

Relationship between psychological responses and physical environments in forest settings

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ABSTRACT

The present study aimed to clarify the relationship between psychological responses to forest and urban environmental settings and the physical variables that characterize these environments, by examining the psychological responses of 168 subjects to their physical environment. Field experiments were conducted in 14 forests and 14 urban areas across Japan. The semantic differential (SD) method was employed in which a questionnaire was administered to subjects prior to their walks in the forests and urban areas. In addition, the profile of mood states (POMS) questionnaire was administered before and after the walks, as well as before and after they sat and viewed the forest and urban landscapes. The environmental variables measured were air temperature, relative humidity, radiant heat, wind velocity, and two indices of thermal comfort [predicted mean vote (PMV) and predicted percentage dissatisfied (PPD)]. Responses to the SD questionnaire indicated that compared to urban settings, forest settings are perceived as being significantly more enjoyable, friendly, natural, and sacred. The POMS measures of tension and anxiety (T-A), depression and dejection (D), anger and hostility (A-H), vigor (V), confusion (C), fatigue (F), and total mood disturbance (TMD) showed significant differences between the forests and urban areas. These results strongly support the suggestion that forest settings have attention restoration effects. The psychological responses to physical environments were also significantly related to air temperature, relative humidity, radiant heat, wind velocity, PMV, and PPD. The results of this study might be useful in designing restoration environments in urban areas.

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1. Introduction

Noise pollution, air pollution, work pressure, and other stressors of urban life are increasingly driving humans to seek some form of stress relief (Frumkin, 2001). As a result, interest in the environmental stress experienced by urban dwellers is growing (Ulrich et al., 1991). Generally, natural environments including urban parks of everyday surroundings, and artificial constructed forests are associated with stronger positive health effects compared to urban environments. (Velarde, Fry, & Tveit, 2007), and outdoor recreation in an “green” environment has been shown to relieve stress in urban dwellers (Knopf, 1983). Ewert (1986) proposed that forest environ-

ments should be viewed as “a great health machine,” and activities conducted in forest settings reportedly provide both preventive and therapeutic health benefits (Kaplan, 1995).

With this background, the European Union initiated the forests, trees, and human health and well-being (COST action E39) study, which was conducted between 2004 and 2008. This study aimed to increase knowledge on the contribution of natural environments to the health and well-being of people residing in Europe. It also aimed to improve the description and evaluation of the relationship of forests and trees with human health (Karjalainen, Sarjala, & Raitio, 2010). The International Union of Forest Research Organizations (IUFRO) has also initiated a special project (task force) investigating the relationship between forests and human health (Karjalainen et al., 2010). In response to these initiatives, the Therapeutic Effects of Forests project was started in 2004 in Japan (Park, Kasetani, Tsunetsugu, Kagawa, & Miyazaki, 2010). As a part of this effort, the Japanese Society of Forest Medicine was established in 2007 under the Japanese Society for Hygiene with the purpose of promoting research in the field of forest medicine, including inves-

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tigations on the effects of forest bathing trips and the therapeutic effects of forests on human health (Park et al., 2010).

Based on empirical studies, nature environments has been shown to provide better emotional, physiological, and restoration than urban environments (Hartig & Staats, 2003). Several studies conducted in different countries have reported that compared to urban environments, natural environments can better enhance human moods (Hartig, Evans, Jamner, Davis, & Gärling, 2003; Laumann, Garling, & Stormark, 2003; Morita et al., 2006) and work performance (Shin, 2007). In the aspects of physiological responses in nature environments, it is more difficult to control the experimental conditions in the field than in the laboratory. However, the rapid progress of technology has enabled the application of certain physiological measurements to experiments in the field (Tsunetsugu, Park, & Miyazaki, 2010).

Recently studies reported lower concentrations of cortisol, lower blood pressure, and lower pulse rates, decreased sympathetic nerve activity (as measured by the low frequency/high frequency (LF/HF) component of heart rate variability (HRV)), enhanced parasympathetic nerve activity (as measured by the HF component of HRV), and higher levels of natural killer (NK) cell activity (a typical index of human immune function) in the human body when the subjects are in forest environments as opposed to when they are in urban environments (Lee, Park, Tsunetsugu, Kagawa, & Miyazaki, 2009; Li et al., 2008; Park et al., 2010, 2009).

The fact that people perceive environments in their complete aspects is a widely known fact. This is why many studies assign their purpose in revealing the relationship of humans and their environments in their complete aspects. I also believe that the fact of the requirement of an analytical approach is also an important fact.

The final aim of the Therapeutic Effects of Forests project is to design a restorative forest environment in an urban natural setting. Several studies have been conducted to identify the various elements that should be included in such environments. However, few have attempted to study restoration environments with a focus on the influence of physical variables of the environment on psychological responses. If the results obtained through this thoroughly structured experimental design are accumulated, it is believed to be able to reveal the mutual relationships of each variable.

In this study, we measured the psychological responses of 168 subjects to their physical environment in 14 forest and 14 urban areas using the semantic differential (SD) method and the profile of mood states (POMS) questionnaire. We also measured six physical variables of the environment within these areas. The aim of this study was to clarify the influence of forest and urban settings on the psychological well-being of humans by conducting field experiments at 14 forest and 14 urban sites across Japan. In addition, we attempted to identify the physical variables within the environments that were responsible for improving the psychological well-being. The results of this study can be used for designing restoration environments in urban areas for relaxation.

This study will firstly discuss the results of the psychological evaluations in the sequence of the SD method and POMS (profile of mood states), followed by the discussion of results of physical variables. Lastly, the relationship between psychological evaluations and the physical variables will be discussed.

2. Materials and methods

2.1. Experimental design

The study areas were located at 14 forests and 14 urban sites across Japan (Fig. 1). The experimental locations used in the study are listed in Table 1. The measurement of environmental variables

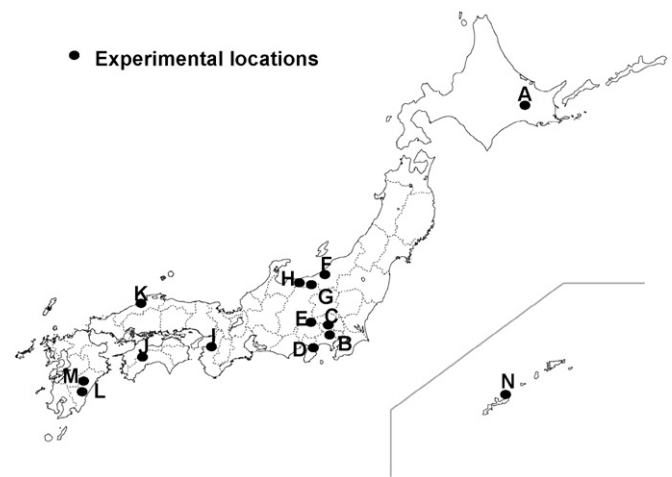


Fig. 1. Map of experimental locations.

have been conducted for 2 days during the most representative term of Japanese summer, as it was done for the psychological measurement. Each experiment involved 12 male university students with no reported history of physical or psychiatric disorders. A total of 168 subjects (age, 20.4 ± 4.1 years) were included over 14 experiments. The study was conducted according to the regulations of the Institutional Review Committee of the Forestry and Forest Products Research Institute in Japan. One day before the experiments began, the subjects were informed of the aim and experimental procedures of the study and their consent was obtained. After this orientation, the subjects previewed the selected forests and urban areas. A practice session to familiarize the subjects with the measurement procedures was then conducted at their place of accommodation. Identical single rooms were prepared and identical meals were provided to each subject for the duration of the study period in order to control these background environmental conditions.

The subjects were randomly divided into two groups. On the first day of the experimental period, 6 subjects were sent to a forest area and the remaining 6 (controls) were sent to an urban area. On the second day, the subjects were sent to the opposite area to eliminate bias of order. Upon arrival in the given area, the subjects sat on chairs and viewed the landscape for 15 min ("Viewing" phase) before noon; they then walked around the area for 15 min ("Walking" phase) in the afternoon (Fig. 2). On site J, a pleasant walking experiment was impossible due to the raining weather of the previous day. A walking experiment has not been conducted on site J.

For psychological evaluations, the SD method (Osgood, 1952) and POMS (McNair & Lorr, 1964) questionnaire were used. The SD method tests the subjective spatial impressions of subjects through a questionnaire with 25 pairs of opposing adjectives, each of which was evaluated on a 13-point scale. The measurements were recorded for one subject at a time after the "Walking" phase of the study between 14:30 and 15:20.

POMS is a well-established, factor analytically derived measure of psychological distress, and its high level of reliability and validity have been documented (McNair & Lorr, 1964.) POMS tests can simultaneously evaluate 6 measures of mood: tension and anxiety (T-A), depression (D), anger and hostility (A-H), vigor (V), confusion (C), fatigue (F), and total mood disturbance (TMD). We used T-scores of POMS for the analysis. For this study, we used the Japanese version of POMS (Yokoyama, Araki, Kawakami, & Takeshita, 1990), which consists of 30 items.

The first and second POMS measurements were performed before (10:40–11:30) and after (11:00–11:50) the "Viewing" phase

Table 1
Experimental locations.

	A	B	C	D	E	F	G
Experimental location	Hokkaido Tsurui-mura	Kanagawa Pref. Atsugi-shi	Tokyo Hinohara-mura	Shizuoka Pref. Kawazu-cho	Yamanashi Pref. Yamanashi-shi	Niigata Pref. Tsunan-machi	Nagano Pref. Kijimadaira-mura
Psychological experiment schedule	Sept. 12–Sept. 14 of 2006	Aug. 8–Aug. 11 of 2006	Sept. 4–Sept. 7 of 2006	Sept. 19–Sept. 22 of 2006	Aug. 22–Aug. 25 of 2006	July 18–July 20 of 2006	July 25–July 28 of 2006
Number of subjects	12	12	12	12	12	12	12
Average age of subjects	20.7 (± 1.3)	21.6 (± 2.1)	21.4 (± 0.9)	20.3 (± 0.6)	21.0 (± 0.9)	20.7 (± 1.8)	22.8 (± 1.2)
Physical environments experiment schedule	Sept. 13 of 2006	Aug. 10 of 2006	Sept. 6 of 2006	Sept. 11–Sept. 22 of 2006	Aug. 23 of 2006	July 19–July 20 of 2006	July 26 of 2006
	H	I	J	K	L	M	N
Experimental location	Nagano Pref. Otari-mura	Wakayama Pref. Koya-cho	Kochi Pref. Yusuhara-cho	Shimane Pref. Iinan-cho	Miyazaki Pref. Aya-cho	Kagoshima Pref. Kirishima-shi	Okinawa Pref. Kunigami-son
Psychological experiment schedule	Sept. 5–Sept. 8 of 2006	Aug. 1–Aug. 4 of 2006	May 16–May 19 of 2006	Sept. 19–Sept. 21 of 2006	July 11–July 13 of 2006	July 4–July 6 of 2006	Feb. 13–Feb. 15 of 2007
Number of subjects	12	12	12	12	12	12	12
Average age of subjects	20.7 (± 1.2)	21.8 (± 1.3)	21.2 (± 0.9)	20.9 (± 1.7)	21.8 (± 1.5)	21.9 (± 0.6)	22.4 (± 0.5)
Physical environments experiment schedule	Sept. 6 of 2006	Aug. 23 of 2006	May 18 of 2006	Sept. 20–Sept. 21 of 2006	July 12–July 13 of 2006	July 5–July 6 of 2006	Feb. 15 of 2007

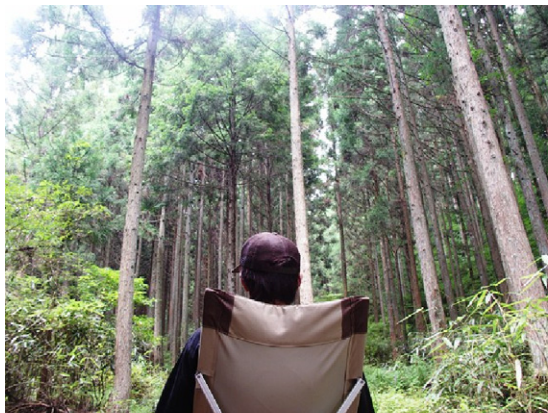


Fig. 2. Photos showing the forest sites used for the “Viewing” and “Walking” phases of the experiments.

of the study. The third and fourth measurements were performed before (14:10–15:00) and after (14:30–15:20) the “Walking” phase of the study. These measurements were performed for one subject at a time. The Steel–Dwass test was used to analyze the psychological responses based on the following 8 conditions: (1) survey responses before the “Viewing” phase in the forest and urban areas, (2) survey responses after the “Viewing” phase in the forest and urban areas, (3) survey responses before the “Walking” phase in the forest and urban areas, (4) survey responses after the “Walking” phase in the forest and urban areas, (5) survey responses before and after the “Viewing” phase in forests, (6) survey responses before and after the “Walking” phase in forests, (7) survey responses before and after the “Viewing” phase in urban areas, and (8) survey responses before and after the “Walking” phase in urban areas. Statistical analysis of physiological data was processed using EXCEL 2007 (Microsoft Inc.). A p value of <0.05 was considered significant.

2.2. Measurement of physical variables in each environment

Air temperature, relative humidity, radiant heat, wind velocity, and two indices of thermal comfort—predicted mean vote (PMV) and predicted percentage dissatisfied (PPD)—were measured at each of the forest and urban sites. These measurements were performed at or close to the areas where the psychological measurements were performed. PMV is an index for evaluating the compound effect of 6 factors related to the thermal environment (air temperature, relative humidity, wind velocity, radiant heat, amount of clothing worn, and metabolism level), and was adapted as an ISO standard to be used as an index of thermal comfort (ISO7730, 2005). PPD is a predicted value calculated from PMV. It predicts the percentage of people dissatisfied with the thermal conditions of their surroundings (ISO7730, 2005). Assumptions relating to the amount of clothing worn and the metabolic levels of the subjects are required for calculating PMV and PPD. In this study, the amount of clothing worn was specified as light summer clothes (clo: 0.5) in July and August and as autumn clothes (clo: 1.0) in the other months surveyed. In terms of the metabolic level, a standing level (met: 2.0) was used for the “Walking” phase of the study. A commercially available PMV meter (Amenity meter, AM-101, Kyoto Electronics Manufacturing Co. Ltd., Japan) was used to measure the air temperature, relative humidity, radiant heat, wind velocity, PMV, and PPD; measurements were recorded every 10 min at the sites surveyed. A portable weather meter (Pocket weather tracker, Kestrel 4000, Nielsen Kellerman Corporation, USA) was used for measuring barometric pressure as well as for measuring the temperature and relative humidity in urban areas.

2.3. Statistical analysis

The Steel–Dwass test was used to analyze the POMS subscales based on the following 8 conditions: (1) survey responses before the “Viewing” phase in the forest and urban areas, (2) survey responses after the “Viewing” phase in the forest and urban areas, (3) survey responses before the “Walking” phase in the forest and urban areas, (4) survey responses after the “Walking” phase in the forest and urban areas, (5) survey responses before and after the “Viewing” phase in forests, (6) survey responses before and after the “Walking” phase in forests, (7) survey responses before and after the “Viewing” phase in urban areas, and (8) survey responses before and after the “Walking” phase in urban areas.

For the comparison of SD method scales between forest and urban setting, a Wilcoxon rank sum test was used. Principal component analysis (using varimax rotation) was performed to analyze the sensory evaluations reported using the SD method.

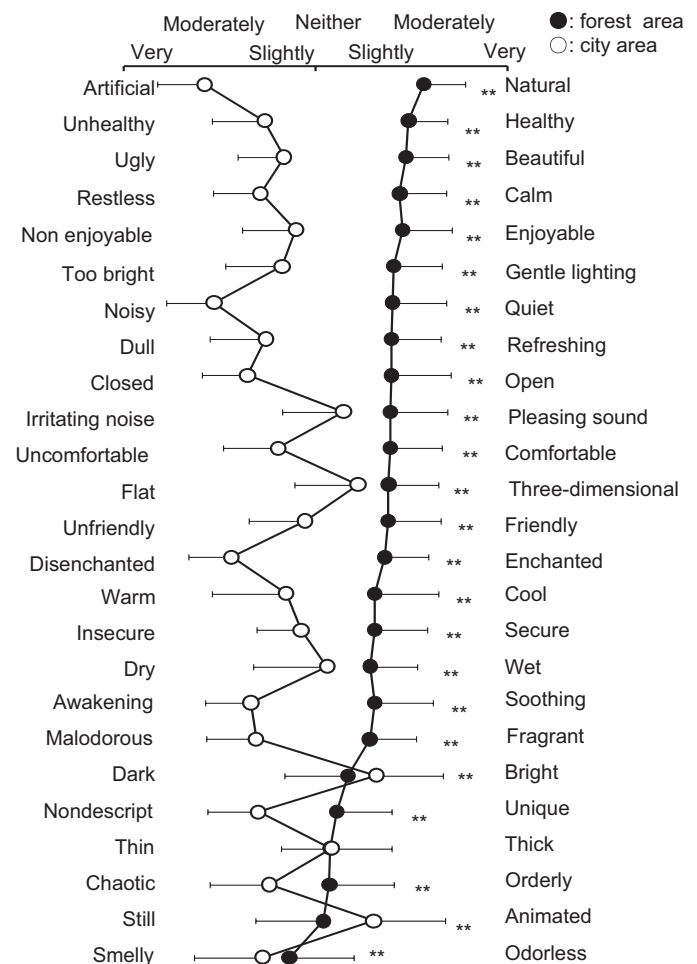


Fig. 3. Results from the evaluations of the psychological responses to forest and urban environments reported using the SD method after the “Walking” phase of the study. Average $\pm$ SD, $N = 162–168$, ** $p < 0.01$, p -value by Steel–Dwass test.

Statistical analysis of physiological data was processed using EXCEL 2007 (Microsoft Inc.). A p value of <0.05 was considered significant.

3. Results

3.1. Results of psychological evaluations performed using the SD method

Fig. 3 shows the SD profile curve of the average values reported by 168 subjects over 14 experiments after the “Walking” phase of the study in forest and urban areas. The figure indicates that compared to urban environments, the forest environments are perceived significantly more times as “natural (vs. artificial),” “healthy (vs. unhealthy),” “beautiful (vs. ugly),” “calm (vs. restless),” “enjoyable (vs. non enjoyable),” “gentle lighting (vs. too bright),” “quiet (vs. noisy),” “refreshing (vs. dull),” “open (vs. closed),” “pleasing sound (vs. irritating noise),” “comfortable (vs. uncomfortable),” “three-dimensional (vs. flat),” “friendly (vs. unfriendly),” “enchanted (vs. disenchanted),” “cool (vs. warm),” “secure (vs. insecure),” “wet (vs. dry),” “soothing (vs. awakening),” “fragrant (vs. malodorous),” “unique (vs. nondescript),” “orderly (vs. chaotic),” and “odorless (vs. smelly).” In contrast, descriptions such as “bright (vs. dark)” and “animated (vs. still)” are reported less often for forest environments than for urban environments.

Table 2
Results of principal component analysis.

	Factor 1	Factor 2	Factor 3
Enjoyable vs. non enjoyable	0.86		
Friendly vs. unfriendly	0.80		
Comfortable vs. uncomfortable	0.76		
Calm vs. restless	0.73		
Refreshing vs. dull	0.70		
Secure vs. insecure	0.69		
Pleasing sound vs. irritating noise	0.67		
Beautiful vs. ugly	0.65		
Fragrant vs. malodorous	0.65		
Healthy vs. unhealthy	0.64		
Natural vs. artificial		0.77	
Enchanted vs. disenchanting		0.75	
Quiet vs. noisy		0.70	
Gentle lighting vs. too bright		0.66	
Soothing vs. awakening		0.65	
Bright vs. dark			0.75
Variance (%)	27.6	24.1	4.4
Cumulative (%)	27.6	51.7	56.1
Cronbach's α	0.980	0.910	–

The results of principal component analysis are shown in Table 2. When the proper value was assumed to be 1 or more, seven repetitions resulted in an end of rotation and three factors were extracted. For the first principal component, variables with a factor loading of 0.6 or more, i.e., “enjoyable (vs. non enjoyable)” (0.86), “friendly (vs. unfriendly)” (0.80), “comfortable (vs. uncomfortable)” (0.76), “calm (vs. restless)” (0.73), “refreshing (vs. dull)” (0.70), “secure (vs. insecure)” (0.69), “pleasing sound (vs. irritating noise)” (0.67), “beautiful (vs. ugly)” (0.65), “fragrant (vs. malodorous)” (0.65), and “healthy (vs. unhealthy)” (0.64), were extracted, and the first principal component was then designated as “the perception of an environment as enjoyable and friendly”. For the second principal component, “natural (vs. artificial)” (0.77), “enchanted (vs. disenchanting)” (0.75), “quiet (vs. noisy)” (0.70), “gentle lighting (vs. too bright)” (0.62), and “soothing (vs. awakening)” (0.65) were extracted, and the second principal component was designated as “the perception of an environment as natural and enchanted.” For the third principal component, “bright (vs. dark)” (0.75) was extracted.

Fig. 4 shows the results of principal component factoring based on the results obtained from the SD method questionnaire comparing psychological responses to forest environment with those to

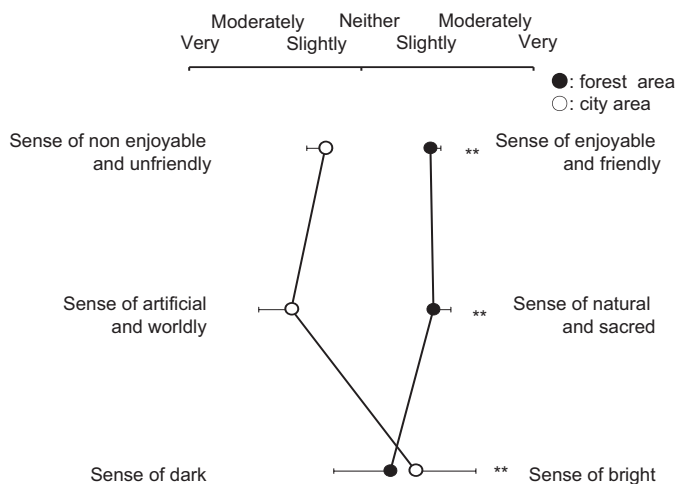


Fig. 4. Results from principal component analysis based on factors derived from the results of the SD method reports of psychological responses to forest and urban environments. Average $\pm$ SD, $N = 162$ – 168 , ** $p < 0.01$, p -value by Steel–Dwass test.

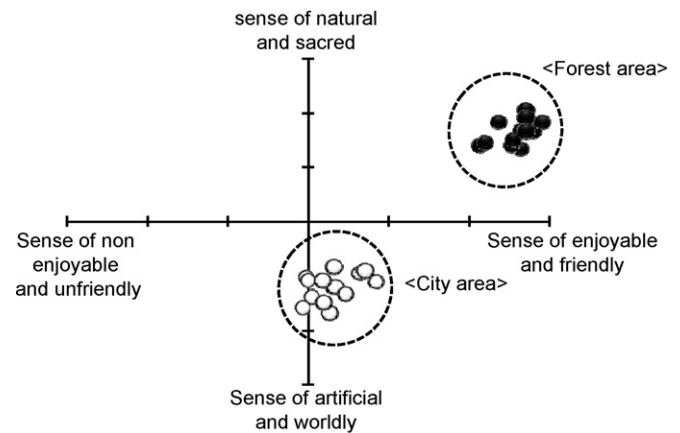


Fig. 5. The spatial and sensory factors identified by the SD method as they relate to the 14 experimental areas. $N = 14$.

urban environments. The first principal component (the perception of an environment as enjoyable and friendly) scored significantly higher in forest settings than in urban settings. The scores for the second principal component (the perception of an environment as natural and enchanted) were also higher in forests setting than in urban settings.

The scores of the first and second principal components are plotted in Fig. 5. The results indicate that forests are perceived as being “enjoyable and friendly” and “natural and enchanted” places whereas urban environments are perceived as being only slightly “enjoyable and friendly” and are not seen as “natural and enchanted” or “artificial and disenchanting” environments.

3.2. Results of psychological evaluations measured by POMS

The Friedman test was used to compare the differences between the POMS results obtained from subjects who visited the forest and urban areas. Significant differences were found in the tension and anxiety (T-A), anger and hostility (A-H), fatigue (F), confusion (C), vigor (V) and total mood disturbance (TMD) subscales of POMS. The results of a post hoc Steel–Dwass test are shown in Fig. 6.

For the tension and anxiety (T-A) subscale, significant differences between the forest and urban areas were observed in scores reported by subjects after the “Viewing” and “Walking” phases of the study. Moreover, significant differences were observed in the scores for tension and anxiety (T-A) before “Viewing” and after “Viewing” as well as before “Walking” and after “Walking” in the urban areas. This suggests that “Viewing” and “Walking” performed in urban areas can increase tension and anxiety.

For the anger and hostility (A-H) subscales of POMS, significant differences between the results reported for the forest and urban areas were observed after “Viewing” as well as after “Walking” phases of the study.

For the fatigue (F) and confusion (C) subscale, significant differences between the results reported for the forest and urban areas were observed for after “Viewing” and after “Walking” phases of the study. Scores for fatigue and confusion after “Viewing” and after “Walking” in forest areas were significantly lower than those reported before “Viewing” and before “Walking” in forest areas. Thus, performing “Viewing” and “Walking” activities in forest areas can reduce fatigue and confusion.

In contrast, for the vigor (V) subscale, scores were significantly higher after “Viewing” and after “Walking” in forest compared to that in urban areas. Moreover, significant differences were found between the before “Viewing” and after “Viewing” and between the before “Walking” and after “Walking,” scores for vigor in the forest

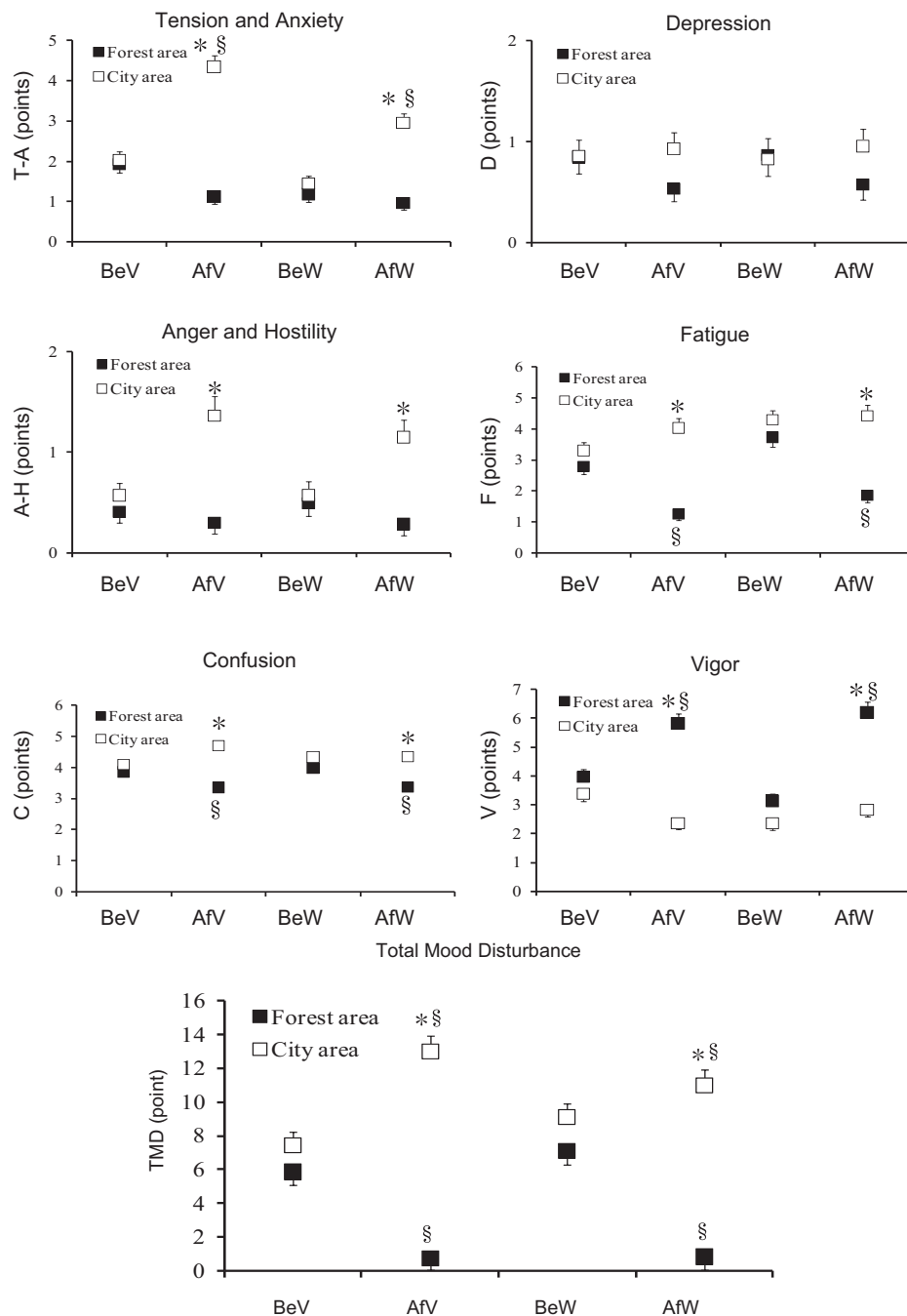


Fig. 6. POMS subscale results showing the observed differences between forests and urban areas. Average $\pm$ SD, $N = 150$ – 168 , * $p < 0.05$; p -value by Steel–Dwass test of the differences between forests and urban areas, $\$p < 0.05$, p -value by Steel–Dwass test of the differences between before and after “Viewing” phase as well as between before and after “Walking” phase. BeV: before “Viewing”; AfV: after “Viewing”; BeW: before “Walking”; AfW: after “Walking”.

area. Thus, performing “Viewing” and “Walking” activities in forest areas can increase vigor.

Scores for the total mood disturbance (TMD) subscale of POMS (calculated by combining $T-A + D + A-H + F + C - V$) are shown in Fig. 6. After performing both “Viewing” and “Walking” activities, the total mood disturbance (TMD) scores were significantly lower for the forest areas than for the urban areas. Moreover, significant differences between the before “Viewing” and after “Viewing” scores as well as between the before “Walking” and after “Walking” scores were observed. Therefore, performing “Viewing” and “Walking” activities in forest environments can decrease total mood disturbance (TMD), and performing “Viewing” and “Walking” activities

in urban environments can increase total mood disturbance (TMD).

3.3. Results from measurements of physical variables

Measurements of the physical variables were conducted for 2 days. The period of measurement was a typical summer season in Japan. The average air temperature in a forest area was $21.1 \pm 4.1^\circ\text{C}$ across the 14 locations. The highest temperature recorded was 28.7°C (site L) and the lowest was 14.1°C (site N). The average air temperature within an urban area was $26.6 \pm 4.9^\circ\text{C}$ across the 14 locations. The highest temperature

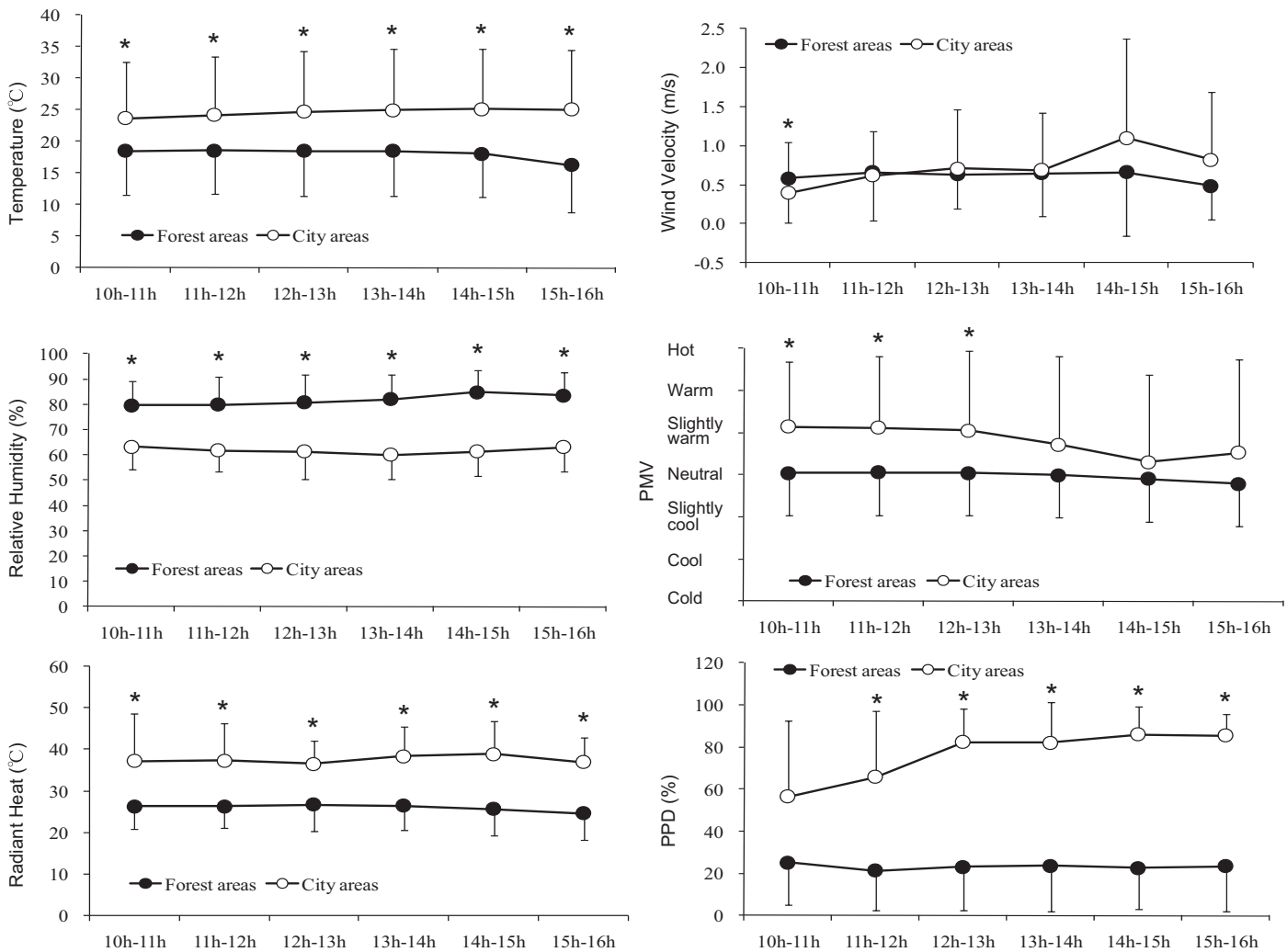


Fig. 7. Physical variables measured in the forests and urban areas. Average $\pm$ SD, $N=162$ (in the forests), 27 (in the urban areas), * $p < 0.05$, p -value by non-paired t -test.

recorded was 34.5°C (site E), and the lowest was 18.9°C (site N).

The average relative humidity in a forest area was $82.5 \pm 11.6\%$ across the 14 locations; the highest humidity recorded was 99.4% (site C) and the lowest 61.3% (site K). The average relative humidity in urban areas was $64.5 \pm 13.7\%$ across the 14 locations; the highest recorded relative humidity was 88.9% (site C) and the lowest 44.1% (site G).

The average radiant heat in a forest area was $22.9 \pm 4.8^\circ\text{C}$; the highest recorded reading was 30.2°C (site B) and the lowest 16.0°C (site N). In urban areas, the average radiant heat was $38.0 \pm 6.8^\circ\text{C}$; the highest recorded radiant heat was 43.5°C (site H) and the lowest 30.5°C (site B).

Measurements of wind velocity in forest areas averaged 0.7 ± 0.5 m/s; the fastest air velocity recorded was 1.6 m/s (site B) and the slowest 0.1 m/s (sites E and J). In the urban areas, the average air velocity recorded was 2.1 ± 1.6 m/s; the fastest air velocity recorded was 3.8 m/s (site H) and the slowest was 0.8 m/s (site B).

The average PMV value (which acts as an index of thermal comfort; ISO7730) was 0.2 (neutral) ± 0.8 in the forest areas; the highest value recorded was 1.8 (site L) and the lowest value was -1.0 (site M). The average PMV value in urban areas was 1.8 (warm) ± 1.2 ; the highest value recorded was 2.7 (site I) and the lowest value was 0.4 (site H).

In forests, the average PPD value (which predicts the percentage of people who will be dissatisfied with the thermal conditions of

their surroundings) was $24.5 \pm 21.6\%$; the highest PPD value was 67.5% (site L) and the lowest value was 6.1% (site G). The average value of PPD was $63.9 \pm 45.6\%$ in urban areas; the highest value was 93.2 (site I) and the smallest value was 11.4% (site H).

Air temperature, relative humidity, and radiant heat measurements over successive 1-h periods between 10 h and 16 h in both forests and urban areas are shown in Fig. 7. The air temperature in forest areas was significantly lower than that recorded in urban areas at all times. The results from the relative humidity measurements indicate that the relative humidity in forest settings was significantly higher than that in urban settings. The radiant heat found in forest areas was also significantly lower than that in urban areas.

Measurements of wind velocity, PMV, and PPD taken over successive 1-h periods between 10 h and 16 h in both forest and urban areas are shown in Fig. 7. In forest areas, wind velocity from 10 h to 11 h was significantly higher than that recorded in urban areas. From 10 h to 12 h, the PMV values recorded in forest areas were significantly lower than those recorded in urban areas; forest areas also had significantly lower PPD readings than those recorded in urban areas from 11 h to 16 h.

3.4. Relationship between psychological evaluations of forest settings and the physical variables that characterize those settings

The relationship between psychological responses and the physical variables of the environments is shown in Table 3. We used

Table 3

Relationship between the results of psychological response and physical variables of environments after the “Walking” phase.

	PMV		PPD (%)		Temperature (°C)		Relative humidity (%)		Radiant heat (°C)		Wind speed (m/s)	
	p-Value	r ²	p-Value	r ²	p-Value	r ²	p-Value	r ²	p-Value	r ²	p-Value	r ²
Sense of enjoyable and friendly	0.001	0.44	0.000	0.69	0.000	0.46	0.000	0.57	0.000	0.39	0.007	0.38
Sense of natural and holy	0.018	0.44	0.000	0.82	0.000	0.55	0.000	0.64	0.000	0.40	0.000	0.48
TMD of POMS in after ‘Walking’	0.024	0.23	0.000	0.47	0.000	0.25	0.000	−0.30	0.000	0.39	0.015	0.29

principal component analysis based on the first and second factor scores determined using the SD method and the TMD score from the POMS questionnaire administered after “Walking” as sources for the psychological responses. Air temperature, relative humidity, radiant heat, wind velocity, and PPD were used as physical variables pertaining to the environment. The *p*-value reported is that of the Spearman’s rank correlation coefficient; the *r*² value is the result of an ordinary correlation analysis. The results indicate that all psychological responses correlated significantly with all physical variables characterizing the environment.

PPD is a predicted value of how many percent of people are dissatisfied with the heat in the environment. PPD is calculated from PMV, which is an index that signifies the compound effect of six factors (temperature, humidity, wind velocity, radiant heat, amount of clothes, and metabolism level). The relationships between the PPD values and psychological responses are shown in Fig. 8. The PPD value and the perception of the environment as being “enjoyable and friendly” showed significant negative correlation (*r*²: 0.69); the PPD value also significantly negatively correlated with the percep-

tion of the environment as being “natural and enchanted” (*r*²: 0.82). However, the PPD value showed a significant positive correlation with the TMD scores from the POMS questionnaire (*r*²: 0.47).

4. Discussions and conclusions

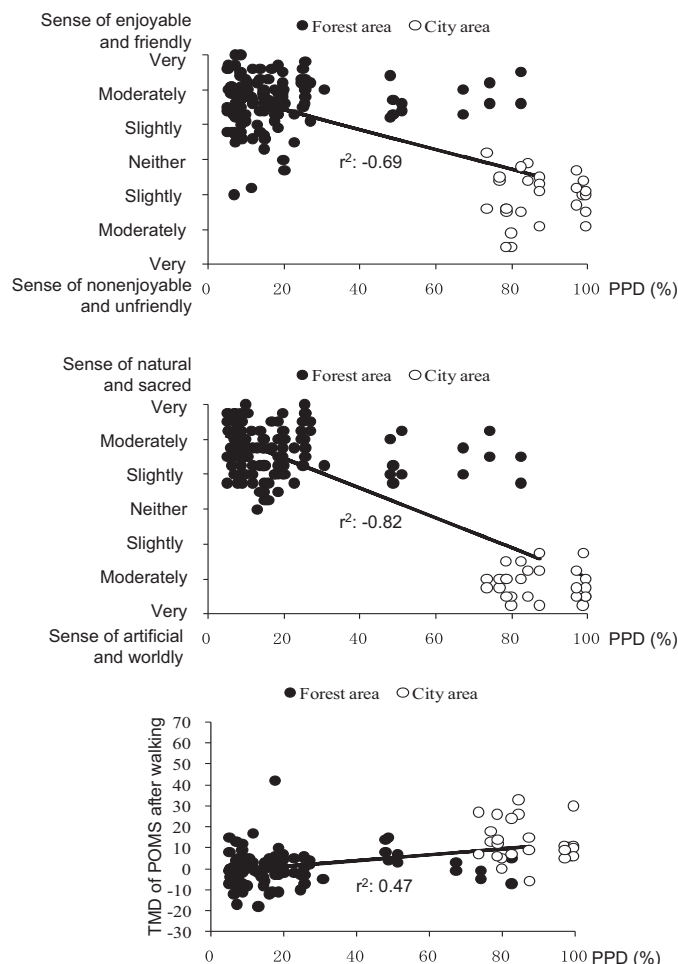
In this study, we investigated psychological responses of humans to forest and urban environments by using field experiments. In addition, we attempted to identify the physical variables within the environments that were responsible for the observed improvements in psychological well-being.

Results of subjective responses using the SD method revealed that subjects reported higher positive emotions when they spent time in forests than when they spent time in urban areas. In particular, these results showed that forest settings were perceived as being very “enjoyable and friendly” and as very “natural and enchanted” places. Decreases in tension and anxiety (T-A), anger and hostility (A-H), fatigue (F), confusion (C), and total mood disturbance (TMD) increased vigor (V) were observed in forests by the POMS test, suggesting that forest settings are capable of enhancing positive mood states and reducing negative mood states.

The results of this study are consistent with those of previous studies documenting people’s emotional responses to scenes of natural and urban landscapes (Hartig et al., 2003; Laumann et al., 2003; Morita et al., 2006; Ulrich et al., 1991). The rapid progress of technology has enabled application of certain physiological measurements to field experiments (Tsunetsugu et al., 2010). Hence, some studies have measured the physiological as well as psychological effects of forest environments on humans. The physiological studies have reported that forests can increase relaxation and positive emotions (Lee et al., 2009; Li et al., 2008; Park et al., 2010, 2009; Tsunetsugu et al., 2010). The results of the SD questionnaire also show that higher positive emotions were experienced in a forest setting, providing further evidence of the beneficial effects of forests on the well-being of people who live in urban areas.

Forests affect humans via their impact on each of the five human senses, including visual (scenery), olfactory (the smell of wood), auditory (sound of running streams or the rustle of leaves), and tactile (feeling the surfaces of leaves and trees) (Tsunetsugu et al., 2010). Previous studies have shown that viewing forest landscapes (such as those found in an urban park in Paris) can increase the incidence of positive emotions (feeling an increased sensation of comfort and feeling soothed), and can decrease blood pressure and prefrontal activity in the brain (Suda et al., 2001). Smelling forest scents (such as Japanese cedar chip) can also decrease blood pressure and prefrontal activity in the brain (Miyazaki, Morikawa, & Yamamoto, 1999). Thus, various studies have indicated that forests have a relaxing effect on humans. However, few field experiments have studied the relationship between the physical variables that characterize the forests and the relaxing effect that environment has on the study subjects. We therefore decided to focus our study on the physical variables that characterize the physical environment, such as air temperature, radiant heat, wind velocity and PPD.

We found that air temperature, radiant heat, wind velocity and PPD were all significantly lower in forests compared with urban areas. In addition, the relative humidity found in a forest setting was significantly higher than that found in an urban setting. PPD

**Fig. 8.** The relationship between PPD and psychological responses. *N* = 123–153

readings, which act as a typical index of the thermal conditions of an environment, were also significantly lower in forests than in urban areas. The average PPD value recorded in forests was $24.5 \pm 21.6\%$, which means that $24.5 \pm 21.6\%$ of people would be dissatisfied with the thermal conditions in that environment. However, the average PPD value taken from the urban environment predicts that $63.9 \pm 45.6\%$ of people would be dissatisfied with the thermal conditions of their surroundings.

Thus, it appears that in terms of thermal conditions, a forest setting is more comfortable for people than an urban setting during the summer in Japan. During the summer, tropical forests may be more uncomfortable than urban environments due to the high temperature and humidity. However, temperate environments as the site of the study are more comfortable than urban environments. Our study results also indicate that thermal comfort is significantly correlated with reports of positive emotions, suggesting that thermal comfort is one of the reasons why people report more positive feelings in forests than in urban areas. Thus urban planners and landscape scientists must consider thermal environments when selecting a resting area, if a more comfortable environment is to be provided to the user of urban forests in the summer.

The limitation of this study is as follows:

- (1) The effects of changes in seasons have not been considered in this paper. As the summer season has a high frequency in forest visits, the authors have set this season as the term of study and have accordingly conducted the study.
- (2) The relationship of the subjective sense of beauty or tranquility and physical variables has not been discussed in this study. It has only focused on the relationship of physical variables and mood states (tension and anxiety, depression, anger and hostility, vigor, confusion, fatigue) using POMS, and the relationship of physical variables and the impression of a space based on the SD method.

In summary, compared to urban areas, in forest areas, (1) the incidence of positive emotions is significantly higher, (2) thermal conditions are more comfortable, and (3) positive emotions are correlated with thermal comfort.

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