Research paper

Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurements

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HIGHLIGHTS

► A short-term viewing of forests has physiological relaxing effects such as lowered diastolic blood pressure and heart rate.
► Viewing forest landscapes caused higher parasympathetic nervous activity and lower sympathetic nervous activity than urban landscapes did.
► The forest landscapes induced a positive mood.

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ABSTRACT

The present study investigated the physiological and psychological effects of viewing urban forest landscapes on 48 young male urban residents. Four forested areas and four urban areas located in central and western Japan were used as the test sites. We found that in the forested areas, the subjects exhibited (i) significantly lower diastolic blood pressure, (ii) significantly higher parasympathetic nervous activity, but significantly lower sympathetic nervous activity, and (iii) significantly lower heart rate. The forest landscapes (iv) obtained better scores in subjective ratings, and (v) induced significantly less negative and more vigorous moods. Taken as whole, these findings suggest that even a short-term viewing of forests has relaxing effects. We have thus concluded that the approach taken in this study is useful in exploring the influences of urban green space on humans, as well as contributing to the planning and design of a healthy environment for urban residents.

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1. Introduction

The possible relationship between contact with nature and good health has long been discussed, and has been demonstrated to a considerable extent (Frumkin, 2001; Thompson, 2011). Despite abundant studies, however, the health benefits of green areas have long been inadequately acknowledged in urban planning and decision-making (Tyrväinen & Korpela, 2009). The current trend of building compact cities does not fully take into account the potential of natural settings in contributing to the quality of working and housing environments, which could enhance the health and well-being of residents.

In order to guarantee the benefits of access to nature areas and raise awareness of the issue in urban planning and green space management, it is fundamentally important to accurately assess the health benefits with validated measurements, and provide objective evidence. A recent review pointed out that although natural spaces and interaction with natural environments are recognized as health-promoting settings, there is a lack of quantitative data and controlled studies (Annerstedt & Währborg, 2011). Scientific information is therefore necessary to strengthen the position of health benefits derived from nature in various urban development and decision-making processes (e.g. Tyrväinen, Pauleit, Seeland, & de Vries, 2005).

There have been several studies that addressed this requirement. From a series of field experiments, it has been reported that visiting forests induced significantly lower blood pressure, pulse rate, salivary cortisol and sympathetic nervous activity, along with significantly higher parasympathetic nervous activity, as compared to a visit in urban areas (e.g. Lee, Park, Tsunetsugu, Kagawa, & Miyazaki, 2009; Lee et al., 2011). Mood states and

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subjective feelings were also improved while in a forest. These findings collectively support the conclusion that green environments have sedative and stress-reducing effects (review by Tsunetsugu, Park, & Miyazaki, 2010). These previous studies, however, dealt with a relatively small group of subjects (i.e., 12 males in each study). One study examined the incidence of positive emotions in natural settings among 168 participants (Park et al., 2011), but only targeted psychological responses. Few research studies, with certain exceptions (e.g., Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2010), have been reported on human response to green environments as assessed based on multiple physiological measurements involving larger groups.

The present study therefore investigated the physiological and psychological responses to forested and urban environments in a larger group than in the previous studies. The aim of this study was to clarify the influence of two different settings and provide evidence to verify green spaces to be incorporated in urban design and planning. The research questions are (i) if there are differences in the effects of environment between forested and urban landscapes, and (ii) if a relatively short-term visit in accessible managed forests has beneficial effects, as it is not necessarily possible to visit green spaces for a long period of time in daily urban life. Our focus was on urban forests that are not primitive, wild nature, but semi- or fully managed nature where safety is secured.

2. Materials and method

The experiments were conducted in four areas located in central and western Japan (Kamiichi town, Toyama Prefecture, Yoshino town, Nara Prefecture; Akiota town, Hiroshima Prefecture, and Oita city, Oita Prefecture, respectively). In each area, participants visited two experimental sites: a forested and an urban site. The forested sites are located approximately 12–70 km from the city centers and their sizes varied from 800 to 34,225 ha. These forests are among the key recreation forests in the local municipalities, and were suggested for use in the study by city authorities. The urban sites were located close to the business or commercial center of each study town and city. In each experimental site, a spot for viewing (hereafter referred to as a viewing point), where the participants viewed the landscape and took measurements was set up on the previous day. The viewing spots were located outdoors in both forested and urban test sites. Two of the forest views (at Kamiichi and Yoshino) were within a mature forest stand mainly populated by conifer species, while another (at Akiota) was dominated by deciduous tree species. The other forest view (at Oita) had a viewpoint with a small lake combined with the forested landscape. No buildings or roads were visible in the forested landscapes except that the spot faced a trail about 5 m in width in Akiota. All urban views included a road in the foreground on which traffic passed at the rate of 10–45 cars per minute. The experiments in the respective areas took two days and were conducted in August or September 2011.

Twelve male university students participated in each experimental area, for a total of 48 participants (21.1 ± 1.1 years old). They were assembled in the morning of the first experimental day and provided written informed consent. This study was conducted under the regulations of the Ethics Committee of the Center for Environment, Health and Field Sciences, Chiba University.

Half of the 12 participants underwent the experiment in a forested site, while the other half was tested in an urban site on the first experimental day. The participants were transferred to each site by bus, which took about an hour to an hour and a half.

At the experimental sites (a forested site or an urban site), each participant waited in turn in a waiting room to participate in an individual viewing session. When the time came, each participant filled out the Profile of Mood States (POMS Japanese version; Yokoyama, Araki, Kawakami, & Takeshita, 1990) questionnaire which assesses six mood states: Tension–Anxiety (T–A), Depression–Dejection (D), Anger–Hostility (A–H), Fatigue (F), Confusion (C), and Vigor (V). After moving by car to a spot for viewing the landscape (taking approximately 5 min), each participant took a 5-min rest sitting in a camping chair, underwent physiological measurements at the same place, and then viewed the landscape for 15 min while sitting quietly in the camping chair. The physiological measurements included continuous measurement of the time periods between two consecutive heartbeats (AC–301A, GMS Corporation), as well as the measurement of systolic blood pressure and diastolic blood pressure (HEM1000, Omron). After viewing the landscape quietly for 15 min, each participant underwent another blood pressure measurement. Three kinds of questionnaires were handed to the participants following the physiological measurements: (i) interview of the levels of comfort, sedation and naturalness, the state of being refreshed (Mackay, Cox, Burrows, & Lazzerini, 1978), and the POMS. Experimental conditions were controlled to be similar in both the forested and urban settings, and between different cities. On the second day of the experiment, the participants visited the opposite area in order to eliminate the effect of order.

3. Analysis

The time intervals of heartbeats were analyzed using the maximum entropy method (Mem-Calc, GMS Ltd.) to calculate the high frequency components (HF; 0.15–0.40 Hz) considered to reflect parasympathetic nervous activity (Cacioppo et al., 1994), and the low frequency components (LF; 0.04–0.15 Hz) that reflect sympathetic nervous activity (Weise & Heydenreich, 1989), in order to obtain the ratio of LF power to HF power (LF/HF).

The HF and LF power values were converted into a natural logarithm, with the means and standard deviations (SD) being computed for every minute. The heart rate for every minute during viewing was also derived from the time intervals. For these data, a paired t-test was conducted to compare the forested and urban areas. To avoid the type I error, the following was considered: The rate at which significant differences would be found between n pairs out of the 15 pairs (taken every minute during the viewing) by error can be calculated by using binomial distribution:

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\binom{n}{15} (0.05)^n (0.95)^{15-n}
\]

when the significance level is 0.05. The calculated rate becomes <0.05 when n is equal to or greater than 3 in both cases. We therefore considered that more than three significant differences out of 15 data pairs obtained during the viewing would constitute a significant change in the physiological index as a whole.

A two-way analysis of variance (ANOVA) was used to determine the effects of the environment and measurement time on blood pressure and the POMS scores. A Wilcoxon signed rank test was conducted for the subjective ratings and the scores for the state of being refreshed.

Two of the 48 participants failed to complete the experimental procedure and were excluded from the analysis. There were some missing data for the HF and LF/HF due to technical reasons, which made the number of data (N) vary between the time points (Figs. 1 and 2). All statistical analysis was conducted by using IBM SPSS statistics 19, and p < 0.05 was considered significant.
4. Results

The main effect of the environment was significant in terms of diastolic blood pressure ($p=0.034$, $\eta^2_p = 0.10$), which was significantly lower in the forested areas than in the urban areas. No significant main effect was observed for systolic blood pressure.

Time-series variation in the HF power was continuously significantly higher in the forested areas (Fig. 1, $p<0.01$ for all time points, with Cohen’s $d$ varying from 0.31 to 0.70 depending on the time point). This suggests that parasympathetic nervous activity was enhanced while viewing scenery in the forests. The LF/HF values were mostly lower in the forests, and since we found a significant difference at 7 out of 15 time points (Fig. 2, $d=0.03–0.54$), we interpreted that to mean a significant suppression of sympathetic nervous activity in the forested areas. The heart rate in the forested areas was also significantly lower during every minute of viewing than in the urban areas ($p<0.01$ for all time points, $d=0.49–0.71$).

The landscapes of the forests were evaluated as being significantly more comfortable ($p=0.00, r=0.51$), soothing ($p=0.00, r=0.53$), and natural ($p=0.00, r=0.59$). Viewing the scenery in the forests induced significantly higher refreshment ($p=0.00, r=0.55$). For the POMS scores, the interaction between the environment and measurement time was significant for the subscales of tension–anxiety ($p=0.00, \eta^2_p = 0.22$), fatigue ($p=0.00, \eta^2_p = 0.30$), confusion ($p=0.01, \eta^2_p = 0.14$), and vigor ($p=0.00, \eta^2_p = 0.23$) (Fig. 3). A simple analysis of the main effects revealed that viewing the scenery in the urban areas increased tension–anxiety ($p=0.00, \eta^2_p = 0.22$), fatigue ($p=0.00, \eta^2_p = 0.35$), confusion ($p=0.01, \eta^2_p = 0.35$), and adversely affected a vigorous mood ($p=0.00, \eta^2_p = 0.26$), as the participants felt significantly more tensed and anxious ($p=0.00$), fatigued ($p=0.00$), confused ($p=0.00$), and significantly less vigorous ($p=0.00$) after viewing the landscape in urban areas. For the tension–anxiety subscale, the environment was also significantly effective before viewing ($p=0.03$).

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Fig. 1. Time-course variation in the high frequency (HF) component of heart rate variability in the forested and urban areas during viewing of the landscapes (Mean ± SD, $N=41–44$, $^{*}{p}<0.01$ by paired $t$-test).

Fig. 2. Time-course variation in the ratio of the high frequency (HF) and low frequency (LF) components of heart rate variability in the forested and urban areas during viewing of the landscapes (Mean ± SD, $N=41–44$, $^{*}{p}<0.05$, $^{**}{p}<0.01$ by paired $t$-test).

Fig. 3. Standardized scores for six mood subscales of the Profile of Mood States (POMS) in the forested and urban areas before and after viewing the landscapes (upper left: Tension–Anxiety, upper right: Depression, middle left: Anger–Hostility, middle right: Fatigue, lower left: Confusion, lower right: Vigor; Mean ± SD, $N=46$, $^{*}{p}<0.05$, $^{**}{p}<0.01$ by two-way repeated ANOVA).
5. Discussion

Statistical analysis revealed that the different environments (forested vs. urban) had different impacts on most of the physiological parameters. The physiological and psychological outcomes were generally in good agreement, supporting the contention that the landscapes of forests have multiple positive effects on humans, especially in terms of relaxation. These outcomes were similar to those found in previous studies (Lee et al., 2009, 2011).

From the perspective of urban planning, we consider that the present study offers two key findings. First, our POMS investigation revealed that the mood states of the participants worsened within 15 min in the urban setting. This partly indicates how much emotional stress people derive from daily life in urban surroundings. Second, we demonstrated that favorable physiological effects were obtainable by quietly spending time in green scenery. This suggests that people who have to stay indoors for a long time, such as office workers or hospitalized patients, could also benefit from nearby green spaces by going outside and feeling the atmosphere for as short a period of time as 15 min. The important thing is effectively planning the allocation of accessible green spaces in business districts, near hospitals, and at other locations, as well as in residential areas.

In the field of medicine, there has been a trend for approximately 20 years to put emphasis on scientific evidence incorporated in clinical practice, which enables evidence-based medicine (EBM). The same should be considered in the field of landscape and urban planning; scientific data that provide concrete evidence on the effects of specific planning should be taken into account to design a truly healthy urban environment. The physiological data in the present study provide important evidence on the utilization of "nature" in landscape planning, design and/or management. The evidence will thus contribute to improving the quality of life for modern urban residents who continuously suffer from many kinds of stress in the modernized artificial environment.

The present study does have some limitations, however. First, each participant visited a forest and an urban area only once for a short period of time, so that the influence of repeated visits and the long-term effects remain unclear. Second, the participants in this study were healthy young males and it is unknown whether the results could be generalized when applied to different groups, such as females, patients, the elderly, and children. Although we can speculate from previous studies, such as one that targeted hospitalized patients (Ulrich, 1984) or elderly (Matsunaga, Park, Kobayashi, & Miyazaki, 2011), that similar outcomes would be obtained for different groups, further studies are still needed to ascertain the effects in diverse groups.

A better knowledge base on the health benefits of urban nature is vitally important in cities of the future, and the knowledge must be translated into planning guidelines and norms in conjunction with land use and green area planners. We consider that the approach employed in this study involving multiple physiological measurements is useful in exploring the effects of urban green space on humans, and contributes to the planning and design of a healthy environment in daily urban life.

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