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Research Paper

The effect of green space behaviour and per capita area in small urban green spaces on psychophysiological responses

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A B S T R A C T

Research has shown that there is a close relationship between small urban green spaces and people's physical and mental health. However, most previous studies focus on the macro-level, and there is a lack of empirical studies using real green spaces as the stimulus. The purpose of this study is to explore the effects of two key factors, namely, green space behaviour (GSB) (walking and sitting) and per capita area (PCA) (high, middle and low), in small urban green spaces on the psychophysiological responses of visitors to these spaces. We recruited 240 participants and randomly assigned them to six bamboo-vegetated green spaces with the following different combinations of PCA and GSB: high-sitting, middle-sitting, low-sitting, high-walking, middle-walking and low-walking. The subjects in all six groups performed the same stress tasks indoors (pre-test), then performed green space restoration tasks outdoors (post-test). We measured the participants' β/α index in multiple brain regions, blood pressure, peripheral capillary oxygen saturation (SpO2) and pulse. In addition, we performed a Stroop assessment of their attention level, used the Profile of Mood States (POMS) and collected data on green space preference. The results showed that people have better psychophysiological responses when GSB is matched with the appropriate PCA in a small urban green space. This study concludes that walking in a high PCA and sitting in a low PCA had the most beneficial effects with regard to reducing stress, improving mood and matching the participants' preferences for urban green spaces. These research results can provide guidance for urban green space planning and design.

1. Introduction

Due to the process of urbanization, numerous people are reside or will reside in cities. According to 2017 data from China's National Bureau of Statistics, China's urban population is approximately 813.5 million (approximately 58.5% of the total population), and the urban green space area is 2.9213 million hectares (including 688,400 ha of urban park green space) (Statistical communique of the People's Republic of China on national economic and social development in, 2017). These figures indicate that the per capita green space with an open space function in China is approximately 8.46 square metres. The distribution of green space is mainly affected by geography and the population, and numerous small urban green spaces already exist in densely populated cities, which is very common worldwide (Astell-Burt, Feng, Mavoa, Badland, & Giles-Corti, 2014). Green space planning and design are closely related to human health, and numerous studies have focused on the impact of green space planning and design on people's physical and mental health. Previous studies have focused on large-scale green spaces or natural environments. Studies have shown that exposure to green spaces can lead to good health outcomes (Hartig, Mitchell, de Vries, & Frumkin, 2014) and can provide physiological and psychological benefits, such as lower blood pressure, lower heart rate (Van Den Berg & Custers, 2011), reduced negative emotions, increased positive emotions (Lee et al., 2014), improved attention (Ulrich et al., 1991), etc.

However, the higher the level of urbanization, the more difficult it is for people in the city to leave the city and visit a large natural environment (Fuller & Gaston, 2009). People visit small urban green spaces more frequently.

Stress levels are a common health concern for researchers. Meghan Hazer et al. used the Perceived Stress Scale (PSS) to evaluate the impact of exposure to community green spaces on people's stress recovery. The results showed that those exposed for 25.5 h a week had 3.1% less stress than those who were not exposed to such spaces (Hazer, Formica, Dieterlen, & Morley, 2018). César San Juan et al. took the urban square (a type of urban open space) as their research object and proved that short-term (half an hour) exposure to in an urban open space led to lower negative emotions and stress (San Juan, Subiza-Perez, & Vozmediano, 2017). Karin Kragsig Peschardt et al. took nine small parks in dense urban areas as their research objects and analysed the

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participants' perceived restorativeness scale (PRS) results and eight perceived sensory dimensions (PSDs) through a questionnaire survey. The results showed that the size of the green space in dense urban areas is not the decisive factor influencing the stress level (Peschardt & Stigsdotter, 2013). For the green space health effect, frequency is more valuable than duration. In addition, the relationship between the structure of a green space and the perception ability such as attention is also relevant. H. Nordh et al. combined key variables of ART (attention restoration theory), such as "being away" and "fascination", and subjective scores, such as "likelihood of restoration" and "preference", with elements of small parks in their analysis. Their results showed that vegetation coverage, the number of trees and shrubs and the apparent area were the most predictive indicators of restoration (Nordh, Hartig, Hagerhall, & Fry, 2009). Due to the close neighbourhood relationship among people, small urban green spaces also have a profound impact on the emotional state (Flouri, Midouhas, & Joshi, 2014), perceived stress (Feda et al., 2014) and physical and mental health benefits (Vujcic & Tomicevic-Dubljevic, 2018) of adolescents and children.

Previous studies have shown the benefits of more frequent exposure to green spaces. Furthermore, due to the frequent contact between urban small green space and urban residents, the impact of human behaviour and the population cannot be ignored. There is a close relationship among small urban green spaces, human factors and psychophysiological health. The structure and distribution of small urban green space affect GSB and PCA, respectively. GSB and PCA further affect the psychophysiological response and health of the human body by affecting sensory process and spatial distance, respectively. Therefore, GSB and PCA form the links between small urban green spaces and psychophysiological responses and are the two key factors of concern in this study. Previous studies usually focused on the structure, distribution and elements of small urban green spaces, and most studies were conducted at the macro-scale and lacked experimental evidence. Based on theories of planning and design and human health, this study explores the effects of GSB and PCA in small urban green spaces from the micro-level on physiological and psychological responses.

1.1. Green space behaviour and human health

There is a close relationship between GSB and health. Regarding urban GSB, walking and sitting are common research objects. Chorong Song et al. recruited young men to study the physiological and psychological indicators of walkers in urban parks and urban areas. The main physiological indicators were heart rate and heart rate variability (HRV), and the psychological indicators included scores on the Profile of Mood States (POMS) and the State-Trait Anxiety Inventory (STAI). This series of experiments was conducted in spring, autumn and winter, and all verified the positive health benefits of urban parks (Song et al., 2013, 2014; Song, Ikei, Igarashi, Takagaki, & Miyazaki, 2015). Goto's study used POMS scores and heart rate as indicators to observe the differences in sitting in three different landscape spaces; the results revealed the physiological and psychological effects of different landscape spaces (Goto, Park, Tsunetsugu, Herrup, & Miyazaki, 2013). Other studies of the effects of sitting in green spaces also focused on issues such as the landscape plant composition (Igarashi, Aga, Ikei, Namekawa, & Miyazaki, 2015), landscape colour (Jang, Kim, Kim, & Pak, 2014), and landscape sound (Evensen, Raanaas, & Fyhri, 2016). Although rigorous comparative experiments are lacking, Hartig's experiments verifying the emotional differences between urban and natural environments showed that walking may provide better emotional recovery benefits (Hartig, Evans, Jamner, Davis, & Gärling, 2003).

GSB is a comprehensive process in which people receive natural stimulation that is transmitted through the senses. The sensory stimulation of green space occurs mostly through the visual sense (Lawson, 2007). There are several individual factors related to vision in green space, such as colour (Jang et al., 2014; Küller, Mikellides, & Janssens, 2009), the index of greenness (Choi et al., 2016) and the visual mechanism. Different behavioural conditions have different single-factor stimuli (Bakouie, Pishnamazi, Zeraati, & Gharibzadeh, 2017). Walking might have the potential to be more varied, free, and visually rich than sitting. In addition to the differences in visual factors, different GSBs may provide other sensory stimuli. Research has shown that sounds from nature are more likely to be perceived and accepted, reducing stress and anxiety, than sounds from cities. Jingwei Zhao asserted that the auditory sense, visual sense and tactile sense have a linkage effect and selected a combination of audio-visual landscapes with better restoration qualities based on experimental findings (Zhao, Xu, & Ye, 2018).

As noted above, GSB affects sensory responses. There is a strong correlation between GSB and physiological and psychological responses, which is greatly important for human health. However, comparative studies on behaviours and studies on physiological and psychological responses are lacking. In addition, GSB is affected by objective factors. Urban green space planning and design, green space quality, green space management and other aspects have a strong impact on GSB (Nath, Zhe Han, & Lechner, 2018). Therefore, research concerning the relationship between GSB and urban small green space is helpful for making decisions during the early planning and design process to provide health-promoting experiences.

1.2. Per capita area and human health

PCA directly affects the spatial distance between people in green spaces. Edward Hall argues that the following four types of spatial distances, which have been widely cited by subsequent researchers, exist: public distance (360 cm or above), social distance (120–360 cm), personal distance (45–120 cm), and intimate distance (0–45 cm) (Hall, 1980). PCA is an important index in urban green space systems and is mainly affected by the population and land area. Particularly in densely populated areas, old urban areas and slum areas, urban green spaces are characterized by small sizes, fragmentation and low quality (Astell-Burt et al., 2014; Roe, Aspinall, & Ward Thompson, 2016), requiring us to pay more attention to small urban green spaces and PCA. In addition, this situation does not exist only in poor areas; even in many developed cities, the trend is towards densification (Beatley, 1999). The scale and distribution of urban green space affect the health of urban people.

Wallner's studies have analysed from a macro-perspective, revealing that resting in a green space can improve teenagers' happiness and cognition and that the effect of a larger green space is better than that of a small green space (Wallner et al., 2018). People pursue high PCAs and large green spaces, but the actual situation of the urban population is that the frequency of contact with small green spaces is much higher than that with large green spaces. However, other studies have demonstrated the value of neighbourhood green space and small green space, which have a higher correlation with health, while green spaces at the city level does not have a correlation with health (Bixby, Hodgson, Fortunato, Hansell, & Fecht, 2015). Increasing community green spaces and green space accessibility can reduce the number of anxiety disorder treatments (Nutsford, Pearson, & Kingham, 2013). Research conducted by Ulrika K. Stigsdotter in Denmark showed that people living 1 km or more away from green spaces were 1.42 times more likely to be stressed than people living 300 m or less away from green spaces (Stigsdotter et al., 2010). Although people generally continue to pursue higher per capita green spaces, researchers' opinions vary on the optimal scale of urban green spaces.

In addition, PCA affects the structure of green spaces, and the structure will, in turn, affect health benefits. Greg Watts evaluated the tranquillity level of green spaces and the degree of relaxation of tourists in different forms of green space. The results showed that trees, hedges and grassy slopes can block urban noise and bring a sense of tranquillity (Watts, 2017). PCA is highly valuable in the planning and design of urban green spaces. Many correlation studies have been conducted on the macro-scale, but few confirmatory studies have been performed on the micro-scale investigating aspects, such as the impact of different PCAs on psychophysiology.

1.3. Psychophysiological indicators used to measure the effects of GSB and PCA

Based on previous studies, researchers focused on the health benefits of green spaces are mainly interested in reducing stress, improving attention, increasing positive emotions, decreasing negative emotions and other related psychophysiological indicators (Chiang, Li, & Jane, 2017). Due to the correlation between physiological and psychological indicators, the present study aims to observe more relevant indicators of the above aspects in small urban green spaces. Certain indicators, such as attention, mood states, stress, preference, etc., are usually measured using questionnaires or tests.

Physiological indicators, including blood pressure, peripheral capillary oxygen saturation (SpO2), pulse (Chen, Yu, & Lee, 2018) and electroencephalogram (EEG) (Chiang et al., 2017), are usually measured using devices. EEG devices are usually divided into single-channel and multi-channel devices, and dry electrodes are often used in experiments (Kacha, Matsumoto, & Mansouri, 2015; Neale et al., 2017; Tilley, Neale, Patuano, & Cinderby, 2017). EEG devices with more channels can provide results from different brain regions (Rodríguez, Rey, & Alcañiz, 2013). At present, most devices can accept brain waves of 4–5 frequencies: delta, theta, alpha, beta, and gamma. The most commonly used forms of EEG indicators are the single index (θ, α, β) and the ratio (θ/β, β/α, $\theta/(\alpha + \beta)$, $(\alpha + \theta)/\beta$, $(\alpha + \theta)/(\alpha + \beta)$) (Zou, Liu, Guo, & Wang, 2015). In many studies on visual and physiological responses, β/α is considered the most suitable indicator of difference (Hsu & Wang, 2013; Kim, Kim, & Kim, 2015). Measurements of physiological indicators can be compared over a short period or monitored dynamically over a long period (Goto et al., 2013; Song et al., 2015). The physiological and psychological effects of green spaces need to be observed comprehensively, and the evaluation of the results must rely on theories, such as attention restoration theory (ART) (Kaplan, 2016; Kaplan, Kaplan, & Ryan, 1998; Kaplan, 1995) and stress reduction theory (SRT) (Ulrich et al., 1991).

1.4. Aims and hypotheses

GSB and PCA are two factors that are particularly important for the health effects of small urban green spaces, but they are rarely studied together. Moreover, few studies have investigated the effects of these two factors on physiological and psychological responses in small urban green spaces. Therefore, this study aims to demonstrate the effects of GSB and PCA on psychophysiological responses and certain health aspects such as attention, stress and mood through the designed green space model (real-world bamboo green space). This experiment was designed to examine two of the most common types of GSB, namely, walking and sitting, and three levels of PCA, namely, high, middle and low. Due to the different per capita green spaces under different urban conditions, it is impossible to have a unified standard of measurement; thus, the PCAs in this study are relative. Based on the comprehensive consideration of previous studies and other green space studies, we propose the following expectations:

Regarding the main effect of GSB or PCA, it is expected that the effect of walking is better than that of sitting on many psychophysiological indicators, while the middle PCA may have the best results on many indicators.

Regarding the interaction effect of the two variables, whether the GSB is walking or sitting, the high PCA will be the most appropriate component to produce optimal results.

There will be some indicators that do not show significant differences, whether in the main effect or the interaction effect.

2. Methods

2.1. Experimental space

Two experimental spaces were arranged on the campus of Sichuan Agricultural University (103°51′39″E, 30°42′22″N, 512 m): an indoor room (pre-test area) and a simulated green space (post-test area). The simulated green space is an experimental space modified from a real green space environment. We established a 120 square metre rectangular space enclosed by bamboo with lawn as the underlying surface. Bamboo is one of the most common Chinese urban greening plants, and it has a good enclosure effect and can block the adverse factors of the urban environment (Chen, Zhang, Zhang, Booth, & He, 2009; Flynn, Chan, Zhu, & Yu, 2017; Wang, Innes, Dai, & He, 2010). The edge formed by bamboo separates the simulated green space from the outside world, helping to control the variables. This space cannot contain all the elements and forms of a genuine green space, and the elements of the green space are not the focus of this experiment. The aim of this simulated green space was to create a realistic space. The two independent variables are GSB (sitting and walking) and PCA (high, middle and low). PCA is a relative quantity that is obtained by setting a different total number (high = 3, medium = 10, low = 30) of subjects and volunteers in the simulated green space. The following six experimental groups of the simulated green space were formed through an orthogonal experimental design: high-sitting, middle-sitting, low-sitting, high-walking, middle-walking and low-walking (Fig. 1a–f). This simulated green space has the advantages of a real environmental stimulation and controllable variables, which is more conducive to studying the interaction effects and main effects of the variables.

The behaviours of the subjects in each simulated green space were basically the same (same location and walking route), and the volunteers were asked to engage in random behaviours to make the environment more realistic. We chose 11 days in October 2018 (from 11:00 to 13:00 and 15:00 to 17:00 every experiment day) as the experiment time. Indoor environmental indicators (air temperature, air humidity, intensity of illumination and noise) were maintained at 21 °C, 65%, 500 lx, and 25 dB, respectively. To decrease the impact of outdoor environmental thermal comfort, we used the physiological equivalent temperature (PET) value as a reference. The value of the PET of the simulated green space was calculated using RayMan software with meteorological data (air temperature, air humidity, wind speed and global radiation) (Matzarakis, Rutz, & Mayer, 2007, 2010). We decided whether or not to continue the experiment based on the weather forecast and conducted real-time climate monitoring every hour. The PET value is regarded as an important index for measuring thermal comfort, and the PET value (°C) in this study was almost always maintained within a comfortable range (comfortable: 18–23 °C; slightly warm: 23–29 °C; slightly cool: 13–18 °C) (Fig. 2) (Höppe, 1999).

2.2. Participants

The participants included subjects and volunteers. A total of 240 randomly selected college students with an average age of 20.2 years (range = 17–26, SD = 1.76) participated in this study as subjects. Among the subjects, 47% were males and 53% were females. Recruitment posters on campus required the subjects to be non-smokers, not to have any history of mental illness, and to have a normal body mass index (BMI) (range = 18.5–23.9). All subjects were proven to be free from any obvious social disorder and anxiety through advance psychological questionnaires (STAI-FORM Y, the Social Anxiety Subscale of the Self-Consciousness Scale and the Shyness Scale). Volunteers, who were a part of the green simulated environment, were also recruited through posters on campus; they were required to have good physical health and no history of mental illness. All participants

Fig. 1. Six experimental groups of the simulated green space (people marked with numbers are the subjects; the other people are volunteers).

received detailed information regarding the experiment and the rules of this experiment beforehand and voluntarily provided their informed consent.

2.3. Measurements

2.3.1. EEG, blood pressure, finger SpO2 and finger pulse rate

The EEG measurements were using a non-invasive Emotiv EPOC + EEG headset with 14 channels (AF4, AF3, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1 and O2) adapting the international 10–20 position system. Previous studies have confirmed the reliability and accuracy of this device (Neale et al., 2017; Suh & Yim, 2018; Tilley et al., 2017). The human brain is a complex system that is divided into four lobes (frontal, temporal, parietal and occipital). This study analysed the data from only 8 channels (F3 and F4 of the frontal lobe control complex for cognition, language, emotion and behaviour; T7 and T8 of the temporal lobe control audio and visual memory and language processing functions; P7 and P8 of the parietal lobe control sensory connection and reception; and O1 and O2 of the occipital lobe control all visual information) (Kacha et al., 2015) (Fig. 3). We used the β/α index (the β waves are related to the alertness state, while the α waves are related to the relaxation state) as the main evaluation index

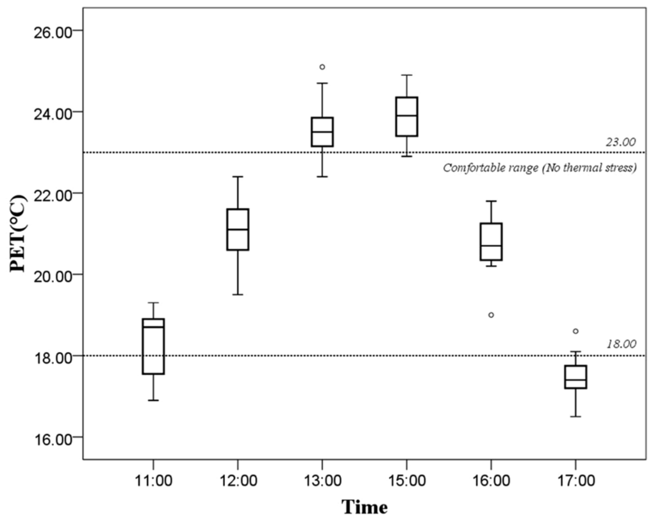


Fig. 2. PET values measured at hourly time points over 11 days (the experiment time was from 11:00 to 13:00 and from 15:00 to 17:00 every day).

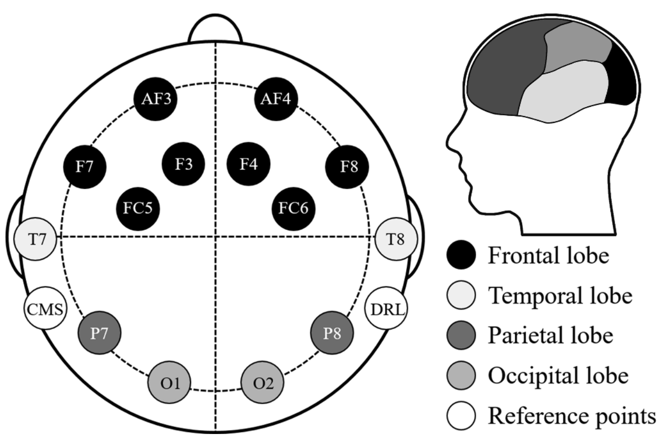


Fig. 3. Areas of the four brain lobes and positions of the 14 channels.

of brainwave activity; the β/α index has been considered a good visual evaluation value in previous studies (Hsu & Wang, 2013). The higher the β/α index, the more nervous and stressed the individual is; conversely, the lower this index is, the more relaxed and calm the individual is (Suh & Yim, 2018). Brainwave signals were sent to the computer's hard disk through the headset, and original data were obtained through the process of baseline removal and filtering. Blood pressure (systolic blood pressure and diastolic blood pressure) was measured using an Omron sphygmomanometer (HEM-7011). Finger SpO2 and finger pulse rate were measured using a Yuwell pulse oximeter (YX301). The measurement process used for the physiological indicators in this study was non-invasive and harmless.

2.3.2. Attention

In this task, attention was measured by the Stroop colour task. In previous studies, the Stroop test has been used extensively in attention recovery research (Chiang et al., 2017; Hartig et al., 2003; San Juan et al., 2017). The Stroop effect refers to the interference of the human dominant response with the non-dominant response. Therefore, the Stroop test requires subjects to actively suppress their own interference (Stroop, 1992). The Stroop colour task evaluates the attention of subjects according to the interference effect of word meaning (dominant response) on colour (non-dominant response). Six colours (black, white, red, green, yellow and blue) were used in this test; they were presented on one page each with one Chinese character with a different colour (e.g., the Chinese character for "white" was printed in red). The subjects were required to say aloud the colour of the ink instead of the meaning of the Chinese character. During this process, an assistant recorded the total number of correct responses within one minute.

2.3.3. Mood states

The mood states were measured using the Chinese version of the POMS adapted by Beili (1995). The subjects were required to rate 40 adjectives expressing mood states on a five-point Likert scale ranging from 0 (not at all) to 4 (very much). The POMS consists of seven emotional subscales, including tension, anger, depression, fatigue, vigour, confusion and self-esteem. The total mood disturbance (TMD) index is calculated by adding all negative mood scores and subtracting all positive mood scores based on 100 points (TMD = tension + anger + depression + fatigue − vigour + confusion − self-esteem + 100).

2.3.4. Preference

We measured preference using five Likert scale questions (each question had five response options ranging from 0 = "not at all" to 4 = "very much") regarding the subjects' overall impression of the environment, per capita area, behaviour, colour, and plants. The total score represents the green space preference.

2.4. Procedure

A total of 240 subjects were randomly assigned to six groups. The first stage was the pre-test conducted in the indoor room. All subjects performed the same tasks in the first stage, including the 6-minute high-pressure learning task and the 4-minute trail making test (TMT) (Arnett & Labovitz, 1995; Tombaugh, 2004). The subjects were first instructed to sit and put on the EEG device, and after a 40-second baseline of the device (baseline time was not included in the analysis), the tasks began. The learning tasks were foreign language translation and math problems that were far more difficult than the college students' level, and the TMT tasks included connecting lines, finding adjacent repeating letters and placing numbers in order from a page of random numbers (Chiang et al., 2017). All subjects were told in advance to complete the tasks quickly and accurately, which has been demonstrated to cause fatigue in the brain and body (Cahn et al., 1995; Gotts, Ellis, Deary, Barclay, & Newton, 2015). At the end of the pre-test, blood pressure, finger SpO2, and finger pulse rate were measured, and the subjects' attention and mood states were tested (Stroop test and POMS questionnaire, respectively).

In the second stage, the subjects in all six groups were required to perform a post-test in the corresponding simulated green space (the six different simulated green spaces described in 2.1), and the total duration of the recovery activity was 10 min. At the outset, all subjects were informed of the necessary experimental requirements to avoid the effect of non-experimental factors, including not talking to other people or using electronic equipment and comfortably wearing the EEG equipment. The subjects in the walking group carried a computer in a backpack during the experiment to ensure continuous data (Aspinall, Mavros, Coyne, & Roe, 2015). All of the volunteers were told before the experiment that they could not interfere with the subjects, but they remained randomly positioned and were freely active to simulate an actual green space scene. Blood pressure, finger SpO2, finger pulse rate,

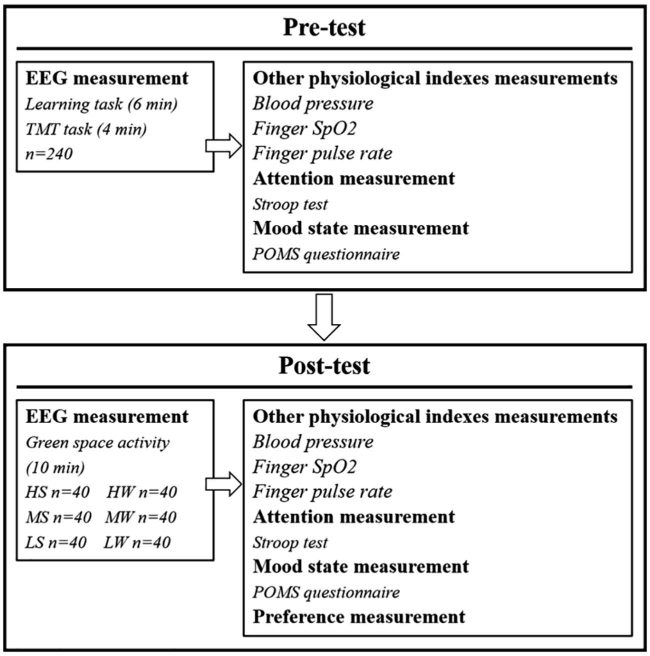


Fig. 4. Study procedure (HS = high-sitting, MS = middle-sitting, LS = low-sitting, HW = high-walking, MW = middle-walking and LW = low-walking).

attention, mood states and preference were also measured after the green space activity. The post-test lasted a total of 30 min (Fig. 4).

2.5. Statistical analysis

Analysis of covariance (ANCOVA) was used to analyse the differences in all indicators (β/α index, blood pressure, finger SpO2, finger pulse rate, positive mood, negative mood, TMD and preference) among all the groups, taking the pre-test results as covariates and eliminating the effect of the different baseline results (preference has no covariates). First, the main effect analysis and interaction effect analysis were conducted using GSB and PCA as independent variables. The purpose of this step was to compare the differences in all indicators under the influence of a single variable. Then, the simple-effects analysis was performed on those indicators with a significant interaction effect with GSB and PCA. The purpose of this step was to further compare the differences of indicators under different combinations of two variables (GSB and PCA). SPSS 22.0 software was used for all analyses.

3. Results

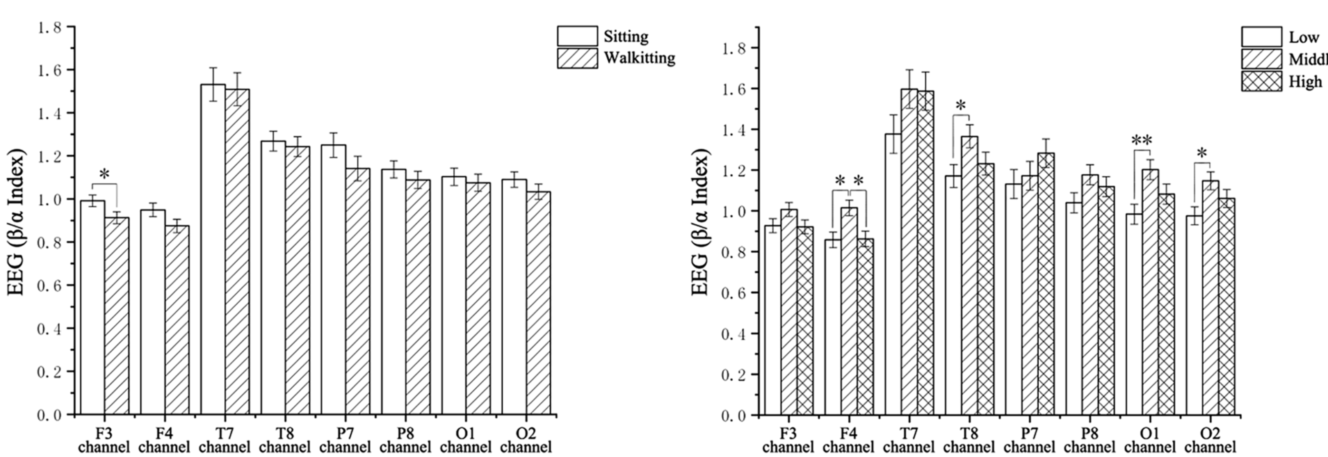
3.1. Effects of GSB and PCA on EEG, blood pressure, finger SpO2 and finger pulse rate

To observe the effects of GSB and PCA on the differences among the six groups, we used ANCOVA to analyse the post-test physiological indicators across the groups (the pre-test results were the covariates). Based on the main effect of GSB, the β/α index of the walking groups (M = 0.913) significantly lower than that of the sitting groups (M = 0.991) only in the F3 channel. Based on the main effect of PCA, four channels (F4, T8, O1, and O2) showed the significantly lowest β/α index of the low groups (M = 0.858, 1.171, 0.984 and 0.976) and the highest β/α index of the middle groups (M = 1.015, 1.365, 1.202 and 1.147). In addition, the F4 channel showed a significantly lower β/α index of the high groups (M = 0.863) than that of the middle groups (M = 1.015) (Fig. 5a, b).

A significant interaction effect of GSB and PCA was observed only on the O2 channel. Then, the simple-effects analysis on the β/α index of the O2 channel showed two significant differences in GSB (the walking groups (M = 1.045) were lower than the sitting groups (M = 1.249), PCA = middle) and PCA (the low groups (M = 0.910) were lower than the middle groups (M = 1.249), GSB = sitting) (Fig. 6a, b).

The main effects and interaction effects of blood pressure, finger SpO2 and finger pulse rate were analysed using ANCOVA. Based on the main effect of PCA, the finger pulse rate of the low (M = 74.675) and high (M = 74.138) groups were significantly lower than those of the middle groups (M = 77.624), and a significant interaction effect of GSB and PCA on the finger pulse rate was observed. We did not observe a significant main effect or interaction effect of systolic blood pressure (SBP), diastolic blood pressure (DBP) or finger SpO2, suggesting that these indicators of the subjects in this small green space did not vary based on GSB and PCA (Fig. 7a, b).

The simple-effects analysis on the finger pulse rate showed three significant differences in GSB (the sitting groups (M = 72.060) were lower than the walking groups (M = 77.289), PCA = “low”), PCA (the low groups (M = 72.060) were lower than the middle groups (M = 76.925), GSB = “sitting”) and PCA (the high groups (M = 73.285) were lower than the middle groups (M = 78.323), GSB = “walking”) (Fig. 8a, b).



(a)Main effect of GSB (b)Main effect of PCA

Fig. 5. Values of EEG (β/α index) in the main effects analysis (N = 40; mean ± standard error; * $p < 0.05$; ** $p < 0.01$).

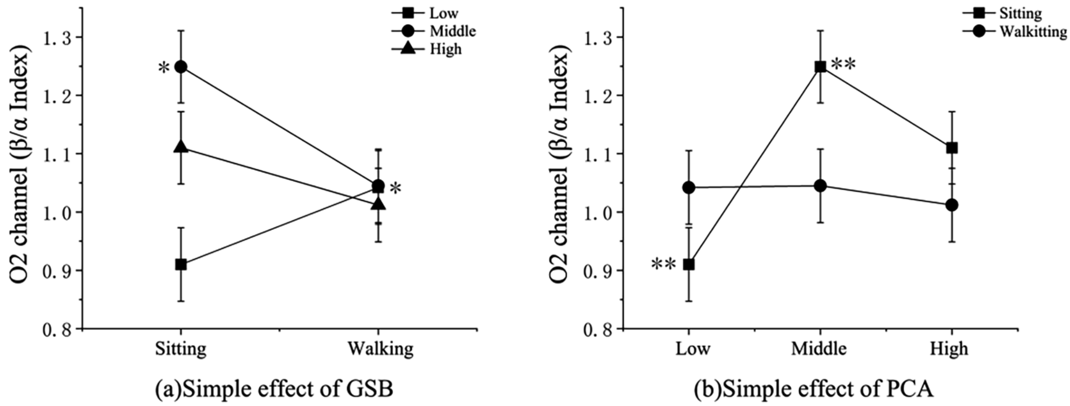


Fig. 6. Values of O2 channel (β/α index) in the simple-effects analysis (N = 40; mean ± standard error; * p < 0.05; ** p < 0.01).

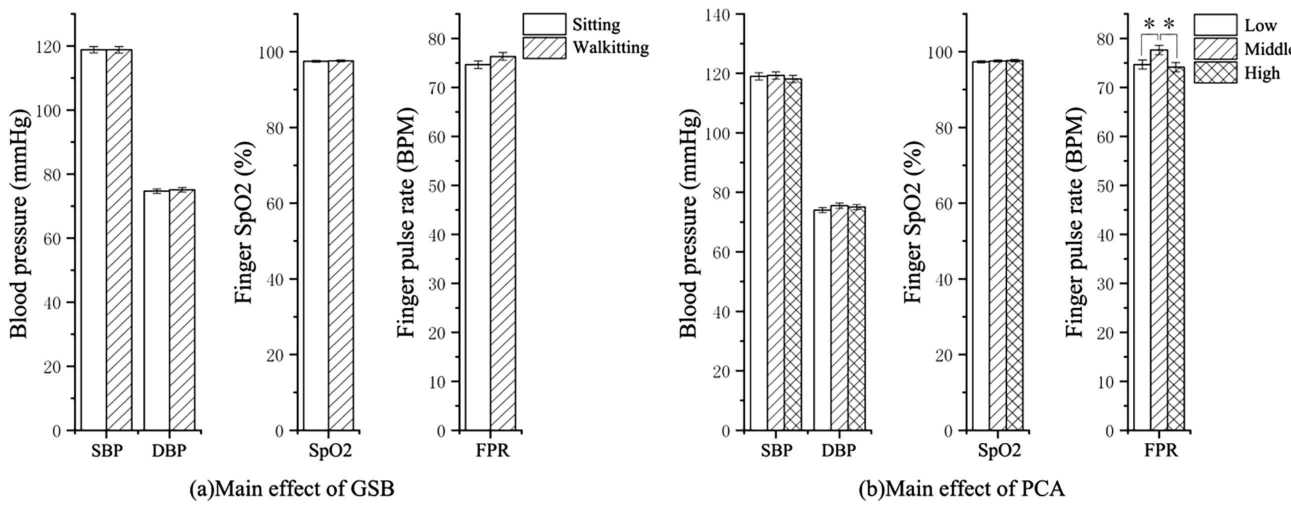


Fig. 7. Values of blood pressure, finger SpO2 and finger pulse rate in the main effects analysis (N = 40; mean ± standard error; * p < 0.05; ** p < 0.01).

The ANCOVA results corresponding to the above values regarding EEG, blood pressure, finger SpO2 and finger pulse rate are presented in Appendix A (Table A1–A4).

3.2. Effects of GSB and PCA on attention, mood and preference

Do GSB and PCA have main effects and interaction effects on attention, mood and preference? We used ANCOVA to analyse these factors and obtained non-significant results for attention but significant results for the other indicators. Based on the main effect of PCA, the negative mood of the low groups (M = 6.563) was significantly higher than that of the high groups (M = 4.637) and middle groups (M = 5.225), and preference also showed a significant main effect of PCA (the low groups (M = 13.325) were significantly lower than the negative mood of the high (M = 14.212) and middle (M = 14.763) groups) (Fig. 9a, b).

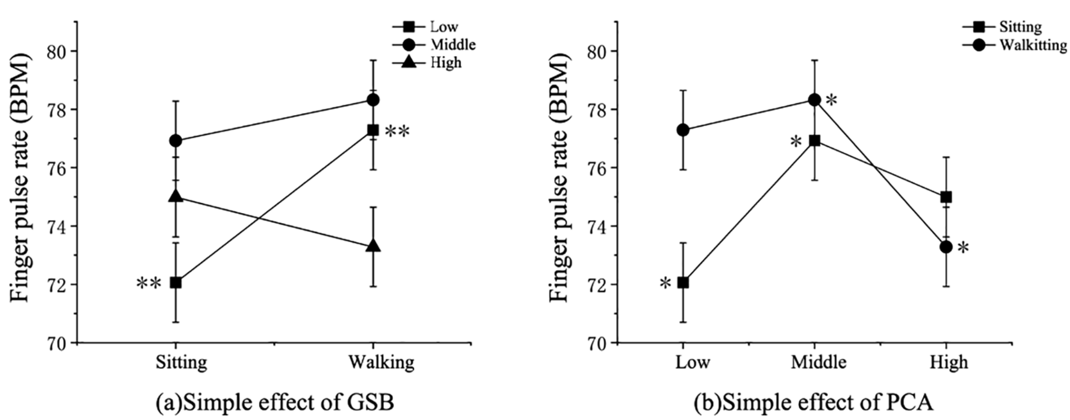


Fig. 8. Values of finger pulse rate in the simple-effects analysis (N = 40; mean ± standard error; * p < 0.05; ** p < 0.01).

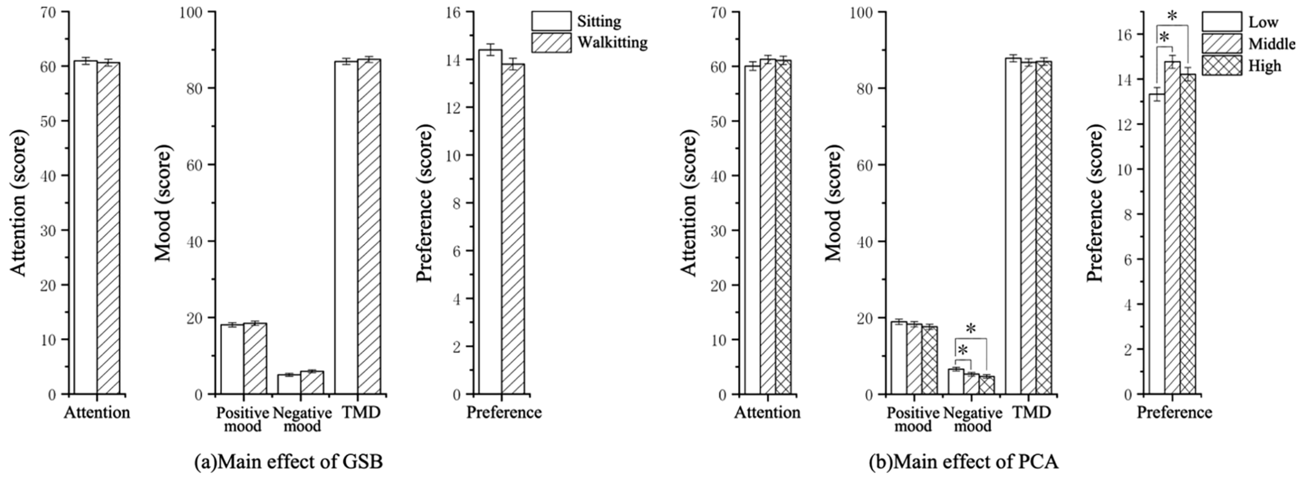


Fig. 9. Values of attention, mood and preference in the main-effects analysis (N = 40; mean ± standard error; * $p < 0.05$; ** $p < 0.01$).

Then, we performed simple-effects analysis on four indicators (positive mood, negative mood, TMD, and preference) with significant interaction effects of GSB and PCA. The results are as follows (Fig. 10a–d).

Positive mood showed three significant differences in GSB (the sitting groups (M = 16.244) were lower than the walking groups (M = 19.037), PCA = "high"), GSB (the sitting groups (M = 20.416) were higher than the walking groups (M = 17.403), PCA = "low") and PCA (the low groups (M = 20.416) were higher than the high groups (M = 16.244), GSB = "sitting").

Negative mood also showed three significant differences in GSB (the sitting groups (M = 5.863) were higher than the walking groups (M = 3.411), PCA = "high"), GSB (the sitting groups (M = 4.827) were lower than the walking groups (M = 8.298), PCA = "low") and PCA (the high groups (M = 3.411) were lower than the low (M = 8.298) and middle (M = 6.119) groups, GSB = "walking").

TMD showed four significant differences in GSB (the sitting groups (M = 89.789) were higher than the walking groups (M = 84.163), PCA = "high"), GSB (the sitting groups (M = 84.533) were lower than the walking groups (M = 91.063), PCA = "low"), PCA (the low groups (M = 84.533) were lower than the high groups (M = 89.789), GSB = "sitting") and PCA (the low groups (M = 91.063) were higher than the high groups (M = 84.163), GSB = "walking").

Preference showed five significant differences in GSB (the sitting groups (M = 13.425) were lower than the walking groups (M = 15.000), PCA = "high"), GSB (the sitting groups (M = 15.350) were higher than the walking groups (M = 14.175), PCA = "middle"), GSB (the sitting groups (M = 14.425) were higher than the walking groups (M = 12.225), PCA = "low"), PCA (the high groups (M = 13.425) were lower than the middle groups (M = 15.350), GSB = "sitting") and PCA (the low groups (M = 12.225) were lower than the high (M = 15.000) and middle (M = 14.175) groups, GSB = "walking").

The ANCOVA results corresponding to the above values regarding attention, mood and preference are presented in Appendix A (Tables A5 and A6).

4. Discussion

Based on a series of experiments and data analysis, this study obtained interesting findings about the effects of two variables (GSB and PCA) in small urban green spaces on physiology and psychology. We will discuss these results in combination with the theory of planning and design to provide a reference for urban green space construction.

4.1. Do GSB and PCA affect attention and stress level?

In this experiment, the evaluation of attention and stress was based on physiological indicators. EEG (β/α index) was used as the main evaluation indicator of stress level, and blood pressure, finger SpO2 and finger pulse rate were used as auxiliary indicators. The evaluation of attention level was based on Stroop test scores.

The lower the β/α index in this experiment, the lower the stress level. First, the significant result of GSB's main effect was observed only on the F3 channel (in the frontal lobe and control complex cognition, language, emotion and behaviour). This result shows that in a small urban green space, walking is more effective for relaxation than sitting. This finding echoes previous research on the positive role of walking in green spaces in recovery (Aspinall et al., 2015; Hartig et al., 2003; Neale et al., 2017). However, the main effect of PCA was shown in the F4, T8, O1 and O2 channels, suggesting that a lower PCA is better. This finding is inconsistent with the results recommended by previous studies (high PCA is better) and the expectation of this experiment, so it was important to further observe this interaction. The significant result of the interaction effect was observed on the O2 channel (in the occipital lobe and control all visual information), and it further revealed the possible internal mechanism. When the PCA is of middle type, walking is the best; when the GSB is sitting, the lower PCA is the best. Although not all channels showed significant differences, the results of channels with significant differences were consistent. Therefore, we believe that the interaction effect of the O2 channel and these main effects are representative because the stimulus of green space mainly comes from vision (Lawson, 2007). This finding showed the positive value of the suitable combination of GSB and PCA on physiological stress level.

In this experiment, blood pressure and finger SpO2 did not differ significantly across the groups. We infer that the stimulation time might be one reason why the differences in blood pressure and finger SpO2 were not obvious. A previous study has shown that the positive effect of the green environment on physiological indexes, such as blood pressure and finger SpO2, is dynamic. The positive effect will increase quickly in

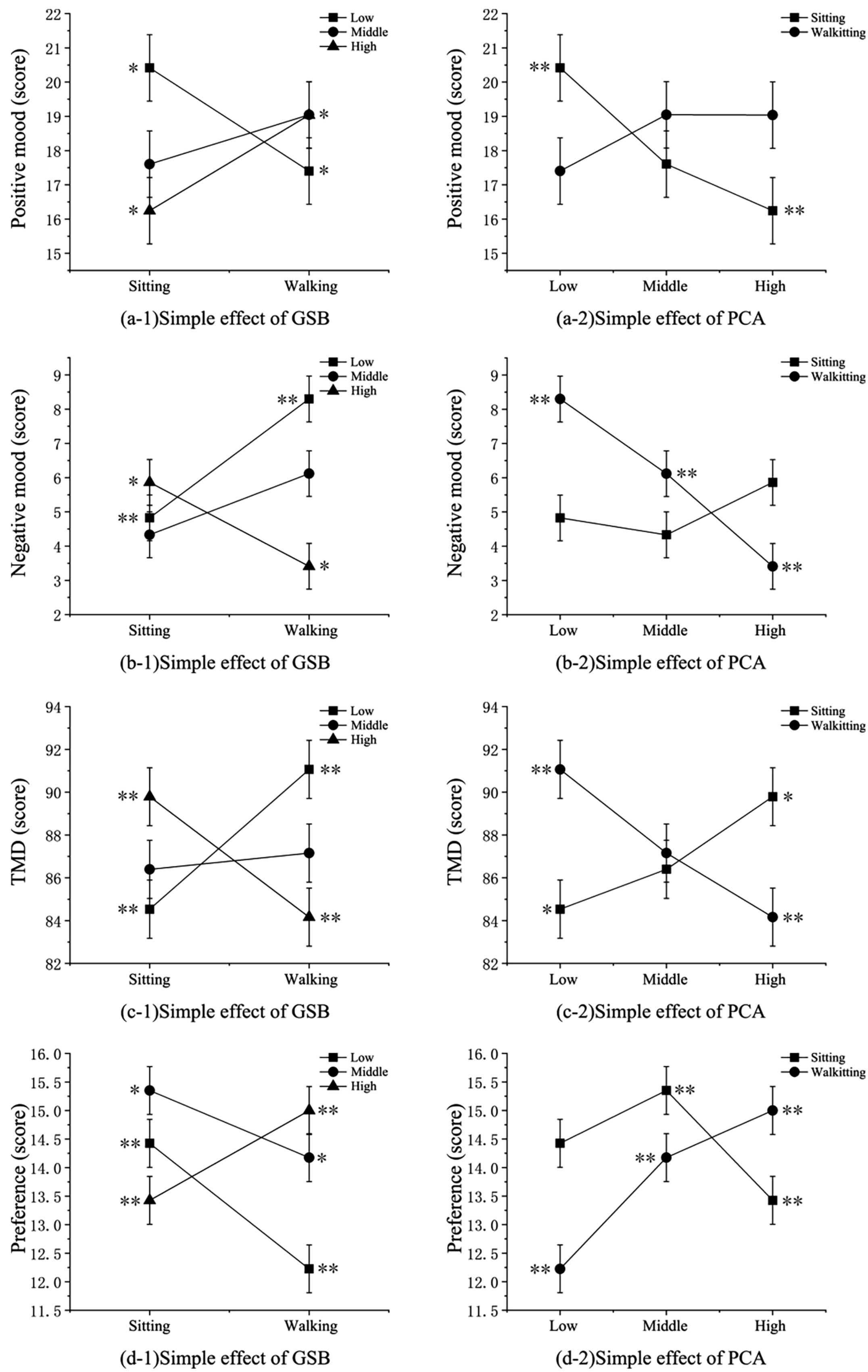


Fig. 10. Values of attention, mood and preference in the simple-effects analysis (N = 40; mean ± standard error; * $p < 0.05$; ** $p < 0.01$).

the first few minutes; then, the effect will decrease and disappear over the long term (Hartig et al., 2003). In addition, we observed significant results of finger pulse rate in both the main effect and the interaction effect. The lower the pulse rate in the normal range, the less physiological tension and stress. These results showed better results in the high PCA and low PCA condition. By performing further interaction effect analyses, we found that a lower pulse was achieved after walking in the high PCA conditions and sitting in the low PCA conditions. These results are consistent with the EEG results.

However, there were no significant differences in attention level among the groups. “Being away”, “fascination”, “extent” and “compatible” are the four key points of SRT (Kaplan, 1995), and some studies on large natural green spaces have demonstrated the restoration of attention level (Taylor & Kuo, 2009). This difference may be because the simulated green space form used in the present experiment was not complex, or it may be because the characteristics (small area) of small urban green spaces make it difficult for GSB and PCA, especially GSB, to reveal differences in attention level.

4.2. Do GSB and PCA affect the mood state and people’s preference?

A subjective psychological questionnaire was used to evaluate emotions and preferences in this experiment; therefore, we discuss it in greater detail in combination with the theory of spatial design psychology. The main effect of PCA showed consistent significant effects on the negative mood and preference indicators, in which the middle and high PCA are better. This result reflects human’s territorial sense of space, in which a larger space is preferred (Lawson, 2007). The interaction effect explains the relationship between GSB and PCA in additional indicators. More beneficial results (more positive emotions, less negative emotions and TMD and stronger preference) appeared in the two combinations of high-walking and low-sitting. According to previous theories, first, humans are not only territorial but also socially communicative (Peschardt & Stigsdotter, 2013), which means that there are different needs for spontaneous activities (such as walking) and social activities (such as communication) based on the number of people in a space (Gehl, 2003). Second, the low-sitting group experienced a “centripetal social” communication space for satisfying non-contact social distance (120–360 cm), and this stimulation promoted a positive psychological effect. Additionally, walking is more likely to require a “centrifugal social” space; thus, the higher PCA of the high-walking group provides people with more security and fewer barriers, providing psychological benefits (Hall, 1980; Lawson, 2007).

Overall, in this experiment, we observed the changes in the physiological and psychological indicators caused by GSB and PCA and found consistencies and differences in these changes. Due to the influence of GSB and PCA, there are differences among several groups in small urban green spaces. Considering only GSB’s effect, walking is more effective, and this is consistent with our hypothesis. Regarding only PCA’s effect, there are two results that are contrary to our hypothesis as follows: the low PCA is better, and the high PCA is better, indicating that the physiological and psychological results are not always consistent. In the further interaction effects analysis, the physiological indicators and psychological indicators are basically the same. During walking, the high PCA is better, whereas during sitting, the low PCA is better. Thus, the combinations of high-walking and low-sitting have the best effects. This result is different from our hypothesis that only high PCA is suitable. However, consistent with our hypothesis, not all indicators are significantly affected by GSB and PCA, including blood pressure, finger SpO2 and attention. This finding is consistent with previous research, suggesting that the approaches of ART and SRT are not consistent in urban green spaces (Li & Sullivan, 2016).

4.3. Limitations and future research

There are certain limitations to this study. Although the results between certain physiological and psychological indicators were consistent, the internal physiological correlation and mechanisms still need further explanation. In this experiment, there were no long-term measurements and onlylittle dynamic monitoring, which limits a deeper discussion of certain results. The two variables (GSB and PCA) were limited to only 2–3 gradients, and there are more situations that can be explored. More subjects of different ages and occupations and more green space forms can be studied in the future. In addition, this experiment focuses on the influences of GSB and PCA in green spaces. Future research could focus on the difference between small urban green spaces and other urban spaces to better verify the health value of the small green space.

4.4. Application

The results of this experiment can be employed as a reference in urban green space planning and design. We believe a high PCA is not the only goal, and we can be more strategic in addressing the uneven distribution of urban green spaces. According to the experimental results, in urban areas with a low per capita green space, enclosed communication spaces can be created to prevent external interference, and as many seats as possible can be set up in the space. In urban areas with a high per capita green space, a large number of walking spaces can be set up, and trees or wetlands can be increased to improve ecological benefits. Additionally, we should adjust measures to local conditions and consider the structure and form of green spaces.

5. Conclusion

This study focused on the health benefits of small urban green spaces and investigated the physiological and psychological indicators of people in a simulated green space under the impact of the following two key factors: GSB and PCA. We analysed the main effect and interaction effect of the two factors and obtained numerous significant results. First, the results of the main-effect analysis showed that the health benefits of walking were better than those of sitting, and the high PCA and the low PCA showed better results for different indicators. Second, importantly, after further interaction analysis, we found that GSB needs to be matched with the appropriate PCA to maximize the health benefits. The results of this study showed that the effects of walking in a high PCA and sitting in a low PCA are the best. In addition, the experimental results proved that the physiological and psychological response results of urban green space are not completely consistent and that the approaches of ART and SRT are also inconsistent. Finally, this study provided valuable suggestions for urban green space planning and design, such as taking measures according to local conditions, providing suitable a green space structure and advocating for a more reasonable layout of green spaces instead of blindly pursuing larger green spaces.

Acknowledgements

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Appendix A

Table A1
Main effect and interaction effect of GSB and PCA on the EEG (β/α Index) across the experimental groups (Covariates: pre-tests. Dependent variables: post-tests).

EEG (β/α Index)	Sum of Squares	df	Mean Square	F	Sig.	Partial $\eta 2$	Pairwise Comparisons
F3 channel							
Pre-test	7.994	1	7.994	89.080	0.000	0.277	
GSB	0.361	1	0.361	4.025	0.046 *	0.017	S > W
PCA	0.357	2	0.178	1.989	0.139	0.017	
GSB × PCA	0.455	2	0.227	2.535	0.081	0.021	
Error	20.910	233	0.090				
$R^2 = 0.321$ (Adj $R^2 = 0.304$)							
F4 channel							
Pre-test	0.005	1	0.005	0.043	0.836	0.000	
GSB	0.329	1	0.329	2.928	0.088	0.012	
PCA	1.271	2	0.636	5.649	0.004 **	0.046	H, L < M
GSB × PCA	0.189	2	0.094	0.838	0.434	0.007	
Error	26.221	233	0.113				
$R^2 = 0.064$ (Adj $R^2 = 0.040$)							
T7 channel							
Pre-test	18.274	1	18.274	25.975	0.000	0.100	
GSB	0.029	1	0.029	0.041	0.839	0.000	
PCA	2.493	2	1.247	1.772	0.172	0.015	
GSB × PCA	1.035	2	0.517	0.735	0.480	0.006	
Error	163.921	233	0.704				
$R^2 = 0.116$ (Adj $R^2 = 0.093$)							
T8 channel							
Pre-test	1.298	1	1.298	5.101	0.025	0.021	
GSB	0.038	1	0.038	0.151	0.698	0.001	
PCA	1.573	2	0.786	3.091	0.047 *	0.026	M > L
GSB × PCA	0.350	2	0.175	0.687	0.504	0.006	
Error	59.290	233	0.254				
$R^2 = 0.051$ (Adj $R^2 = 0.027$)							
P7 channel							
Pre-test	26.887	1	26.887	68.411	0.000	0.227	
GSB	0.704	1	0.704	1.791	0.182	0.008	
PCA	0.974	2	0.487	1.239	0.292	0.011	
GSB × PCA	0.199	2	0.099	0.253	0.777	0.002	
Error	91.574	233	0.393				
$R^2 = 0.255$ (Adj $R^2 = 0.235$)							
P8 channel							
Pre-test	1.182	1	1.182	6.234	0.013	0.026	
GSB	0.142	1	0.142	0.751	0.387	0.003	
PCA	0.748	2	0.374	1.973	0.141	0.017	
GSB × PCA	0.203	2	0.101	0.535	0.586	0.005	
Error	44.167	233	0.190				
$R^2 = 0.051$ (Adj $R^2 = 0.027$)							
O1 channel							
Pre-test	0.165	1	0.165	0.856	0.356	0.004	
GSB	0.046	1	0.046	0.240	0.625	0.001	
PCA	1.896	2	0.948	4.920	0.008 **	0.041	M > L
GSB × PCA	0.235	2	0.117	0.609	0.545	0.005	
Error	44.889	233	0.193				
$R^2 = 0.048$ (Adj $R^2 = 0.024$)							
O2 channel							
Pre-test	0.143	1	0.143	0.914	0.340	0.004	
GSB	0.191	1	0.191	1.220	0.270	0.005	
PCA	1.170	2	0.585	3.746	0.025 *	0.031	M > L
GSB × PCA	1.174	2	0.587	3.760	0.025 *	0.031	
Error	36.386	233	0.156				
$R^2 = 0.067$ (Adj $R^2 = 0.043$)							

Note: Lower β/α index values indicate more relaxation and calmness. GSB means green space behaviour. PCA means per capita area. *$p < 0.05$; **$p < 0.01$.

Table A2
Simple effects analysis of the indicators that have significant interaction effects on the EEG (β/α Index).

EEG (β/α Index)	Sum of squares	df	Mean square	F	Sig.	Partial $\eta 2$	Pairwise comparisons
O2 channel							
GSB (PCA = H)	0.189	1	0.189	1.211	0.272	0.005	
Error	36.386	233	0.156				
GSB (PCA = M)	0.836	1	0.836	5.351	0.022 *	0.022	S > W
Error	36.386	233	0.156				
GSB (PCA = L)	0.342	1	0.342	2.191	0.140	0.009	
Error	36.386	233	0.156				
PCA (GSB = S)	2.310	2	1.155	7.397	0.001 **	0.060	M > L
Error	36.386	233	0.156				
PCA (GSB = W)	0.026	2	0.013	0.082	0.921	0.001	
Error	36.386	233	0.156				

Note: Lower β/α index values indicate more relaxation and calmness. GSB means green space behaviour. PCA means per capita area. H means high. M means middle. L means low. S means sitting. W means walking. * $p < 0.05$; ** $p < 0.01$.

Table A3
Main effect and interaction effect of GSB and PCA on blood pressure, finger SpO2 and finger pulse rate across the experimental groups (Covariates: pre-tests. Dependent variables: post-tests).

Indicators	Sum of squares	df	Mean square	F	Sig.	Partial $\eta 2$	Pairwise comparisons
SBP (mmHg)							
Pre-test	13253.718	1	13253.718	119.252	0.000	0.339	
GSB	0.185	1	0.185	0.002	0.967	0.000	
PCA	62.369	2	31.184	0.281	0.756	0.002	
GSB × PCA	163.054	2	81.527	0.734	0.481	0.006	
Error	25895.756	233	111.141				
$R^2 = 0.355$ (Adj $R^2 = 0.338$)							
DBP (mmHg)							
Pre-test	6702.977	1	6702.977	109.346	0.000	0.319	
GSB	11.432	1	11.432	0.186	0.666	0.001	
PCA	92.834	2	46.417	0.757	0.470	0.006	
GSB × PCA	131.120	2	65.560	1.069	0.345	0.009	
Error	14283.044	233	61.301				
$R^2 = 0.330$ (Adj $R^2 = 0.313$)							
Finger SpO2 (%)							
Pre-test	22.269	1	22.269	3.357	0.068	0.014	
GSB	1.113	1	1.113	0.168	0.682	0.001	
PCA	4.090	2	2.045	0.308	0.735	0.003	
GSB × PCA	2.128	2	1.064	0.160	0.852	0.001	
Error	1545.475	233	6.633				
$R^2 = 0.021$ (Adj $R^2 = 0.005$)							
Finger pulse rate (BPM)							
Pre-test	5838.379	1	5838.379	78.997	0.000	0.253	
GSB	161.117	1	161.117	2.180	0.141	0.009	
PCA	562.585	2	281.293	3.806	0.024 *	0.032	H, L < M
GSB × PCA	479.972	2	239.986	3.247	0.041 *	0.027	
Error	17220.069	233	73.906				
$R^2 = 0.292$ (Adj $R^2 = 0.273$)							

Note: SBP means systolic blood pressure. DBP indicates diastolic blood pressure. GSB means green space behaviour. PCA means per capita area. * $p < 0.05$; ** $p < 0.01$.

Table A4
Simple-effects analysis of the indicators that have significant interaction effects on blood pressure, finger SpO2 and finger pulse rate.

Indicators	Sum of squares	df	Mean square	F	Sig.	Partial $\eta 2$	Pairwise comparisons
Finger pulse rate (Bpm)							
GSB (PCA = H)	57.811	1	57.811	0.782	0.377	0.003	
Error	17220.069	233	73.906				
GSB (PCA = M)	39.072	1	39.072	0.529	0.468	0.002	
Error	17220.069	233	73.906				
GSB (PCA = L)	546.521	1	546.521	7.395	0.007 **	0.031	S < W
Error	17220.069	233	73.906				
PCA (GSB = S)	479.686	2	239.843	3.245	0.041 *	0.027	M > L
Error	17220.069	233	73.906				
PCA (GSB = W)	566.342	2	283.171	3.832	0.023 *	0.032	H < M
Error	17220.069	233	73.906				

Note: GSB means green space behaviour. PCA means per capita area. H means High. M means Middle. L means Low. S means Sitting. W means Walking. * $p < 0.05$; ** $p < 0.01$.

Table A5
Main effect and interaction effect of GSB and PCA on attention, mood and preference across the experimental groups (Covariates: pre-tests. Dependent variables: post-tests).

Indicators	Sum of squares	df	Mean square	F	Sig.	Partial $\eta 2$	Pairwise comparisons
Attention (score)							
Pre-test	9464.988	1	9464.988	199.366	0.000	0.461	
GSB	5.957	1	5.957	0.125	0.723	0.001	
PCA	68.414	2	34.207	0.721	0.488	0.006	
GSB × PCA	1.879	2	0.939	0.020	0.980	0.000	
Error	11061.762	233	47.475				
$R^2 = 0.475$ (Adj $R^2 = 0.461$)							
Positive mood (score)							
Pre-test	4885.756	1	4885.756	130.051	0.000	0.358	
GSB	9.919	1	9.919	0.264	0.608	0.001	
PCA	64.524	2	32.262	0.859	0.425	0.007	
GSB × PCA	369.085	2	184.543	4.912	0.008 **	0.040	
Error	8753.344	233	37.568				
$R^2 = 0.380$ (Adj $R^2 = 0.364$)							
Negative mood (score)							
Pre-test	1453.044	1	1453.044	81.628	0.000	0.259	
GSB	52.513	1	52.513	2.950	0.087	0.013	
PCA	155.308	2	77.654	4.362	0.014 *	0.036	H, M < L
GSB × PCA	371.398	2	185.699	10.432	0.000 **	0.082	
Error	4147.606	233	17.801				
$R^2 = 0.317$ (Adj $R^2 = 0.299$)							
TMD (score)							
Pre-test	5445.691	1	5445.691	74.065	0.000	0.241	
GSB	18.456	1	18.456	0.251	0.617	0.001	
PCA	46.739	2	23.369	0.318	0.728	0.003	
GSB × PCA	1478.701	2	739.351	10.056	0.000 **	0.079	
Error	17131.559	233	73.526				
$R^2 = 0.287$ (Adj $R^2 = 0.268$)							
Preference (score)							
GSB	21.600	1	21.600	3.057	0.082	0.013	
PCA	84.175	2	42.087	5.956	0.003 **	0.048	H, M > L
GSB × PCA	152.425	2	76.212	10.786	0.000 **	0.084	
Error	1653.400	234	7.066				
$R^2 = 0.135$ (Adj $R^2 = 0.117$)							

Note: Positive mood (vigour + self-esteem). Negative mood (tension + anger + depression + fatigue + confusion). TMD (total mood disturbance) = tension + anger + depression + fatigue − vigour + confusion − self-esteem + 100. GSB means green space behaviour. PCA means per capita area. * $p < 0.05$; ** $p < 0.01$.

Table A6
Simple effects analysis of the indicators that have significant interaction effects on attention, mood and preference.

Indicators	Sum of squares	df	Mean square	F	Sig.	Partial η2	Pairwise comparisons
Positive mood (score)							
GSB (PCA = H)	155.990	1	155.990	4.152	0.043 *	0.018	S < W
Error	8753.344	233	37.568				
GSB (PCA = M)	41.426	1	41.426	1.103	0.295	0.005	
Error	8753.344	233	37.568				
GSB (PCA = L)	181.568	1	181.568	4.833	0.029 *	0.020	S > W
Error	8753.344	233	37.568				
PCA (GSB = S)	362.136	2	181.068	4.820	0.009 **	0.040	H < L
Error	8753.344	233	37.568				
PCA (GSB = W)	71.558	2	35.779	0.952	0.387	0.008	
Error	8753.344	233	37.568				
Negative mood (score)							
GSB (PCA = H)	119.773	1	119.773	6.728	0.010 *	0.028	S > W
Error	4147.606	233	17.801				
GSB (PCA = M)	63.578	1	63.578	3.572	0.060	0.015	
Error	4147.606	233	17.801				
GSB (PCA = L)	240.913	1	240.913	13.534	0.000 **	0.055	S < W
Error	4147.606	233	17.801				
PCA (GSB = S)	48.503	2	24.251	1.362	0.258	0.012	
Error	4147.606	233	17.801				
PCA (GSB = W)	478.068	2	239.034	13.428	0.000 **	0.103	H < M, L
Error	4147.606	233	17.801				
TMD (score)							
GSB (PCA = H)	632.480	1	632.480	8.602	0.004 **	0.036	S > W
Error	17131.559	233	73.526				
GSB (PCA = M)	11.545	1	11.545	0.157	0.692	0.001	
Error	17131.559	233	73.526				
GSB (PCA = L)	852.634	1	852.634	11.596	0.001 **	0.047	S < W
Error	17131.559	233	73.526				
PCA (GSB = S)	568.198	2	284.099	3.864	0.022 *	0.032	H > L
Error	17131.559	233	73.526				
PCA (GSB = W)	956.973	2	478.487	6.508	0.002 **	0.053	H < L
Error	17131.559	233	73.526				
Preference (score)							
GSB (PCA = H)	49.612	1	49.612	7.021	0.009 **	0.029	S < W
Error	1653.400	234	7.066				
GSB (PCA = M)	27.612	1	27.612	3.908	0.049 *	0.016	S > W
Error	1653.400	234	7.066				
GSB (PCA = L)	96.800	1	96.800	13.700	0.000 **	0.055	S > W
Error	1653.400	234	7.066				
PCA (GSB = S)	74.150	2	37.075	5.247	0.006 **	0.043	H < M
Error	1653.400	234	7.066				
PCA (GSB = W)	162.450	2	81.225	11.495	0.000 **	0.089	H, M > L
Error	1653.400	234	7.066				

Note: Positive mood (vigour + self-esteem). Negative mood (tension + anger + depression + fatigue + confusion). TMD (total mood disturbance) = tension + anger + depression + fatigue − vigour + confusion − self-esteem + 100. GSB means green space behaviour. PCA means per capita area. H means high. M means middle. L means low. S means sitting. W means walking. * $p < 0.05$; ** $p < 0.01$.

References

Arnett, J. A., & Labovitz, S. S. (1995). Effect of physical layout in performance of the Trail Making Test. *Psychological Assessment, 7*, 220–221. https://doi.org/10.1037/1040-3590.7.2.220.

Aspinall, P., Mavros, P., Coyne, R., & Roe, J. (2015). The urban brain: Analysing outdoor physical activity with mobile EEG. *British Journal of Sports Medicine, 49*(4), 272–276. https://doi.org/10.1136/bjsports-2012-091877.

Astell-Burt, T., Feng, X., Mavoa, S., Badland, H. M., & Giles-Corti, B. (2014). Do low-income neighbourhoods have the least green space? A cross-sectional study of Australia's most populous cities. *BMC Public Health, 14*, 292. https://doi.org/10.1186/1471-2458-14-292.

Bakouie, F., Pishnamazi, M., Zeraati, R., & Gharibzadeh, S. (2017). Scale-freeness of dominant and piecemeal perceptions during binocular rivalry. *Cognitive Neurodynamics, 11*(4), 319–326. https://doi.org/10.1007/s11571-017-9434-4.

Beatley, T. (1999). *Green Urbanism: Learning From European Cities.* Washington: Island Press.

Beili, Z. (1995). Brief introduction of POMS scale and its model for China. *Journal of Tianjin Institute of Physical Education, 10*(1), 35–37.

Bixby, H., Hodgson, S., Fortunato, L., Hansell, A., & Fecht, D. (2015). Associations between green space and health in English cities: An ecological, cross-sectional study. *PLoS ONE, 10*(3), e0119495. https://doi.org/10.1371/journal.pone.0119495.

Cahn, D. A., Salmon, D. P., Butters, N., Wiederholt, W. C., Corey-Bloom, J., Edelstein, S. L., & Barrett-Connor, E. (1995). Detection of dementia of the Alzheimer type in a population-based sample: Neuropsychological test performance. *Journal of the International Neuropsychological Society, 1*, 252–260. https://doi.org/10.1017/S1355617700000242.

Chen, H.-T., Yu, C.-P., & Lee, H.-Y. (2018). The effects of forest bathing on stress recovery: Evidence from middle-aged females of taiwan. *Forests, 9*(7), https://doi.org/10.3390/f9070403.

Chen, X., Zhang, X., Zhang, Y., Booth, T., & He, X. (2009). Changes of carbon stocks in bamboo stands in China during 100 years. *Forest Ecology and Management, 258*(7), 1489–1496. https://doi.org/10.1016/j.foreco.2009.06.051.

Chiang, Y.-C., Li, D., & Jane, H.-A. (2017). Wild or tended nature? The effects of landscape location and vegetation density on physiological and psychological responses. *Landscape and Urban Planning, 167*, 72–83. https://doi.org/10.1016/j.landurbplan.2017.06.001.

Choi, J. Y., Park, S. A., Jung, S. J., Lee, J. Y., Son, K. C., An, Y. J., & Lee, S. W. (2016). Physiological and psychological responses of humans to the index of greenness of an interior space. *Complementary Therapies in Medicine, 28*, 37–43. https://doi.org/10.1016/j.ctim.2016.08.002.

Evensen, K. H., Raanaas, R. K., & Fyhri, A. (2016). Soundscape and perceived suitability for recreation in an urban designated quiet zone. *Urban Forestry & Urban Greening, 20*, 243–248. https://doi.org/10.1016/j.ufug.2016.09.003.

Feda, D. M., Seelbinder, A., Baek, S., Raja, S., Yin, L., & Roemmich, J. N. (2014). Neighbourhood parks and reduction in stress among adolescents: Results from Buffalo, New York. *Indoor and Built Environment, 24*(5), 631–639. https://doi.org/10.1177/1420326x14535791.

Flouri, E., Midouhas, E., & Joshi, H. (2014). The role of urban neighbourhood green space in children's emotional and behavioural resilience. *Journal of Environmental Psychology, 40*, 179–186. https://doi.org/10.1016/j.jenvp.2014.06.007.

Flynn, A., Chan, K. W., Zhu, Z. H., & Yu, L. (2017). Sustainability, space and supply chains: The role of bamboo in Anji County, China. *Journal of Rural Studies, 49*, 128–139. https://doi.org/10.1016/j.jrurstud.2016.11.012.

Fuller, R. A., & Gaston, K. J. (2009). The scaling of green space coverage in European cities. *Biology Letters, 5*(3), 352–355. https://doi.org/10.1098/rsbl.2009.0010.

Gehl, J. (2003). *Life Between Buildings.* VAN: Nosrand Reinhold.

Goto, S., Park, B.-J., Tsunetsugu, Y., Herrup, K., & Miyazaki, Y. (2013). The effect of garden designs on mood and heart output in older adults residing in an assisted living facility. *Herd: Health Environments Research & Design Journal, 6*, 27–42. https://doi.org/10.1177/193758671300600204.

Gotts, Z. M., Ellis, J. G., Deary, V., Barclay, N., & Newton, J. L. (2015). The association between daytime napping and cognitive functioning in chronic fatigue syndrome. *PLoS ONE, 10*(1), e0117136. https://doi.org/10.1371/journal.pone.0117136.

Hall, E. T. (1980). The silent language. *Anchor Books, 38*, 87–96. https://doi.org/10.2307/3111440.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology, 23*(2), 109–123. https://doi.org/10.1016/s0272-4944(02)00109-3.

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health, 35*, 207–228. https://doi.org/10.1146/annurev-publhealth-032013-182443.

Hazer, M., Formica, M. K., Dieterlen, S., & Morley, C. P. (2018). The relationship between self-reported exposure to greenspace and human stress in Baltimore, MD. *Landscape and Urban Planning, 169*, 47–56. https://doi.org/10.1016/j.landurbplan.2017.08.006.

Höppe, P. (1999). The physiological equivalent temperature – A universal index for the biometeorological assessment of the thermal environment. *International Journal of Biometeorology, 43*(2), 71–75. https://doi.org/10.1007/s004840050118.

Hsu, B. W., & Wang, M. J. (2013). Evaluating the effectiveness of using electroencephalogram power indices to measure visual fatigue. *Perceptual and Motor Skills, 116*(1), 235–252. https://doi.org/10.2466/29.15.24.PMS.116.1.235-252.

Igarashi, M., Aga, M., Ikei, H., Namekawa, T., & Miyazaki, Y. (2015). Physiological and psychological effects on high school students of viewing real and artificial pansies. *International Journal of Environmental Research and Public Health, 12*(3), 2521–2531. https://doi.org/10.3390/ijerph120302521.

Jang, H. S., Kim, J., Kim, K. S., & Pak, C. H. (2014). Human brain activity and emotional responses to plant color stimuli. *Color Research & Application, 39*(3), 307–316. https://doi.org/10.1002/col.21788.

Kacha, L., Matsumoto, N., & Mansouri, A. (2015). Electrophysiological Evaluation of Perceived Complexity in Streetscapes. *Journal of Asian Architecture and Building Engineering, 14*, 585–592. https://doi.org/10.3130/jaabe.14.585.

Kaplan, R. (2016). The nature of the view from home: Psychological benefits. *Environment and Behavior, 33*(4), 507–542. https://doi.org/10.1177/00139160121973115.

Kaplan, R., Kaplan, S., & Ryan, R. L. (1998). *With People in Mind.* Washington: Island Press.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15*, 169–182. https://doi.org/10.1016/0272-4944(95)90001-2.

Kim, J.-Y., Kim, J.-T., & Kim, W. (2015). Psycho-physiological responses of drivers to road section types and elapsed driving time on a freeway. *Canadian Journal of Civil Engineering.* https://doi.org/10.1139/cjce-2014-0392.

Küller, R., Mikellides, B., & Janssens, J. (2009). Color, arousal, and performance-A comparison of three experiments. *Color Research & Application, 34*(2), 141–152. https://doi.org/10.1002/col.20476.

Lawson, B. R. (2007). The language of space. *Nature, 252*, 93. https://doi.org/10.1038/252093a0.

Lee, J., Tsunetsugu, Y., Takayama, N., Park, B. J., Li, Q., Song, C., ... Miyazaki, Y. (2014). Influence of forest therapy on cardiovascular relaxation in young adults. *Evidence-Based Complementary and Alternative Medicine, 2014*, 834360. https://doi.org/10.1155/2014/834360.

Li, D., & Sullivan, W. C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning, 148*, 149–158. https://doi.org/10.1016/j.landurbplan.2015.12.015.

Matzarakis, A., Rutz, F., & Mayer, H. (2007). Modelling radiation fluxes in simple and complex environments-application of the RayMan model. *International Journal of Biometeorology, 51*(4), 323–334. https://doi.org/10.1007/s00484-006-0061-8.

Matzarakis, A., Rutz, F., & Mayer, H. (2010). Modelling radiation fluxes in simple and complex environments: Basics of the RayMan model. *International Journal of Biometeorology, 54*(2), 131–139. https://doi.org/10.1007/s00484-009-0261-0.

Nath, T. K., Zhe Han, S. S., & Lechner, A. M. (2018). Urban green space and well-being in Kuala Lumpur, Malaysia. *Urban Forestry & Urban Greening, 36*, 34–41. https://doi.org/10.1016/j.ufug.2018.09.013.

Neale, C., Aspinall, P., Roe, J., Tilley, S., Mavros, P., Cinderby, S., ... Thompson, C. W. (2017). The aging urban brain: Analyzing outdoor physical activity using the emotiv affectiv suite in older people. *Journal of Urban Health, 94*(6), 869–880. https://doi.org/10.1007/s11524-017-0191-9.

Nordh, H., Hartig, T., Hagerhall, C. M., & Fry, G. (2009). Components of small urban parks that predict the possibility for restoration. *Urban Forestry & Urban Greening, 8*(4), 225–235. https://doi.org/10.1016/j.ufug.2009.06.003.

Nutsford, D., Pearson, A. L., & Kingham, S. (2013). An ecological study investigating the association between access to urban green space and mental health. *Public Health, 127*(11), 1005–1011. https://doi.org/10.1016/j.puhe.2013.08.016.

Peschardt, K. K., & Stigsdotter, U. K. (2013). Associations between park characteristics and perceived restorativeness of small public urban green spaces. *Landscape and Urban Planning, 112*, 26–39. https://doi.org/10.1016/j.landurbplan.2012.12.013.

Rodríguez, A., Rey, B., & Alcañiz, M. (2013). Validation of a low-cost EEG device for mood induction studies. *Studies in Health Technology & Informatics, 191*, 43. https://doi.org/10.3233/978-1-61499-282-0-43.

Roe, J., Aspinall, P. A., & Ward Thompson, C. (2016). Understanding relationships between health, ethnicity, place and the role of urban green space in deprived urban communities. *International Journal of Environmental Research and Public Health, 13*(7), https://doi.org/10.3390/ijerph13070681.

San Juan, C., Subiza-Perez, M., & Vozmediano, L. (2017). Restoration and the city: The role of public urban squares. *Frontiers in Psychology, 8*, 2093. https://doi.org/10.3389/fpsyg.2017.02093.

Song, C., Ikei, H., Igarashi, M., Miwa, M., Takagaki, M., & Miyazaki, Y. (2014). Physiological and psychological responses of young males during spring-time walks in urban parks. *Journal of Physiological Anthropology, 33*, 8. https://doi.org/10.1186/1880-6805-33-8.

Song, C., Ikei, H., Igarashi, M., Takagaki, M., & Miyazaki, Y. (2015). Physiological and psychological effects of a walk in urban parks in fall. *International Journal of Environmental Research and Public Health, 12*(11), 14216–14228. https://doi.org/10.3390/ijerph121114216.

Song, C., Joung, D., Ikei, H., Igarashi, M., Aga, M., Park, B.-J., ... Miyazaki, Y. (2013). Physiological and psychological effects of walking on young males in urban parks in winter. *Journal of Physiological Anthropology, 32*, 18. https://doi.org/10.1186/1880-6805-32-18.

Statistical communique of the People's Republic of China on national economic and social development in (2017). 2017. Retrieved from http://www.stats.gov.cn/tjsj/zxfb/201802/t20180228_1585631.html.

Stigsdotter, U. K., Ekholm, O., Schipperijn, J., Toftager, M., Kamper-Jorgensen, F., & Randrup, T. B. (2010). Health promoting outdoor environments–associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scandinavian Journal of Public Health, 38*(4), 411–417. https://doi.org/10.1177/1403494810367468.

Stroop, J. R. (1992). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology General, 121*, 15–23. https://doi.org/10.1037/0096-3445.121.1.15.

Suh, Y. A., & Yim, M.-S. (2018). "High risk non-initiating insider" identification based on EEG analysis for enhancing nuclear security. *Annals of Nuclear Energy, 113*, 308–318. https://doi.org/10.1016/j.anucene.2017.11.030.

Taylor, A. F., & Kuo, F. E. (2009). Children with attention deficits concentrate better after walk in the park. *Journal of Attention Disorders, 12*(5), 402–409. https://doi.org/10.1177/1087054708323000.

Tilley, S., Neale, C., Patuano, A., & Cinderby, S. (2017). Older people's experiences of mobility and mood in an urban environment: A mixed methods approach using electroencephalography (eeg) and interviews. *International Journal of Environmental Research and Public Health, 14*(2), https://doi.org/10.3390/ijerph14020151.

Tombaugh, T. N. (2004). Trail making Test A and B: Normative data stratified by age and education. *Archives of Clinical Neuropsychology, 19*, 203–214. https://doi.org/10.1016/S0887-6177(03)00039-8.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*, 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7.

Van Den Berg, A. E., & Custers, M. H. (2011). Gardening promotes neuroendocrine and affective restoration from stress. *Journal of Health Psychology, 16*(1), 3–11. https://doi.org/10.1177/1359105310365577.

Vujcic, M., & Tomicevic-Dubljevic, J. (2018). Urban forest benefits to the younger population: The case study of the city of Belgrade, Serbia. *Forest Policy and Economics, 96*, 54–62. https://doi.org/10.1016/j.forpol.2018.08.006.

Wallner, P., Kundi, M., Arnberger, A., Eder, R., Allex, B., Weitensfelder, L., & Hutter, H. P. (2018). Reloading Pupils' Batteries: Impact of Green Spaces on Cognition and Wellbeing. *International Journal of Environmental Research and Public Health, 15*(6), https://doi.org/10.3390/ijerph15061205.

Wang, G., Innes, J. L., Dai, S., & He, G. (2010). Achieving sustainable rural development in Southern China: The contribution of bamboo forestry. *International Journal of Sustainable Development & World Ecology, 15*(5), 484–495. https://doi.org/10.3843/SusDev. 15.5:9.

Watts, G. (2017). The effects of "greening" urban areas on the perceptions of tranquillity. *Urban Forestry & Urban Greening, 26*, 11–17. https://doi.org/10.1016/j.ufug.2017.05.010.

Zhao, J., Xu, W., & Ye, L. (2018). Effects of auditory-visual combinations on perceived restorative potential of urban green space. *Applied Acoustics, 141*, 169–177. https://doi.org/10.1016/j.apacoust.2018.07.001.

Zou, B., Liu, Y., Guo, M., & Wang, Y. (2015). EEG-based assessment of stereoscopic 3D visual fatigue caused by vergence-accommodation conflict. *Journal of Display Technology, 11*(12), 1076–1083. https://doi.org/10.1109/jdt.2015.2451087.