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ORIGINAL ARTICLE

Physiological and Psychological Effects of Exposure to Artificial Waterfalls in Green Space Planning

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Abstract

Given the growing attention to nature and health in modern society, this study considered the role of a waterscape facility as a key element in a landscape's influence on users' physiological and psychological responses. The subjects were 28 university students, and the collected data included systolic and diastolic blood pressure, salivary amylase concentration, semantic differential (SD) scales, and profile of mood states (POMS). As compared to a space without any waterscape element (Type G), relaxation in a space with a waterscape element (Type W) was found to significantly reduce of systolic and diastolic blood pressure and salivary amylase concentration. The SD scale and POMS findings showed that Type W evoked active, bright, dynamic, free, vital, interesting, and cheerful images and improved mood states by enhancing vigor while inhibiting depressive feelings. These findings indicate waterscape facilities can improves users' mood states and may enhance their health.

Key words : Waterscape element, Blood pressure, Salivary amylase, POMS, SD scales

1. Introduction

In recent years, people's reduced contact with nature and increasing medical expenses due to falling birth rate and an aging population have become matters of serious social concern (Fried et al., 2004; Moon and Kim, 2009). To address these problems, a range of initiatives taken by governments and research institutions include promotion of the positive effects of nature on healing and health (Morimoto et al., 2006; Rodiek, 2002; Tsunetsugu et al., 2010).

The general belief that human can enhance their sense of relaxation and comfort through contact with natural environment has been verified in recent empirical studies showing that time spent in forests or urban green spaces positively influence people's health and psychological well-being (Lee et al., 2011; Matsuba et al., 2011; Tsunetsugu et al., 2007; Ulrich et al., 1991). To properly utilize urban landscape space for the purposes of health promotion, environmental psychological evaluation of such space would seem crucial in verifying how this might be achieved (Lee et al., 2011). Data of this kind seem likely to provide a useful point of reference for future landscape design in terms of the physiological and

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psychological effects of urban landscape space (Hansmann et al., 2007).

In utilizing urban landscape space in this way, the waterscape facility has been identified as one key element in enhancing users' comfort (Park, 2006). Such facilities not only create a beautiful landscape in terms of visual richness but also support a range of water-based activities and opportunities for cultural and community development (Lee et al., 2008). The water element also contributes to improvement of physical environment by, for instance, reducing air temperature (Oh et al., 2010). In multiple ways, then, waterscape facilities may potentially influence user's physiological and psychological responses.

Previous studies on waterscape facilities can be classified as 1) studies of traditional water landscape in traditional gardens, including techniques and historical and cultural interpretation of symbolism and meaning (Choi, 2010; Lee and Kim, 2012); 2) studies on waterscape facility in residential areas such as apartment complexes, in terms of design technique, revitalization and maintenance/management (Kang and Sim, 2010; Kim et al., 2010; Lee, 2004; Lee et al., 2008); 3) environmental comfort analysis, relating to such changes as thermal environment and anion distribution (Kim et al., 2013; Oh et al., 2010). To date, however, most such studies have focused on physical or utilization conditions.

The present study, in contrast, will include an evaluation of both physiological and psychological effects of waterscape facilities on their users, as a point of reference for environmental psychological evaluation of such landscape spaces.

2. Materials and methods

2.1. Materials and experimental setting

To evaluate physiological and psychological responses to the introduction of waterscape facility, the study should ideally compare two spaces of the same size and shape, with and without waterscape facilities. In practice, it is difficult to find such places for comparison. Instead, the present study compared physiological and psychological responses to the same location when the waterscape facility was on (Type W) and off (Type G) (Fig. 1). On/off conditions were repeated for each participant group and stimulus presentation, and the sequence in which stimuli presented to subjects was randomized.

The experiment was conducted in a pocket park located in Gyeongpo provincial park in Gangneung -shi, where an artificial waterfall had been installed.

Fig. 1. Relaxation spaces with artificial waterfall. Type W: waterscape facility on; Type G: waterscape facility off.

As there was little traffic, the park was quiet and attracted many tourists and local residents. The artificial waterfall, which was designed in the form of Seokgasan, featured natural rocks and pine trees (*Antipathes japonica*), and azaleas (*Rhododendron*) planted between the rocks. The waterfall cascaded from a height of 3 m above the Seokgasan (150 ton/day, 20 hp electric power); the sound level was measured at 64~75 dB using a noise meter (LA-5110, ONO-Sokki), and was evaluated for subjective comfort on a 7-point scale by participants in the study. The average temperature and relative humidity on the experimental day were 23.3℃ and 48.6%.

2.2. Participants

The study participants were 28 university students (14 males and 14 females) with mean age of 23.3 years (standard deviation, ± 2.0). Those with past or current physical and psychological disorders were identified through screening, as such disorders could potentially influence the results (Jo et al., 2013; Lee et al., 2011). After providing an overview of the research and precautions for measurements, informed consent was obtained according to the regulations of the Human Investigation Ethics Committee of the Korean Environmental Sciences Society.

2.3. Measures

Physiological effects were measured in terms of systolic and diastolic blood pressure and heart rate as indicators of autonomic nervous system activity, using a digital blood pressure monitor (HEM-1000, OMRON). Salivary amylase concentration, which is commonly used as a stress marker because it indicates sympathetic nerve activity, was also measured by a digital monitor (NIPRO, INNIMEDICS) for ease of measurement and rapid results (Iwasaki et al., 2007; Jo et al., 2010). To gain an understanding of psychological effects, two self-report questionnaires were introduced. First, mood states was assessed using the profile of mood states (POMS) instrument, which is a psychological scale measuring short-term mood states. The brief version was selected, consisting of 30 questionnaires, rated on a 5-pints scale (Kim et al., 2003). As a second measure, impressions of waterscape element was evaluated using a semantic differential (SD) scale, which is psychological rating scale that assesses subjective impressions or images of external stimuli (Osgood et al., 1957). In the present study, 20 pairs of contrasting adjectives related to landscape were rated on a 7-points scale (Han et al., 2005).

2.4. Experimental procedures

Fig. 2 describes the experimental protocol. Following an overview and detailed explanation of the experiment, the subject was placed in a seated

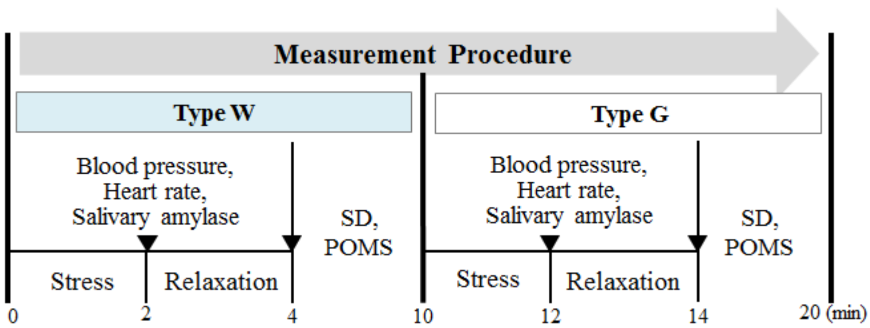


Fig. 2. Timeline of physiological and psychological measurement during exposure to Type W and Type G (order randomly reversed for half the subjects). ▼ indicates the physiological measurement.

position at the point where they could not see waterfall. To introduce an element of psychological stress, they were then asked to answer 20 questions involving the four fundamental arithmetic operations. After 2 minutes, their physiological responses (systolic and diastolic blood pressure, heart rate, and salivary amylase concentration) were measured. After that, the subject was invited to relax while viewing Type W. After 2 minutes of relaxing in this way, the four physiological responses were again measured. Following the physiological measurements, the subject was asked to complete the two questionnaires (POMS and SD scales). Then, their physiological and questionnaire responses to Type G were collected in the same way. The order of Type W and Type G were randomized.

2.5. Data Analysis

All physiological responses to Type W and Type G were compared using a paired t test (two-sided) (Lee et al., 2011; Matsuba et al., 2011). After calculating T-scores, POMS data were analyzed as rating of six mood states: tension-anxiety (T-A), depression-dejection (D), anger-hostility (A-H), fatigue (F), vigor (V), and confusion (C). SD data were analyzed by comparing rating scores for Type W and Type G. For both POMS and SD results, significant differences were identified using the Wilcoxon signed-rank test. For all data, the

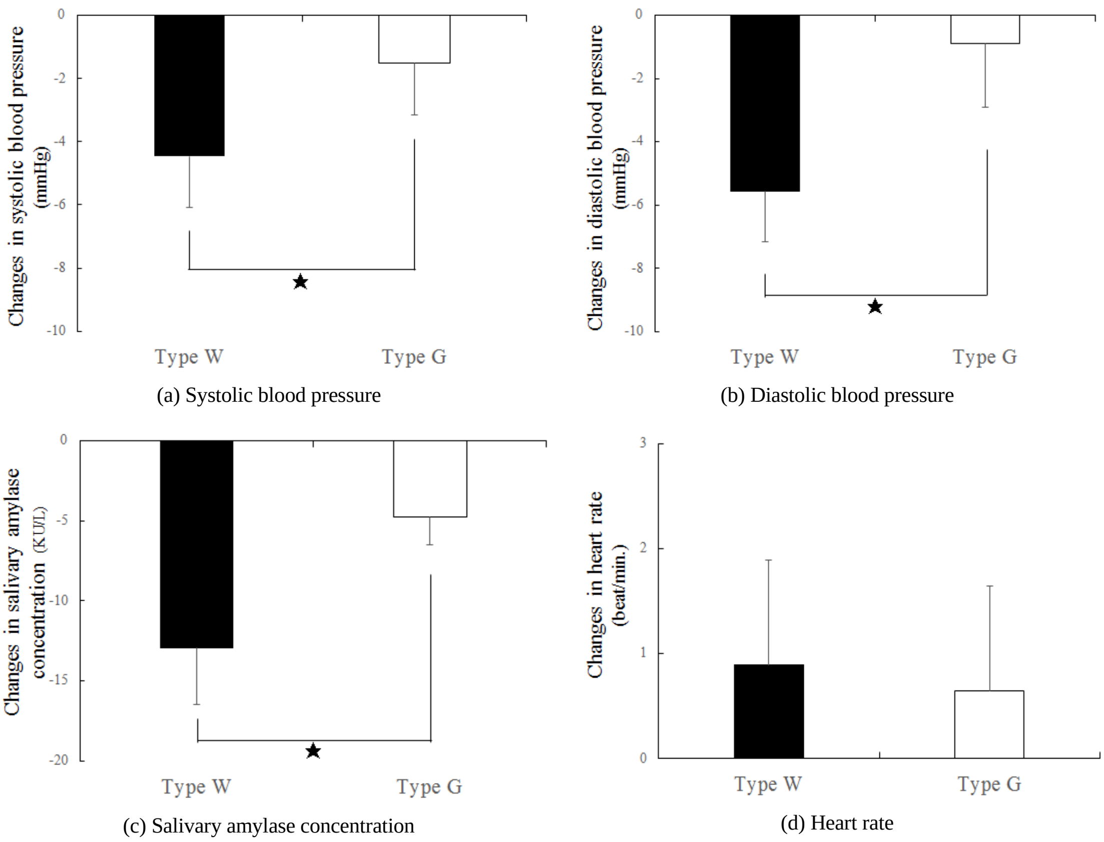


Fig. 3. Comparison of changes in physiological responses (stress-relaxation) to Type W and Type G (N=28). Significant differences were verified by paired t-test (two-sided).★ Significance at $P < 0.05$ (Mean ± SE).

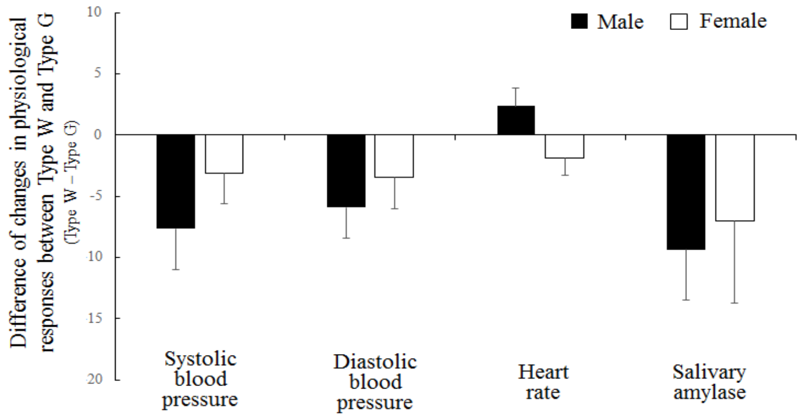


Fig. 4. Comparison of male and female subjects' physiological changes in terms of relaxation-stress for Type W and Type G. (Male subjects, N = 14; female subjects, N = 14). Significant differences were verified by paired t-test (two-sided) (Mean ± SE).

significance level was set at $P < 0.05$, and data were represented as mean ± standard error (SE).

3. Results

3.1. Physiological responses

Figure 3 shows the difference in physiological responses to Type W and Type G. For Type W, significant decreases were observed in systolic (a) and diastolic (b) blood pressure, salivary amylase concentration (c) ($P < 0.05$) unlike Type G. Whereas no significant changes were observed in heart rate (d).

The reduction of blood pressures indicates that the relaxation in Type W had a relieving effect on the body by suppressing sympathetic nervous activity; the reduction in salivary amylase concentration in Type W also indicates relaxation, resulting in relief of stress.

Fig. 4 compares male and female subjects in terms of physiological. Although systolic and diastolic blood pressure and salivary amylase concentration showed a greater tendency to decrease in males than in females, there was no significant difference between the genders.

3.2. Psychological responses

Fig. 5 shows changes in mood states during relaxation in Type W and in Type G. Compared with Type G, relaxation in Type W resulted in a lower depression-dejection score (D, $P < 0.05$) and a higher vigor score (V, $P < 0.01$). These results indicate that Type W enhanced positive feelings such as vigor while reducing negative feelings such as depression.

Comparison of changes in mood states between males and females, shows that depression-dejection feeling decreased more in males than females when relaxing after being stressed in Type W ($P < 0.05$). This result indicates a potential gender-based psychological change.

SD results indicate that the Type W landscape left positive impressions that included active, bright, dynamic, free, vital, beautiful, interesting, cheerful, healing and romantic ($P < 0.01$); as well as liked, clean, and natural ($P < 0.05$) (Fig. 7). In the POMS test, impressions such as active, dynamic, free, vital, cheerful, and healing are thought to be related to higher vigor scores and lower depression-dejection

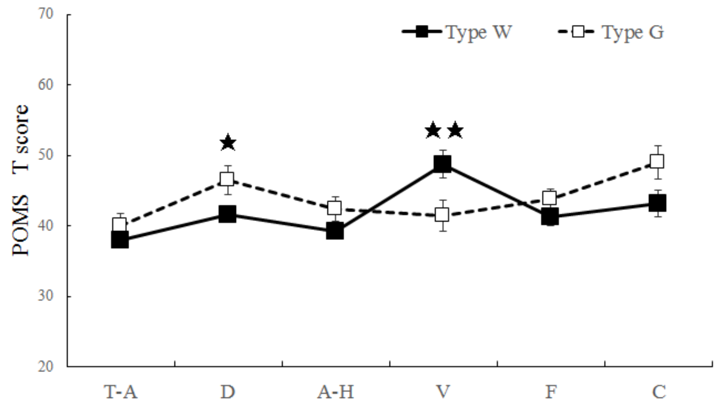


Fig. 5. T-score for the profile of mood states (POMS): Type A and Type G; T-A = tension-anxiety; D = depression-dejection; A-H = anger-hostility; V = vigor; F = fatigue; C = confusion. Comparison of means of total subjects for Type W and Type G (N=28). Significant differences were verified by Wilcoxon signed-rank test.★, ★★ Significance at $P < 0.05$ or < 0.01, respectively (Mean ± SE).

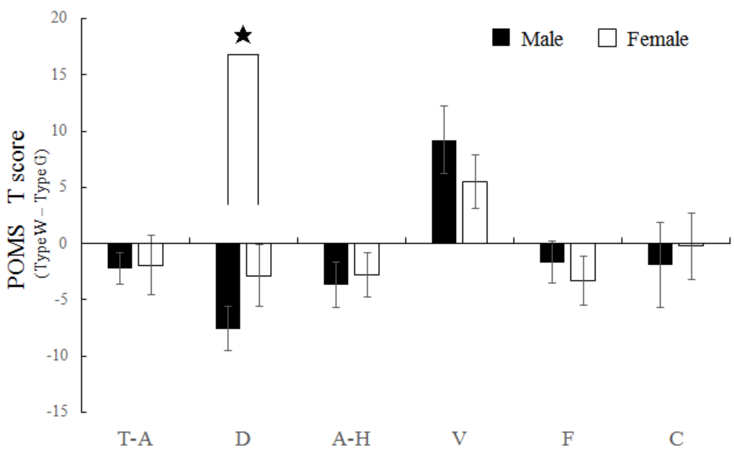


Fig. 6. T-score (Type W-Type G) for profile of mood states (POMS); T-A = tension-anxiety; D = depression-dejection; A-H = anger-hostility; V = vigor; F = fatigue; C = confusion. Comparison of changes in mood states (Type W-Type G) between male (N=14) and female subjects (N=14). Significant differences were verified by Wilcoxon signed-rank test. ★ Significance at $P < 0.05$ (Mean ± SE).

scores.

Males evaluated the Type W landscape as active, bright, dynamic ($P < 0.01$), as well as vital and cheerful ($P < 0.05$). This result links to males' POMS results, with a tendency for males to experience more feelings of vigor and fewer feelings of depression-dejection than females. Females evaluated Type W in terms of positive landscape images such as liked, active, bright, dynamic, familiar, free, vital, beautiful, clean, interesting, cheerful, healing, and romantic ($P < 0.01$), as well as natural and happy ($P < 0.05$) (Fig. 8). This result shows female was evoked various images than males, unlike the POMS results: female exhibited less changes in mood states than males.

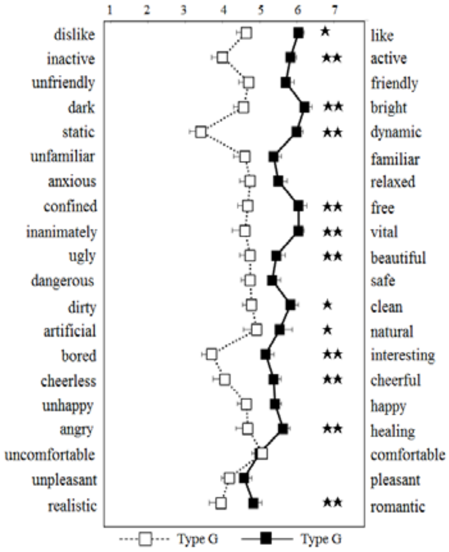
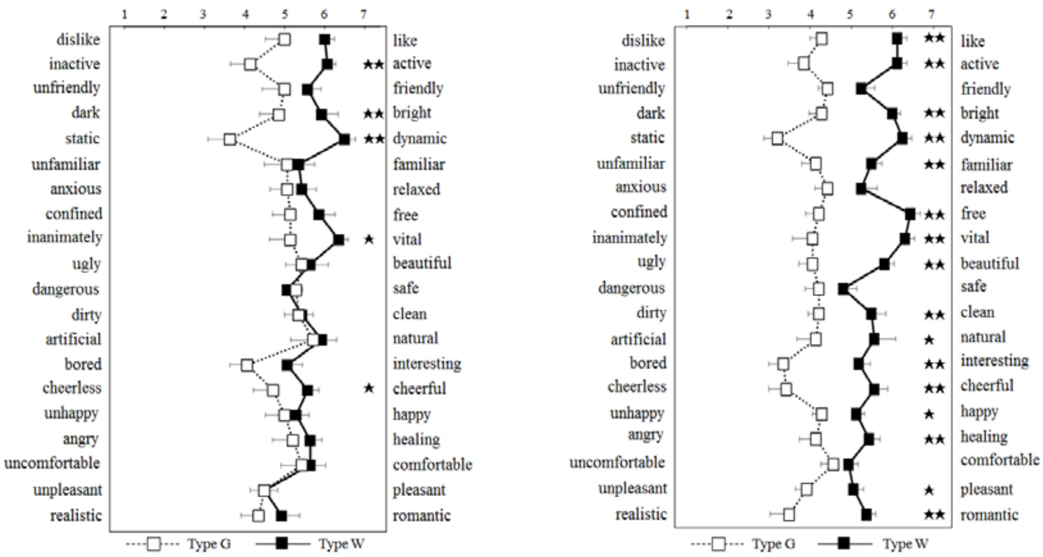


Fig. 7. Mean semantic differential (SD) scores for Type W and Type G. Comparison of means (all subjects, N=28) between Type W and Type G. Significant differences were verified by Wilcoxon signed-rank test. ★, ★★ Significance at $P < 0.05$ or < 0.01, respectively (Mean ± SE).

3.3. Factors influencing physiological and psychological responses

Table 1 displays the statistical results related to sensory aspects of mood states changes by contacting with waterscape element. 14 participants, which is the half of the total subjects, responded that auditory sensation of waterscape influenced on their mood changes, and 12 participants, which is 42.9% of the subjects, responded that the visual sensation of waterscape influenced on their mood states. In comparison of male and female, male were more influenced on their mood changes by visual aspect of waterscape, whereas female were influenced on their mood changes by auditory aspects of waterscape.

Relating to the comfort evaluation of waterscape element in this experimental setting, it was analyzed by vison, auditory, and touch aspects using 7-point SD scale. Participants had natural, relaxed, beautiful images by visually, pleasant and beautiful sound by auditory, and good-mood, refreshing, and vibrant



(a) Male (N=14) (b) Female (N=14)

Fig. 8. Mean semantic differential (SD) scores for Type W and Type G; comparison of means of male (a) or female (b) subjects for Type W and Type G. Significant differences were verified by Wilcoxon signed-rank test. ★ Significance at $P < 0.05$ or < 0.01, respectively (Mean ± SE).

Table 1. Responses relating to sensory aspects of mood states changes when in contact with waterscape facility

	Male	Female	Total
Vision	8 (28.6%)	4 (14.3%)	12 (42.9%)
Auditory	6 (21.4%)	8 (28.6%)	14 (50%)
Touch	0 (0%)	2 (7.1%)	2 (7.1%)
Total			28 (100%)

feelings by touch (Fig. 9).

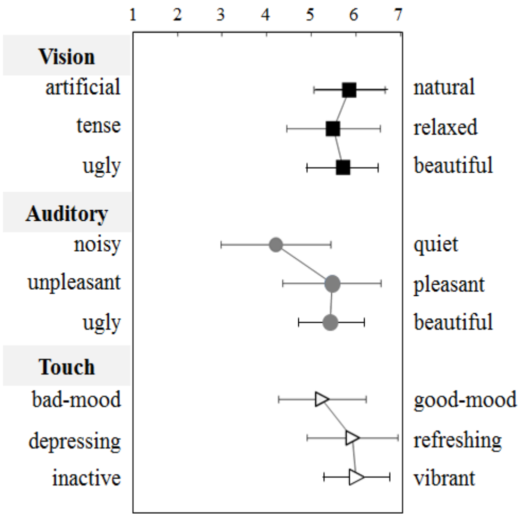


Fig. 9. Comfort evaluation of waterscape element (N=28).

4. Discussion

Researchers have increasingly demonstrated the health benefits of contact with nature. A great deal of researches focused on forests or urban green spaces, whereas there are relatively few studies on waterscape facility in landscape space, which has been aware of enhancing user's comfort (Lee et al., 2011; Tsunetsugu et al., 2010). The present study demonstrated some of potential benefits of exposure to waterscape facility using biological and verbal measures. Physiologically, relaxation in waterscape facility resulted in relieving effect on the body through reducing blood pressure and had the effect of stress relief through decreasing salivary amylase concentration. This finding is correlates with previous study, in which systolic and diastolic blood pressure were lower after walking in a forest; salivary cortisol concentration, which is another stress marker, decreased after walking in a forest or urban greenery (Lee et al., 2011; Matsuba et al., 2011; Tsunetsugu et al., 2007). Accordingly it is assumed that we may expect same physiological effects through relaxing in waterscape facility as like walking in forest or urban park.

Psychologically, the waterscape facility enhanced vigor while reducing depressed feelings and evoked positive impressions that included active, bright, dynamic, free, vital, beautiful, interesting, cheerful, healing and romantic. This explains the common experience that waterscape facility influence a positive effect on our mood and emotions. These results on verbal indexes were also partly correlated with those of physiological results as like previous studies (Park et al., 2011).

To reduce confounding variables in physiological and psychological response, this study controlled participants by university students in 20s. Accordingly, the effects found in this study might not be generalizable to certain populations (Lee et al., 2011). This study also demonstrate the effect using a certain type of waterscape facility although many types of waterscape facilities have been introduced in landscape space in practice. The study did not find the clear benefits of such heart rate change that have been found in previous studies. This might have been previous studies used a longer exposure to stimuli (Jo et al., 2013; Tsunetsugu et al., 2007). Further studies are needed to consider some points in which with a wider range of participants, different type of facility, and methodologies using a longer presentation time. It would be a useful fundamental data for physiological and psychological effects of waterscape facility.

The findings of the study support common experiential knowledge of the comfort of waterscape facility on human and provide evidence that health benefits of urban green spaces are derived from not only greenery or plants, but also waterscape element.

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