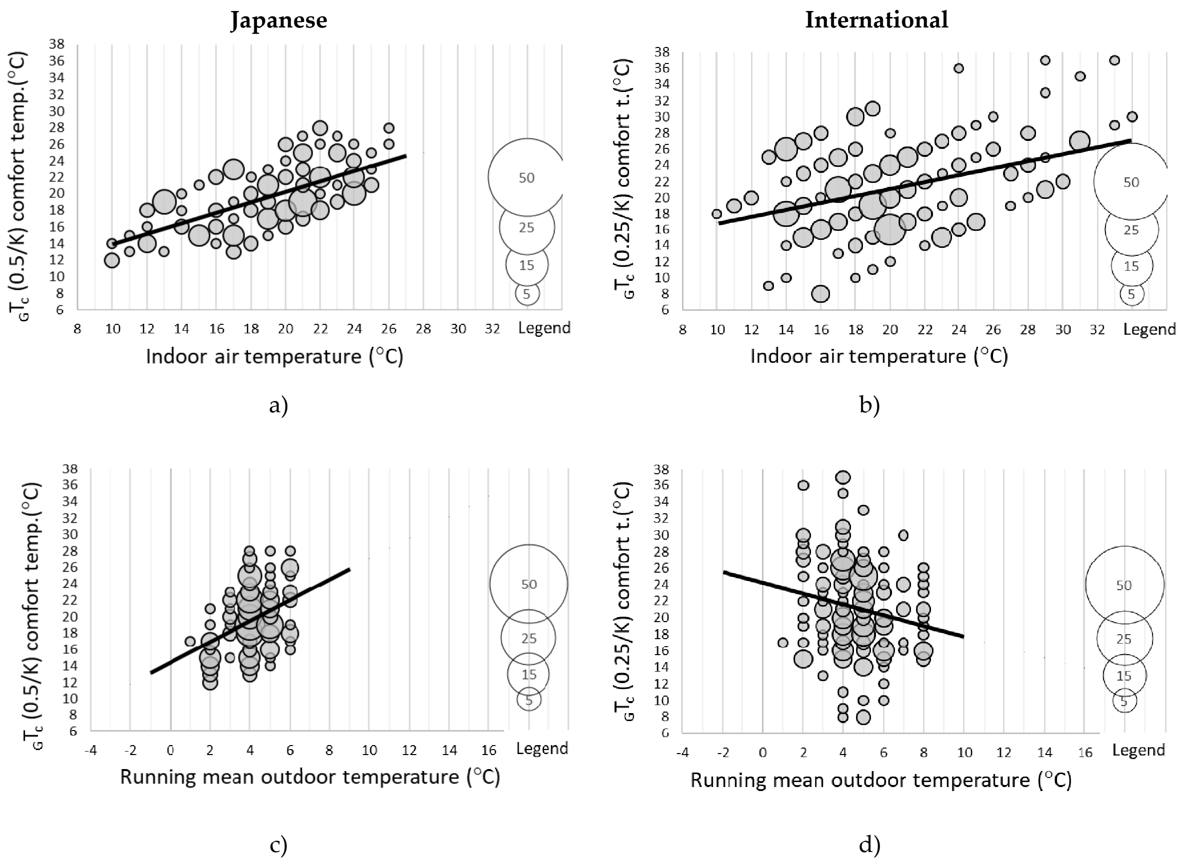


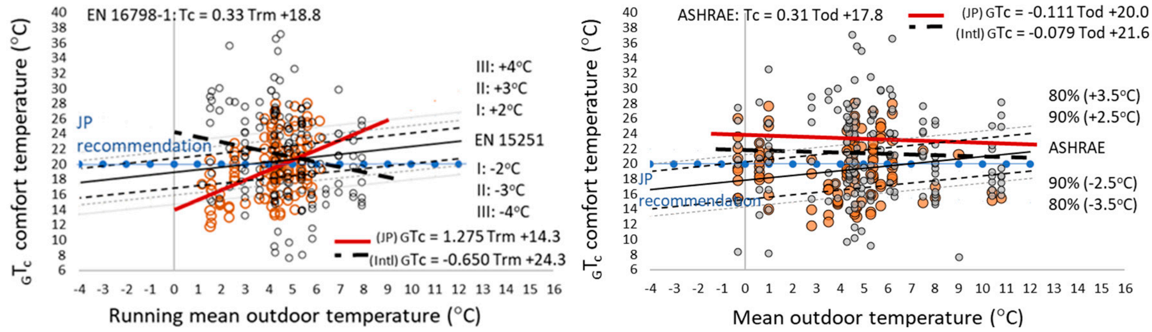
Figure 17. Griffiths comfortable temperature at 0.5/K (**a**) regression with indoor air temperature for Japanese subjects; (**b**) regression with indoor air temperature for non-Japanese subjects; (**c**) regression with a running mean outdoor air temperature for Japanese subjects; (**d**) regression with a running mean outdoor air temperature for non-Japanese subjects.

3.5. Comparison with Related Standards

A number of international standards regulate the indoor environment [41]. They have established thermal comfort models to predict the indoor comfortable temperature based on the mean/ running mean outdoor temperature. The comfortable temperature derived for Japanese and international students was correlated to running mean outdoor air temperature as calculated in Section 3.2 and to mean daily outdoor temperature to compare the results to EN 16798−1 [34], and ASHRAE [33], respectively.

The calculated comfortable temperature in winter had no significant correlation to the outdoor daily mean temperature irrespective of nationality. However, the neutral and comfortable temperatures estimated in the current study fall within the range of 20–24 °C as recommended for winter by ASHRAE [33].

The temperature considered as comfortable by Japanese and non-Japanese subjects had a significant correlation ($p < 0.001$ and $p<0.05$, respectively) to the outdoor daily running mean temperature. However, it was positive for the Japanese dataset, and negative for the non-Japanese dataset. In addition, the Japanese subjects' sensitivity to T_{rm} is almost two times higher than the non-Japanese subjects' sensitivity (Figure 18, Table 11). Comparing to EN 16798, it was observed that sizeable amount of data points is within the range of group III—"an acceptable, moderate level of expectation and may be used for existing buildings" [34], but a sizable amount is outside as well. For new buildings and renovations, level II should be targeted, and while the regression lines mainly remain within these limits, a bulk of datapoints are above and below. Furthermore, the model from the current study demonstrated much higher sensitivity for both Japanese and non-Japanese subjects than the standard suggests, and for the non-Japanese, the correlation is even reversed as compared to the standard.



a) b)

Figure 18. Comparison of comfortable temperature with standards: (**a**) EN 16798-1 and (**b**) ASHRAE.

The winter energy conservation measures in Japan, issued by METI (Ministry of Economy, Trade and Industry) recommend indoor temperature in winter no higher than 20 °C (blue dotted line in Figure 18) in order to limit the energy consumption, and thus, address the issues of energy dependency of the country [42]. The same is the winter threshold suggested for residential buildings in EN 16798-1 too; however, there it is the recommended minimum-temperature should be no less than 20 °C in winter [34]. The threshold line cuts through the middle of the dataset of comfortable temperatures estimated by the current study, and it makes it difficult to suggest which recommendation is more suitable for the targeted study group. In their field survey, Indraganti et al. [9] already questioned the rational basis for the METI requirements.

3.6. Comparison with Existing Research

From the data collected during the winter stage of the current survey, it was observed that the thermal acceptability was over 85% irrespective of nationality. The winter comfortable temperature for both Japanese and non-Japanese subjects higher than 22 °C as derived from linear regression (see Section 3.3, Table 7), and the Griffith's model estimated a comfortable temperature of 20 °C for Japanese students, and 22 °C for non-Japanese students (see Section 3.4.4.). The comfortable temperature for non-Japanese subjects is at a 2 °C wider range and at a 2 °C higher average than the comfortable temperature for the Japanese subjects. As for the sensitivity to indoor changes—Japanese subjects were two times more sensitive, and for either Japanese or non-Japanese, the comfortable temperature increased with the increase of the indoor temperature. However, the changing outdoor conditions affected comfortable temperature differently—for the Japanese, the correlation was again positive, but for the non-Japanese, it was reversed. With the increase of the running mean outdoor temperature, the indoor comfortable temperature for Japanese students increased too, but decreased for the non-Japanese.

At the dawn of adaptive research, Humphreys [4] (p. 60) and Goromosov [43] attributed such a reverse relation to unpleasantly hot or cold conditions when people tend to use cooling or heating, respectively. Applying that logic, it appears that in winter, non-Japanese students in dormitories tend to use heating more. It was assumed at the beginning of the current study that the absence of economic restraint might reveal the genuine comfortable temperature, however, Humphreys assumes it might as well lead to the complete opposite results, to conceal it, "people might run buildings warmer or cooler than normal" if money is not an issue and "become adapted to different temperatures" [4]. There might be a liable possibility that the observed wider comfortable temperature range in the non-Japanese vote is because non-Japanese students feel less financially restrained as the period of dormitory stay is partially financially supported. On the other hand, it is possible that the well-known Japanese thrifty mentality is affecting the results of the survey. In any case, subjective financial evaluation is a factor worth exploring further as in such young individuals, it displays an attitude that will affect their energy consumption for a long period ahead.

In the year-long study in Japanese offices, Rijal et al. [15] (Table 12) also observed a high rate of thermal acceptability of the indoor environment; however, the winter comfortable temperature was 24.3 (4.3 °C higher than the recommended 20 °C by METI [42], and 2.3–4.3 °C higher than the current study). Nakano et al. [16] and Goto et al. [17] also observed high neutral and comfortable temperatures in Japanese offices. Japanese subjects' sensitivity was studied in a survey by Rijal et al. [15], which yielded results from the day-wise datasets. This showed it was lower than the sensitivity observed in the current study (0.45/K and 0.55/K, respectively) probably because of the differences in the data division (HT mode vs. non-specified mode).

Table 12. Comparison with existing research in winter.

Area	Reference	Building Type	Season	Temperature (Variable) °C	Temperature (°C) in Mode			
					FR	CL	HT	ns
Japan (Tokai)	This Study (Section 3.4.2)	dormitory	winter	Neutral temp. (T_i)				$_{JP}$21; $_{Intl}$22
Japan (Tokai)	This study (Section 3.4.4)	dormitory	winter	Comfortable temp. (T_i)				$_{JP}$20; $_{Intl}$22
Japan (Chubu)	[13]	Residential	four Seasons	Comfortable temp. (T_i)	$_{JP}$22.7	$_{JP}$27.1	$_{JP}$18.9	
Japan (Kanto)	[14]	residential	four seasons	Comfortable temp. (T_i)	$_{JP}$24.1	$_{JP}$27.0	$_{JP}$20.2	
Japan (Kanto)	[15]	office	four seasons	Neutral temp. (T_g)	$_{JP}$25.1	$_{JP}$25.0	$_{JP}$25.6	
Japan (Kanto)	[15]	office	four seasons	Comfortable temp. (T_g)	$_{JP}$25.0 ± 1.7	$_{JP}$25.4 ± 1.5	$_{JP}$24.3 ± 1.6	
Japan (Kanto)	[16]	office	four seasons	Neutral temp. (T_{op})				$_{JP}$24.8 $_{Intl}$22.7
Japan	[17]	office	four seasons	Comfortable temp. (SET*)				$_{JP}$26
Japan (Fukushima)	[18]	temporary houses	winter, spring, summer	Neutral temp. (T_i)		$_{JP}$22.8–24.8	$_{JP}$13–17	
China (Harbin)	[23]	dormitory	autumn, winter, spring	Neutral temp. (T_i)			$_{Intl}$20.9–22.6	
China (Beijing)	[24]	dormitory	winter	Neutral temp. (T_i)			$_{Intl}$23	

Note: T_g: Globe temperature (°C); T_i: Indoor air temperature (°C); SET*: Standard Effective Temperature (°C); FR: Free-running mode—without the use of mechanical heating/cooling; CL: Cooling mode—mechanical cooling was used; HT: Heating mode—mechanical cooling was used; ns: The heating/ cooling mode was not specified.

The results of the current study coincided with the results of Ning et al. [23] from their three-season-long dormitory study that covered the entire winter heating period in Harbin, China. They also observed neutral temperatures within 21–23 °C range, as well as clothing adjustment as the main adaptive behavior. However, in the temporary houses in Fukushima, North Japan investigated by Shinohara et al. [18], Japanese neutral thermal sensation in winter was at notably lower temperatures (13–17 °C). This shift from higher observed values, through equal ones and eventually lower, may be attributed to the economic and psychological factors. As for the office environment in Kanto, the subjects are not the directly responsible party for the consumption payments, in Harbin they are, and, in Fukushima after the earthquake, the occupants must have been under major financial stress and trying to limit their expenses to their minimum.

4. Conclusions

A field survey about environmental comfort in typical university dormitory buildings in Japan was conducted during the winter of 2017–2018. The aim of the study was: (1) To snapshot the subjective thermal comfort of the Japanese and non-Japanese students relative to temperature, humidity and other factors; (2) to understand the difference, if any, between the temperature defined as neutral or comfortable; and (3) to get an insight how tolerant are the students to their indoor environment.

Subjective votes were collected using traditional paper questionnaire. Simultaneously, measurements of physical parameters of the indoor and outdoor environment were conducted, and the two datasets were linked. The correlation of the subjective neutrality and comfort were investigated in relation to nationality; as well as the effect of thermal sensation to occupants' preference and tolerance to their indoor environment.

The study revealed that the voted subjective neutrality is strongly disconnected from the outdoor climate for both observed groups. There still could be observed a mild downward trend in the averaged TSV and TC at outdoor temperatures below zero, reversing upward again at about 4−5 °C outdoors. In the lowest area, a bigger percentage of non-Japanese students were using air conditioning for heating.

For both Japanese and non-Japanese students, thermal responses were strongly correlated to one another, where feeling warmer resulted in an increase of subjective comfort and decrease in the desire to warm up the indoor environment. Voted thermal acceptability was invariably above 85%.

During winter, the recorder indoor humidity was very low; however, it did not affect the thermal sensation vote. For both Japanese and non-Japanese students, the thermal sensation was significantly determined only by the indoor temperature. The effects of clothing and activity were also negligible.

The neutral indoor temperature could be estimated as 21 °C for Japanese students, and as 22 °C for non-Japanese (by linear regression analysis). However, the highest probability of voting neutral for Japanese students was only 65%, and it was estimated within 19–22 °C indoor temperature. For non-Japanese students, it is 75% within 19–24°C indoors.

Japanese students were notably more sensitive to their indoor environment as compared to non-Japanese ones (sensitivity of 0.55/ K and 0.20/ K respectively), and the comfortable temperature for Japanese subjects could be estimated as 20 °C and as 22 °C for non-Japanese. The calculated indoor comfort for both groups was correlated to the changing outdoor climate (T_{rm}) that could have been reassuring about estimating indoor comfort based on outdoor climate. However, there was a significant difference in the comfort we calculated, and the comfort voted by the participating subjects.

For both Japanese and non-Japanese students, the yielded predicting models from the survey deviated from the models in the current international standards. In addition, the voted and the estimated neutrality and comfort in the study were mostly above the recommended maximum winter indoor temperature in Japan. As the recommendation is set considering the energy conservation, it is reasonable to further investigate how to make it possible to lower down the subjective neutral and comfortable temperatures without compromising personal comfort.

5. Limitations to the Study

There are certain limitations to the study as follows:

(1) Because of the Japanese lifestyle, some typical daily activities are conducted at a different height than usual—closer to or directly on the floor. This can include studying, sleeping, resting. The measuring instruments were placed in relation to the working plane in each particular room, causing deviation from the standard established heights. In our survey, the devices were placed within 0.6–1.1 m as opposed to the standard heights for measurements (0.1 m, 0.6 m, 1.1 m for sedentary activity);

(2) The measured air velocity suggested still air. This prevented any chance of analyzing further the effect of air velocity to the subjective thermal responses. In the future, it is necessary to conduct a field survey focused especially regarding air velocity, its correlation to behavioral adaptation and the effect on subjective thermal responses.

(3) Operative indoor temperature is calculated from the radiant and the air temperature in the room. In a room for residential occupancy without large hot or cold surfaces, air temperature alone can be used as an estimate of the operative temperature. However, we do acknowledge that not measuring the radiant temperature leaves room for unwanted assumptions, and we do consider it a limitation to the study

Author Contributions: Conceptualization (V.D., K.T., Y.N.); Methodology (V.D., K.T., Y.N.), Software (V.D.), Formal Analysis (V.D.), Investigation (V.D.), Resources (K.T., Y.N.), Data Curation (V.D.), Writing—Original Draft Preparation (V.D.), Writing—Review & Editing (V.D.), Visualization (V.D.), Supervision (K.T., Y.N.), Project Administration (K.T., Y.N.), Funding Acquisition (K.T., Y.N.).

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Part 2: Questionnaire about subjective perception of the indoor environment (Please, fill it in 3 times per day—just after waking up; at noon; just before going to bed)		
Date and time: year	month day	hour (am/pm) min
◻ Wake up	◻ Noon	◻ Going to bed
Environmental Conditions **RIGHT NOW** (perception, evaluation, preference, acceptability)		
1-① How do you feel about the thermal environment at this precise moment in your room? I feel: ◻ hot ◻ warm ◻ slightly warm ◻ neutral ◻ slightly cool ◻ cool ◻ cold	1-② How do you find the thermal environment of your room? ◻ very comfortable ◻ comfortable ◻ slightly comfortable ◻ slightly uncomfortable ◻ uncomfortable ◻ very uncomfortable	1-③ Please state how would you prefer to be now: ◻ warmer ◻ no change ◻ cooler 1-④ How do you judge the thermal environment? ◻ Acceptable ◻ Unacceptable
2-① How do you feel about the humidity in your room? I feel:very humid ◻ humid ◻ slightly humid ◻ neutral ◻ slightly dry ◻ dry ◻ very dry	2-② How do you find the humidity of your room? ◻ very comfortable ◻ comfortable ◻ slightly comfortable ◻ slightly uncomfortable ◻ uncomfortable ◻ very uncomfortable	2-③ Please state how would you prefer to be now: ◻ more humid ◻ no change ◻ dryer 2-④How do you judge the humidity in your room? ◻ Acceptable ◻ Unacceptable
3-① How do you feel about the air movement within your room? I feel: ◻ very strong movement ◻ strong movement ◻ slight movement ◻ neutral ◻ slightly still ◻ still ◻ very still	3-② How do you find the air movement of your room? ◻ very comfortable ◻ comfortable ◻ slightly comfortable ◻ slightly uncomfortable ◻ uncomfortable ◻ very uncomfortable	3-③ Please state how would you prefer to be now: ◻ stronger air movement ◻ no change ◻ weaker air movement 3-④ How do you judge the air movement in your room? ◻ Acceptable ◻ Unacceptable

4-① How do you feel about the air quality in your room? I feel:

- ☐ very stuffy air
- ☐ stuffy air
- ☐ slightly stuffy
- ☐ neutral
- ☐ slightly fresh air
- ☐ fresh air
- ☐ very fresh air

4-② How do you find the air quality of your room?

- ☐ very comfortable
- ☐ comfortable
- ☐ slightly comfortable
- ☐ slightly uncomfortable
- ☐ uncomfortable
- ☐ very uncomfortable

4-③ Please state how would you prefer to be now:

- ☐ more stuffy
- ☐ no change
- ☐ more fresh

4-④How do you judge the air quality in your room?

- ☐ Acceptable
- ☐ Unacceptable

5-① How do you feel about the odours in your room? I feel:

- ☐ very strong odours
- ☐ noticeable
- ☐ slightly noticeable
- ☐ neutral
- ☐ slightly unnoticeable
- ☐ unnoticeable
- ☐ no odors at all

5-② How do you find the odours in your room?

- ☐ very comfortable
- ☐ comfortable
- ☐ slightly comfortable
- ☐ slightly uncomfortable
- ☐ uncomfortable
- ☐ very uncomfortable

5-③ Please state how would you prefer to be now:

- ☐ more noticeable odours
- ☐ no change
- ☐ less noticeable odours

5-④ How do you judge the odours in your room?

- ☐ Acceptable
- ☐ Unacceptable

6-① How do you feel about the brightness level of your room? I feel:

- ☐ very bright
- ☐ bright
- ☐ slightly bright
- ☐ neutral
- ☐ slightly dim
- ☐ dim
- ☐ very dim

6-② How do you find the brightness of your room?

- ☐ very comfortable
- ☐ comfortable
- ☐ slightly comfortable
- ☐ slightly uncomfortable
- ☐ uncomfortable
- ☐ very uncomfortable

6-③ Please state how would you prefer to be now:

- ☐ brighter
- ☐ no change
- ☐ dimmer

6-④ How do you judge the brightness in your room?

- ☐ Acceptable
- ☐ Unacceptable

7-① How do you feel about the noise level in your room? I feel:

- ☐ very disturbing
- ☐ disturbing
- ☐ slightly disturbing
- ☐ neutral
- ☐ slightly unnoticeable
- ☐ unnoticeable
- ☐ not at all noticeable

7-② How do you find the noise level in your room?

- ☐ very comfortable
- ☐ comfortable
- ☐ slightly comfortable
- ☐ slightly uncomfortable
- ☐ uncomfortable
- ☐ very uncomfortable

7-③ Please state how would you prefer to be now:

- ☐ higher noise levels
- ☐ no change
- ☐ lower noise levels

7-④ How do you judge the noise level in your room?

- ☐ Acceptable
- ☐ Unacceptable

Please, mark the closest to your clothing, activity and personal control over the room environment:

CLOTHING (circle the appropriate)	**ACTIVITY** **(in the last 30 min)**	%	**CONTROLS** (circle the appropriate)
Shirt, short/long sleeves	Sitting (passive work)		Door opened/closed
Trousers/long skirt	Sitting (active work)		Window slightly open
Dress	Standing relaxed		Window wide open
Pullover	Standing working		Lights on/off
Jacket	Walking outdoors		Air-condition on (heat)
Long/short socks	Walking indoors		Air-condition on (cool)
Shoes	Riding a bicycle outdoors		Air-condition off
Sneakers	Other (specify) … …		Fan on/off
Slippers			Local heater on/off
Other (specify) … …			Blinds open/closed
	Total	**100%**	Other (specify) … …

8-① During THE LAST 30 min have you experienced any of the following symptoms? (*please, check ALL that apply*)	
◻ dry, itching or irritated eyes ◻ headache ◻ sore or dry throat ◻ unusual tiredness, fatigue or drowsiness ◻ stuffy or runny nose, or sinus congestion ◻ cough or difficulty breathing ◻ tired or strained eyes	◻ tension, irritability or nervousness ◻ pain or stiffness in back, shoulders or neck ◻ sneezing ◻ dizziness or lightheadedness ◻ nausea or upset stomack ◻ dry or itchy skin ◻ others (please specify)
8-② Within THE LAST 30 min did you eat a snack or meal? ◻ Yes ◻ No	**8-④ Within THE LAST 30 min** did you smoke a cigarette? ◻ YES ◻ NO
8-③ Within THE LAST 30 min did you have a drink that was: YES/NO ◻ HOT ◻ COLD ◻ Caffeinated	**8-⑤ Within THE LAST 30 min** did you adjust your clothing? (*if YES, please describe briefly*) ◻ YES ◻ NO

THANK YOU FOR PARTICIPATING IN THERMAL COMFORT SURVEY

Appendix B

Table A1. List of garments used in the questionnaire and the clo values assigned for winter.

Garment	Clo	Garment	Clo	Garment	Clo
Shirt (short sleeves)	0.19	Pullover	0.36	Shoes	0.07
Shirt (long sleeves)	0.25	Jacket	0.44	Sneakers	0.07
Trousers/long skirt	0.24	Long socks	0.03	Slippers	0.03
Dress	0.47	Short socks	0.02	Other	0.72

Table A2. List of activities used in the questionnaire and the Met values assigned.

Activity	Met	Wording in ASHRAE handbook (Chapter 9, Table 4)
Sitting (passive work)	1.0	Office activities—reading seated; writing
Sitting (active work)	1.2	Office activities—filing seated
Standing (relaxed)	1.2	Resting—standing, relaxed
Standing (working)	2.7	Miscellaneous Occupational Activities: Housecleaning
Walking outdoors	2.6	Walking (on level surface) 4.3 km/h
Walking indoors	1.7	Office activities: Walking about
Riding a bicycle	4.0	Bicycling <16 km/h. general, leisure to work or for pleasure (The value for "riding a bicycle" from: https://community.plu.edu/~{}chasega/met.html)
Other activity indoors	1.0	Resting—seated, quiet

Table A3. Descriptive statistic: Thermal responses in relation to climate. Frequency distribution all winter data points (%) N = 300.

T_{out}	TSV (all)							TC (all)						TP (all)			TA (all)		AC mode (all)	
	−3	−2	−1	0	1	2	3	−3	−2	−1	1	2	3	−1	0	1	0	1	HT	FR
−3.0	0	0	25	50	0	25		0	0	25	50	25	0	0	25	75	100	0	0	100
−2.0	0	0	40	10	10	40		0	0	10	30	50	10	0	80	20	100	0	30	70
−1.0	11	11	11	56	0	11		11	11	11	22	44	0	0	44	56	78	22	22	78
0.0	0	13	50	13	13	13		0	0	19	38	44	0	0	56	44	94	6	50	50
1.0	8	4	15	27	31	15		0	8	8	31	54	0	0	77	23	92	8	19	81
2.0	17	6	20	17	9	31		3	6	26	20	46	0	3	54	43	89	11	37	63
3.0	27	9	20	16	20	9		4	16	31	20	29	0	0	36	64	82	18	58	42
4.0	18	14	16	18	23	11		0	11	30	16	41	2	5	45	50	86	14	48	52
5.0	12	8	23	15	23	19		0	4	35	15	42	4	4	50	46	96	4	58	42
6.0	0	41	12	12	35	0		0	6	24	41	24	6	0	35	65	88	12	47	53
7.0	18	9	27	18	9	18		0	9	27	36	18	9	0	45	55	82	18	36	64
8.0	10	5	15	25	30	15		0	10	10	25	55	0	5	55	40	90	10	45	55
9.0	0	22	33	22	22	0		0	0	33	33	33	0	0	44	56	100	0	56	44
10.0	17	0	17	33	17	17		0	0	17	67	17	0	17	33	50	100	0	100	0
11.0	0	0	43	29	29	0		0	0	0	14	71	14	0	57	43	100	0	57	43
12.0	0	0	50	0	50	0		0	0	0	50	50	0	0	50	50	100	0	0	100
13.0	20	0	40	0	20	20		0	20	0	0	60	20	0	40	60	80	20	40	60
14.0	0	0	20	20	60	0		0	0	0	40	40	20	0	60	40	100	0	60	40
15.0	0	0	0	67	33	0		0	0	0	67	0	33	0	100	0	100	0	33	67
Total	13	10	22	20	21	15		1	8	22	26	40	3	2	50	48	90	10	45	55

Note: The table presents the distribution of winter data points in % of raw total, where T_{out}: Outdoor air temperature (°C), TSV: Thermal sensation vote, TC: Thermal comfort vote; TP: Thermal preference vote, TA: Thermal acceptability vote, AC mode: Air conditioning mode, FR: Free running mode (without using air conditioning); HT: Heating mode (using air conditioning for heating).

Table A4. Descriptive statistic: Thermal responses in relation to climate. Frequency distribution Japanese winter data points (%) N = 128.

T_{out}	TSV (JP)							TC (JP)						TP (JP)			TA (JP)		AC mode (JP)	
	−3	−2	−1	0	1	2	3	−3	−2	−1	1	2	3	−1	0	1	0	1	HT	FR
−3.0	0	0	50	17	17	17			0	0	50	50		0	83	17	100	0	33	67
−2.0	0	0	0	75	0	25			0	0	0	100		0	100	0	100	0	0	100
−1.0	0	20	50	10	10	10			0	30	40	30		0	50	50	90	10	70	30
0.0	13	7	20	13	27	20			13	13	20	53		0	67	33	87	13	27	73
1.0	25	5	25	5	15	25			10	30	25	35		5	50	45	85	15	40	60
2.0	35	6	35	12	0	12			12	47	24	18		0	29	71	82	18	59	41
3.0	19	13	6	6	38	19			0	44	13	44		13	50	38	94	6	44	56
4.0	22	11	11	11	33	11			0	44	11	44		0	56	44	100	0	67	33
5.0	0	29	14	14	43	0			0	29	43	29		0	57	43	100	0	71	29
6.0	25	25	0	25	0	25			0	50	50	0		0	25	75	75	25	50	50
7.0	0	0	0	38	38	25			0	13	25	63		13	88	0	100	0	50	50
8.0	0	25	25	25	25	0			0	50	25	25		0	50	50	100	0	50	50
9.0	33	0	0	33	0	33			0	33	67	0		33	0	67	100	0	100	0
10.0	0	0	0	100	0	0			0	0	100	0		0	0	100	100	0	100	0
11.0	0	0	0	0	100	0			0	0	0	100		0	100	0	100	0	0	100
12.0	0	0	0	50	50	0			0	0	50	50		0	50	50	100	0	50	50
13.0	0	0	0	100	0	0			0	0	100	0		0	100	0	100	0	100	0
14.0	16	9	20	17	21	16			5	30	27	38		4	54	42	91	9	49	51
15.0	0	0	50	17	17	17			0	0	50	50		0	83	17	100	0	33	67
Total	0	0	0	75	0	25			0	0	0	100		0	100	0	100	0	0	100

Note: The table presents the distribution of winter data points in % of raw total, where T_{out}: Outdoor air temperature (°C), TSV: Thermal sensation vote, TC: Thermal comfort vote; TP: Thermal preference vote, TA: Thermal acceptability vote, AC mode: Air conditioning mode, FR: Free running mode (without using air conditioning); HT: Heating mode (using air conditioning for heating).

Table A5. Descriptive statistic: Thermal responses in relation to climate. Frequency distribution non-Japanese winter data points (%) N = 172.

T_{out}	TSV (non-JP)							TC (non-JP)						TP (non-JP)			TA (non-JP)		AC Mode (non-JP)	
	−3	−2	−1	0	1	2	3	−3	−2	−1	1	2	3	−1	0	1	0	1	HT	FR
−3.0	0	0	25	50	0	25		0	0	25	50	25	0	0	25	75	100	0	0	100
−2.0	0	0	25	0	0	75		0	0	25	0	50	25	0	75	25	100	0	25	75
−1.0	20	20	20	40	0	0		20	20	20	40	0	0	0	0	100	60	40	40	60
0.0	0	0	50	17	17	17		0	0	0	33	67	0	0	67	33	100	0	17	83
1.0	0	0	9	45	36	9		0	0	0	45	55	0	0	91	9	100	0	9	91
2.0	7	7	13	33	0	40		7	0	20	13	60	0	0	60	40	93	7	33	67
3.0	21	11	11	18	32	7		7	18	21	18	36	0	0	39	61	82	18	57	43
4.0	18	14	21	25	14	7		0	18	21	18	39	4	0	43	57	82	18	50	50
5.0	6	6	29	18	18	24		0	6	29	18	41	6	6	47	47	94	6	53	47
6.0	0	50	10	10	30	0		0	10	20	40	20	10	0	20	80	80	20	30	70
7.0	14	0	43	14	14	14		0	14	14	29	29	14	0	57	43	86	14	29	71
8.0	17	8	25	17	25	8		0	17	8	25	50	0	0	33	67	83	17	42	58
9.0	0	20	40	20	20	0		0	0	20	40	40	0	0	40	60	100	0	60	40
10.0	0	0	33	33	33	0		0	0	0	67	33	0	0	67	33	100	0	100	0
11.0	0	0	50	17	33	0		0	0	0	0	83	17	0	67	33	100	0	50	50
12.0	0	0	100	0	0	0		0	0	0	100	0	0	0	0	100	100	0	0	100
13.0	20	0	40	0	20	20		0	20	0	0	60	20	0	40	60	80	20	40	60
14.0	0	0	33	0	67	0		0	0	0	33	33	33	0	67	33	100	0	67	33
15.0	0	0	0	50	50	0		0	0	0	50	0	50	0	100	0	100	0	0	100
Total	10	10	23	22	21	13		2	10	16	24	42	5	1	48	52	88	12	42	58

Note: The table presents the distribution of winter data points in % of raw total, where T_{out}: Outdoor air temperature (°C), TSV: Thermal sensation vote, TC: Thermal comfort vote; TP: Thermal preference vote, TA: Thermal acceptability vote, AC mode: Air conditioning mode, FR: Free running mode (without using air conditioning); HT: Heating mode (using air conditioning for heating).

References

1. Ole Fanger, P. *Thermal Comfort*; Danish Technical Press: Copenhagen, Danish, 1970.
2. D'Ambrosio Alfano, F.R.; Olesen, B.W.; Palella, B.I. Povl Ole Fanger's impact ten years later. *Energy Build.* **2017**, *152*, 243–249. [CrossRef]
3. Nicol, F.; Humphreys, M.; Roaf, S. *Adaptive Thermal Comfort: Principles and Practice*, 1st ed.; Routledge: Abington, UK, 2012.
4. Humphreys, M.A.; Nicol, J.F.; Roaf, S. *Adaptive Thermal Comfort. Foundations and Analysis*; Routhledge: Oxon, London, UK, 2016.
5. Brager, G.S.; de Dear, R.J. Thermal adaptation in the built environment: a literature review. *Energy Build.* **1998**, *27*, 83–96. [CrossRef]
6. De Dear, R.J.; Brager, G.S. Developing an adaptive model of thermal comfort and preference. *ASHRAE Trans.* **1998**, *104*, 145–167. Available online: https://cloudfront.escholarship.org/dist/prd/content/qt4qq2p9c6/qt4qq2p9c6.pdf (accessed on 20 February 2019).
7. Lawson, C. Japan's New Growth Strategy: Internationalisation of Japanese Universities. Available online: https://internationaleducation.gov.au/International-network/japan/countryoverview/Documents/2012%20Report%20-%20Internationalisation%20of%20Japanese%20Universities.pdf (accessed on 13 January 2019).
8. Damiati, S.A.; Zaki, S.A.; Rijal, H.B.; Wonorahardjo, S. Field study on adaptive thermal comfort in office buildings in Malaysia, Indonesia, Singapore, and Japan during hot and humid season. *Build. Environ.* **2016**, *109*, 208–223. [CrossRef]
9. Indraganti, M.; Ooka, R.; Rijal, H.B. Thermal comfort in offices in summer: Findings from a field study under the "setsuden" conditions in Tokyo, Japan. *Build. Environ.* **2013**, *61*, 114–132. [CrossRef]
10. Mustapa, M.S.; Zaki, S.A.; Rijal, H.B.; Hagishima, A.; Ali, M.S.M. Thermal comfort and occupant adaptive behaviour in Japanese university buildings with free running and cooling mode offices during summer. *Build. Environ.* **2016**, *105*, 332–342. [CrossRef]
11. Tanabe, S.; Iwahashi, Y.; Tsushima, S.; Nishihara, N. Thermal comfort and productivity in offices under mandatory electricity savings after the Great East Japan earthquake. *Archit. Sci. Rev.* **2013**, *56*, 4–13. [CrossRef]
12. Rijal, H.B.; Humphreys, M.A.; Nicol, J.F. Adaptive model and the adaptive mechanisms for thermal comfort in Japanese dwellings. *Energy Build.* **2019**, *202*, 109371. [CrossRef]

13. Rijal, H.B.; Honjo, M.; Kobayashi, R.; Nakaya, T. Investigation of comfort temperature, adaptive model and the window-opening behaviour in Japanese houses. *Archit. Sci. Rev.* **2013**, *56*, 54–69. [CrossRef]
14. Rijal, H.B.; Humphreys, M.; Nicol, F. Study on adaptive model. Part 3. Development of the adaptive model for thermal comfort in Japanese houses. In Proceedings of the 8th Windsor Conference: Counting the Cost of Comfort in a Changing World, Cumberland Lodge, Windsor, UK, 10–13 April 2014; p. 1013.
15. Rijal, H.B.; Humphreys, M.A.; Nicol, J.F. Towards an adaptive model for thermal comfort in Japanese offices. *Build. Res. Inf.* **2017**, *45*, 717–729. [CrossRef]
16. Nakano, J.; Tanabe, S.; Kimura, K. Differences in perception of indoor environment between Japanese and non-Japanese workers. *Energy Build.* **2002**, *34*, 615–621. [CrossRef]
17. Goto, T.; Mitamura, T.; Yoshino, H.; Tamura, A.; Inomata, E. Long-term field survey on thermal adaptation in office buildings in Japan. *Build. Environ.* **2007**, *42*, 3944–3954. [CrossRef]
18. Shinohara, N.; Tokumura, M.; Kazama, M.; Yonemoto, Y.; Yoshioka, M.; Kagi, N.; Hasegawa, K.; Yoshino, H.; Yanagi, U. Indoor air quality and thermal comfort in temporary houses occupied after the Great East Japan Earthquake. *Indoor Air* **2014**, *24*, 425–437. [CrossRef] [PubMed]
19. Schweiker, M.; Shukuya, M. Comparative effects of building envelope improvements and occupant behavioural changes on the exergy consumption for heating and cooling. *Energy Policy* **2010**, *38*, 2976–2986. [CrossRef]
20. Schweiker, M.; Shukuya, M. Investigation on the effectiveness of various methods of information dissemination aiming at a change of occupant behaviour related to thermal comfort and exergy consumption. *Energy Policy* **2011**, *39*, 395–407. [CrossRef]
21. Schweiker, M.; Shukuya, M.; Wagner, A. Analysis of human interactions together with human-body exergy consumption rate. In Proceedings of the 7th Windsor Conference: The Changing Context of Comfort in an Unpredictable World, Windsor, UK, 12–15 April 2012; Available online: https://publikationen.bibliothek.kit.edu/1000034027/2497116 (accessed on 13 January 2019).
22. Wu, Z.; Li, N.; Wargocki, P.; Peng, J.; Li, J.; Cui, H. Adaptive thermal comfort in naturally ventilated dormitory buildings in Changsha, China. *Energy Build.* **2019**, *186*, 56–70. [CrossRef]
23. Ning, H.; Wang, Z.; Zhang, X.; Ji, Y. Adaptive thermal comfort in university dormitories in the severe cold area of China. *Build. Environ.* **2016**, *99*, 161–169. [CrossRef]
24. Lei, Z.; Liu, C.; Wang, L.; Li, N. Effect of natural ventilation on indoor air quality and thermal comfort in dormitory during winter. *Build. Environ.* **2017**, *125*, 240–247. [CrossRef]
25. He, Y.; Li, N.; Zhang, W.; Peng, J. Overall and local thermal sensation & comfort in air-conditioned dormitory with hot-humid climate. *Build. Environ.* **2016**, *101*, 102–109. [CrossRef]
26. He, Y.; Li, N.; Peng, J.; Zhang, W.; Li, Y. Field study on adaptive comfort in air conditioned dormitories of university with hot-humid climate in summer. *Energy Build.* **2016**, *119*, 1–12. [CrossRef]
27. Belda, M.; Holtanová, E.; Halenka, T.; Kalvová, J. Climate classification revisited: From Köppen to Trewartha. *Clim. Res.* **2014**, *59*, 1–13. [CrossRef]
28. Peel, M.C.; Finlayson, B.L.; Mcmahon, T.A. Updated world map of the Köppen-Geiger climate classification. *Hydrol. Earth Syst. Sci.* **2007**, *11*, 1633–1644. [CrossRef]
29. Japanese Meteorological Agency. Tables of Monthly Climate Statistics, 2019. Available online: https://www.data.jma.go.jp/obd/stats/etrn/view/monthly_s3_en.php?block_no=47654&view=1 (accessed on 17 January 2019).
30. Draganova, V.; Yokose, H.; Tsuzuki, K.; Nabeshima, Y. Adaptive environmental comfort in mixed dormitories during summer in Japan. In Proceedings of the 15th Conference of the International Society of Indoor Air Quality & Climate (ISIAQ), Philadelphia, PA, USA, 22–27 July 2018.
31. Kothari, C.R. *Research Methodology. Methods and Techniques*, 2nd ed.; New Age International (P) Limited: New Delhi, India, 2004.
32. EN ISO 10551:2001. *Ergonomics of the Thermal Environment—Assessment of the Influence of the Thermal Environment Using Subjective Judgement Scales*; CEN: Brussels, Belgium, 2001.
33. ASHRAE. *Thermal Environmental Conditions for Human Occupancy, American Society of Heating*; ANSI/ASHRAE Standard 55-2017; Refrigerating and Air-Conditioning Engineers, Inc.: Atlanta, GA, USA, 2017.
34. CEN. *Energy Performance of Buildings—Ventilation for Buildings—Part 1: Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and, CEN*; EN 16798-1:2019 (E); CEN: Brussels, Belgium, 2017.

35. Katsuno, J.; Rijal, H.B.; Kikuchi, S. Investigation of the comfort temperature and adaptive model in Japanese houses in summer. In Proceedings of the 7th Windsor Conference: The Changing Context of Comfort in an Unpredictable World, Windsor, UK, 12–15 April 2012; Available online: http://nceub.org.uk/w2012/pdfs/session3/W1269%20Jiro.pdf (accessed on 13 January 2019).
36. Humphreys, M.A.; Nicol, J.F. Adaptive thermal comfort and sustainable thermal standards for buildings. *Energy Build.* **2002**, *34*, 563–572. [CrossRef]
37. Li, B.; Du, C.; Yao, R.; Yu, W.; Costanzo, V. Indoor thermal environments in Chinese residential buildings responding to the diversity of climates. *Appl. Therm. Eng.* **2018**, *129*, 693–708. [CrossRef]
38. Yan, H.; Mao, Y.; Yang, L. Thermal adaptive models in the residential buildings in different climate zones of Eastern China. *Energy Build.* **2017**, *141*, 28–38. [CrossRef]
39. Indraganti, M.; Boussaa, D. An adaptive relationship of thermal comfort for the Gulf Cooperation Council (GCC) countries: The case of offices in Qatar. *Energy Build.* **2018**, *159*, 201–212. [CrossRef]
40. Humphreys, M.A.; Rijal, H.B.; Nicol, J.F. Updating the adaptive relation between climate and comfort indoors; New insights and an extended database. *Build. Environ.* **2013**, *63*, 40–55. [CrossRef]
41. Olesen, B.W.; d'Ambrosio Alfano, F.R.; Parsons, K.; Palella, B.I. The history of international standardization for the ergonomics of the thermal environment. In Proceedings of the ICHES 2016 Fifth International Conference Human-Environment System, Nagoya, Japan, 29 October–2 November 2016.
42. METI. Winter Energy Efficiency Measures (in Japanese—English translation), 2016. Available online: http://www.meti.go.jp/english/policy/energy_environment/energy_efficiency/index.html (accessed on 23 February 2019).
43. Goromosov, M.S. *The Physiological Basis of Health Standards for Dwellings*; World Health Organization: Geneva, Belgium, 1968; Available online: https://apps.who.int (accessed on 3 April 2019).

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