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Perceived Sensory Dimensions of Green Areas: An Experimental Study on Stress Recovery

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Abstract: Natural environments have been shown to promote health, and are, therefore, important for achieving social sustainability in cities. As cities grow and become denser, it is important to develop knowledge about the characteristics of natural environments that work to promote health. Perceived Sensory Dimensions (PSDs) is a tool that defines eight different cultural ecosystem services. They correspond to different human needs (rest, exercise, socialising, pleasure, or security) resulting in rehabilitation and health and well-being promotion. An experiment was conducted to study the potential of PSDs to restore people who experienced stressful accidents. One hundred and fifty-seven participants were recruited and asked first to watch a film clip of serious accidents, then to look at the pictures, depicting one particular type of PSDs, while listening to its respective audio recording. Their stress levels were measured before exposure to the stressor (baseline), after exposure to the stressor (pre-test), and after exposure to a particular type of PSDs (post-test). The results show that all eight PSDs effectively provide mental recovery, but there are statistical differences in their potentials. As such, it is proposed that the combined potential of the PSDs is needed, and should be used to increase the capacity and supply of health-promoting urban green areas.

Keywords: evidence-based health design; perceived sensory dimensions; cultural ecosystem services; social sustainability; restorative state; public health; mental health; stress reduction

Citation: Memari, S.; Pazhouhanfar, M.; Grahn, P. Perceived Sensory Dimensions of Green Areas: An Experimental Study on Stress Recovery. *Sustainability* **2021**, *13*, 5419. https://doi.org/10.3390/su13105419

Academic Editors: Helena Nordh, Katinka H. Evensen and Åsa Gren

Received: 23 March 2021
Accepted: 5 May 2021
Published: 12 May 2021

1. Introduction

Growing demands are placed on cities to be built sustainably. So far, the focus has mostly been on the economic and environmental sustainability, but the discussion has increasingly begun to include social sustainability. Scholars argue that social sustainability must include the design of urban open spaces [1,2]. The design of the physical habitat should be combined with content that promotes and supports social life, cultural life, recreation, recovery, and physical activity. These places need to be physically and mentally accessible and include amenities (such as seating, rain protection, and toilets). According to Andersson et al. [3], the social sustainability of cities can be promoted by urban green areas that provide cultural ecosystem services, which include recreation, aesthetic pleasure, physical and mental health, and spiritual experiences—recovery for body and soul. These ecosystem services can promote both physical activity and rest in a restorative nature, which can counteract diseases and prolong life [4]. Research on restorative environments focuses on the physical and psychological benefits of being exposed to nature, claiming that the adverse consequences of a stressful lifestyle and inappropriate built housing environments can potentially be mitigated by opportunities for people to connect with nature [5].

Many long-term illnesses (e.g., depression, anxiety, burnout, and cardiovascular disease), as well as risk factors for many diseases (e.g., obesity, insomnia, and high blood

pressure) depend on an unhealthy lifestyle. This in turn is strongly associated with urbanisation and a stressful life without time and space for health promotive, recuperative activities [6,7]. Stress is when the body readies to face a perceived threat. These threats lead to reactions that have existed in humans for millions of years, and include fight, flight, or freezing reactions. In today's society, the threat may be the risk of failing to meet a deadline, which elevates stress levels, mobilising the body to work efficiently to finish the job on time. There are fundamental differences between long-term and short-term stress. If a person's everyday life feels out of control for a long time, but they must constantly remain active to meet threats, this long-term stress can lead to both physical and mental illness. The body needs recovery after both short-term and long-term stress, but recovery after long-term stress takes time and looks different than recovery after short-term stress [6,8,9].

Much of the research on nature's health-promoting ability has been about comparing built environments with natural environments. As evidence that natural environments have positive effects on health has accumulated, interest has increased in which specific qualities of nature are particularly health-promoting [10–12]. By utilising these environmental qualities, or cultural ecosystem services, urban green environments can be planned and designed to accommodate a restorative experience. Given the shortage of space in urban areas, and the costs of maintaining green areas, it is of fundamental importance to identify the most restorative natural qualities in the planning and design of urban environments. It is important to minimise the risk that governance and management of urban green areas leads to a limited supply of restorative qualities, when guidelines should strive to include different types of restorative qualities. Research is inconsistent regarding what qualities of urban green environments are most important for people to be able to recover from high stress levels. Some qualities have even been identified as adversely affecting psychological recovery. Accordingly, there is a need to explore the ability of different qualities to provide mental restoration, in order to develop an evidence-based health design [13].

1.1. Restorative Qualities

Recommended design solutions and guidelines for qualities can become very detailed and specific [14], and, thus, unmanageable. In evidence-based planning and design, a limited number of clear and validated quality criteria are needed, including the breadth of what urban green areas can offer. The qualities that in various research articles are reported to be health-promoting come mostly from top-down, i.e., theory-driven [15] research. Since the 1980s, two theories have been extensively cited to explain why natural environments are health-promoting. One is the Stress Reduction Theory, developed by Roger Ulrich [16]. The theory suggests that being in natural environments reduces high stress levels. A systematic review of research studies gives this theory some support regarding effects on psychological, and especially emotional stress-reducing effects, but the effects on the physiological stress levels are not clear [17]. The environmental qualities described by Appleton [18], Orians [19], and Balling and Falk [20] are proposed by Ulrich [16] to reduce stress. These theories are themselves theory-driven. They suggest that during the course of evolution humans have developed preferences for environments where they can more easily survive. Appleton [18] argues that people prefer to seek safe environments, where they can view the surroundings without being seen. The theories of Orians [19] and Balling and Falk [20] argue that humans have an inherited preference for relatively open savannah-like environments. People carry these preferences ever since humans developed in the savannah-like environment of Africa.

The second theory is Attention Restoration Theory [21]. It claims that people's ability to focus attention for longer periods is limited. Staying in natural areas can effectively provide recovery from a drained, fatigued directed attention capacity. This theory is to some extent supported by a systematic review of research studies [22]. According to the theory, natural environments supporting restoration from a fatigued directed attention capacity must meet the following conditions: (1) Being away: the area should offer a contrast to the everyday environment. (2) Fascination: the area offers objects and processes

that people find engrossing. (3) Extent: the area is large enough, and (4) Compatibility: the environment supports the activities one wishes to carry out [21]. New methods used in experimental studies on nature and stress have included brain imaging techniques. Recordings of human brain activity were made with mobile EEG headsets while people walked from a busy street into a green park and out again. The results showed brain patterns that indicate lower frustration and higher meditation when walking in a green area, as opposed to moving in busy commercial urban areas [23]. This offers support for the Attention Restoration Theory [21,24]. It proposes that one path to mental well-being supported by access to nature may depend on nature's ability to further a positive emotional attitude and, thus, promote meditation and resilient psychological resources. These effects, thus, mean that natural environments can act as a remedy for various negative effects of stress in everyday life, which aids people to better cope with demands when they arise and helps them to reduce stress levels that have already arisen [7,25].

Based on Kaplan's theory of the four restorative qualities, a measure was developed: Perceived Restorative Scale (PRS) [26]. This was improved by Pasini with colleagues regarding reliability and validity [27]. However, the four resulting validated qualities came to differ from the originals. "Being away" is, e.g., defined by: "Places like that are a refuge from nuisances", reminiscent of a quality highlighted by Ulrich [16]. "Fascination" is, e.g., defined by: "In places like this my attention is drawn to many interesting things". "Extent" is now termed "Scope", and is defined, for example, by: "That place is large enough to allow exploration in many directions", and "In places like that there are few boundaries to limit my possibility for moving about". "Compatibility" is now "Coherence", and is, e.g., defined with: "There is a clear order in the physical arrangement of places like this."

There are a number of studies based on the importance of high biodiversity in urban green areas, where quality of green areas depends upon perceived species richness and variety [28–31]. Some studies focus on qualities related to social activities in the urban green areas, and include amenities such as restaurants, kiosks, toilets, seating, streetlights, etc., or to privacy and security, where, for example, unleashed dogs, litter, and graffiti are not cause for concern (e.g., [32,33]). In addition, studies have investigated qualities related to perceived naturalness (e.g., [34,35]).

1.2. Perceived Sensory Dimensions

The above descriptions of human preferences and needs for different qualities in natural environments and urban green areas have mainly been based on theories. One problem with this focus is that it risks being directed at only one part of the area about which researchers seek knowledge. However, beginning in the mid-1980s, studies not based on any theoretical model, but completely bottom-up, began to consider how people experience and value natural and green areas [15]. Over the years, four comprehensive questionnaire studies have been conducted, each directed to several thousand people [28,36–38]. By means of several factor analyses, the number of qualities has been defined as eight. These quantitative studies have been supplemented by a number of qualitative studies and three full scale experimental case sites: Alnarp Rehabilitation Garden [39], Nacadia health garden [13], and Octovia Park [40]. In these parks and gardens, all PSDs have been used in the design, where some PSDs are more prominent in the design of specific parts. The eight PSDs are intended to meet different therapeutic needs, leading to all types of restorative experiences.

A number of translational studies have also been conducted [41], bringing research results from basic research and experimental case sites to everyday practice, including at the Public Health Agency of Sweden [42] and the Stockholm county council [43].

The eight qualities are experienced, situated, and embodied, and consist of visual, audial, and spatial qualities. They are, therefore, termed Perceived Sensory Dimensions, or PSDs [37,44]. They include qualities that are emphasised as restorative according to the Stress Reduction Theory [16]; Attention Restoration Theory [27]; biodiversity

theories (e.g., [30]); theories of social qualities (e.g., [32]); and naturalness (e.g., [35]). They, thus, cover a wide area.

Each of the PSDs is distinct, and can either occur alone in a green area or together with one or more other PSDs. Combinations of different PSDs can look different [7,45]. However, a comprehensive review of all PSD studies conducted since the 1980s showed that PSDs usually behave in a particular way, especially if one takes into account their clearest expressions. The names of the various PSDs in this article are from this extensive review [44]: Natural (a wild and pristine environment that does not seem to be created by humans, but on the contrary is perceived as spontaneously developed, on its own terms, over an extended period of time); Diverse (a sense of complexity and species richness in the environment, including spatial variations such as undulating ground, multilayer variation, and elements such as rocks and water features); Cohesive (the sense of spatial unity having the potential to contain and surround the individual, to provide an extended, cohesive space, possible to explore and wander around within, spacious); Open (a potentially mix-use open area, with grass surfaces, scattered trees and vistas); Sheltered (a safe haven, a sanctuary, relatively enclosed space, secluded, providing the ambience to relax or play); Social (presence of people, place for social activities including entertainment equipment and restaurants); Serene (a safe peaceful and calm place, with no disturbances like litter, graffiti or noise; offering tranquil natural sounds); and Cultural (cultivated and man-made surroundings combined with cultural elements such as fountains, flowers, and statues).

The study [44] was conducted as a comprehensive quantitative and qualitative review of research on PSDs since the 1980s. Several of the studies examined were performed using factor analysis. They showed that factors with high scores for wilderness and naturalness had low scores for cultural artefacts such as sculptures or landscaped flowerbeds. Similarly, there were factors with high scores for peace and quiet and clear negative scores for environments full of people, with outdoor cafes and music. Several factor analyses had oblique rotation, which for example showed that factors for naturalness correlated with factors for serenity. These quantitative studies are supported by qualitative studies of PSDs. The research shows that the eight PSDs are associated with each other according to Figure 1, and can be interpreted to represent different cultural ecosystem services. There are four axes of opposing qualities: (1) a Natural–Cultural axis, (2) a Cohesive–Diverse axis, (3) a Sheltered–Open axis, and (4) a Serene–Social axis. The right-hand PSDs in the figure are usually linked to the most urban parts, and can work well in small parks and green areas, while the left-hand PSDs in the figure are more often linked to the larger parks and nature reserves. The PSDs on the left side are also significantly more sensitive to various types of disturbances. Social refers to green areas that, for example, contain cafés or other meeting points; Cultural is about cultural artefacts such as flowerbeds, fountains, sculptures, etc. These two PSDs are often tied to the smallest areas, and the two qualities also support each other. On the opposite side is Natural, which refers to natural, spontaneously grown vegetation, while Serene refers to silence and serenity. These qualities are often associated with large areas, and the two PSDs also support each other. Cultural is close to Open, which refers to open spaces, often urban lawns. This openness, and exposure, can also be experienced in natural areas such as meadows or beaches. These open natural areas can be supported by, and correspond to Cohesive. This quality is about perceptions of coherence and unity. On the opposite side is Shelter, referring to a safe place where you can be at peace, undisturbed. This lack of exposure differs from its opposite, Open. Next to Shelter is Diverse, which refers to variety, species richness, and hilly areas, preferably next to watercourses. Each PSD above is supported by the two closest qualities. Social is supported, for example, by both cultural artefacts in Cultural, and by variety, species richness and garden ponds in Diverse.

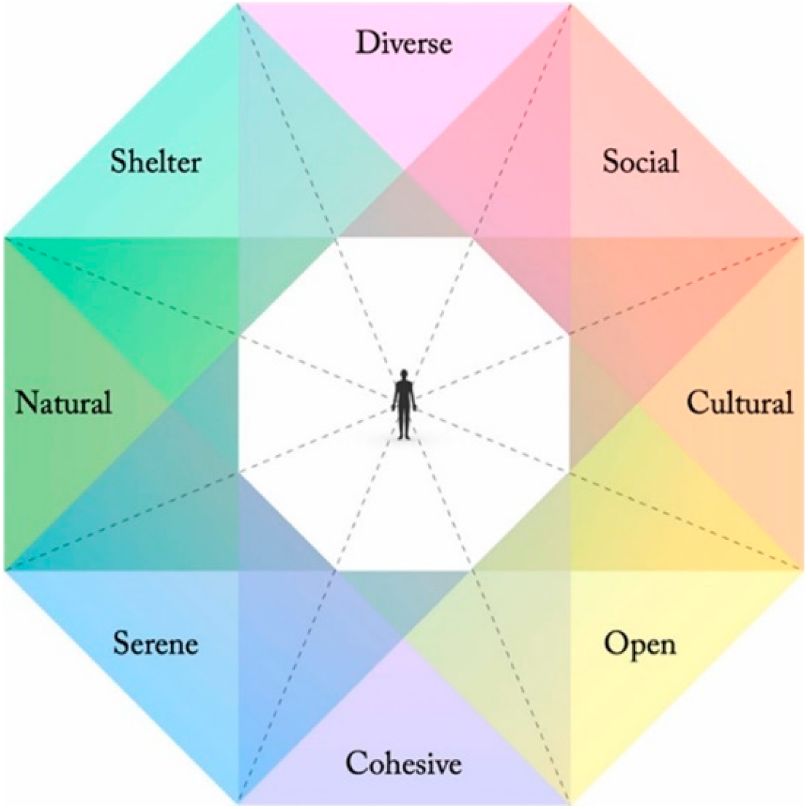


Figure 1. Perceived Sensory Dimensions (PSDs): eight complementary qualities in urban green areas in support of basic human needs. These PSDs can be interpreted to represent cultural ecosystem services [44].

Approximately one hundred studies with PSDs have been conducted in different parts of the world since 2010: for example, in China [46], Estonia [47], Canada [48], Denmark [49], Scandinavia [50], Iran [51], Malaysia [52], and Serbia [53]. These studies show that the PSDs are experienced similarly regardless of cultural context. The classification of the eight PSDs has been confirmed through Multiple Group Method [51], and the potential for using the PSDs as guidelines for designing health-promoting natural environments has been validated [45,54].

1.3. Questions and Aims

PSDs have become increasingly important, and more frequently applied by researchers as a methodological framework in various fields, not least in larger epidemiological studies in public health (e.g., [55]); in the design and planning process of green areas in health care environments [56] and public parks [45]; and when studying the green area preferences of stressed individuals [37,57].

As a result, some PSDs have been identified as most restorative. Reviewing the results reveals an inconsistency about the most restorative PSDs, with some PSDs even identified to affect stress restoration negatively. For instance, by measuring participants' long-term stress levels (Level of Stress, LS), Grahn and Stigsdotter [37] suggest that a combination of the three PSDs, Shelter, Natural, and Diverse, with little or no presence of Social, is the most restorative environment for stressed individuals. Another study, using the Perceived Restorativeness Scale (PRS) and analysing the eight PSDs of Small Public Urban Green Spaces (SPUGS), has revealed that Social and Serene were associated with perceived restorativeness in average people. However, Natural becomes important for the most stressed individuals [58].

A study of care environments, where the Short-version Revised Restoration Scale (SRRS) was used, found that a high presence of Serene, Natural, and Shelter, with little

or no presence of Diverse and Social, was most restorative [51]. Van den Bosch and colleagues [59] conducted a longitudinal epidemiological study of 25,000 people in Sweden. Public health data on mental health were the measures of outcome, and they found that Serene was the most important quality of the outdoor environment regarding support of mental health, especially in women. Vujcic and Tomicevic-Dubljevic [53] found in a study in Belgrade that Serene, Open, Shelter, Social, and Diverse support young people's opportunities to restore their function and capacities. Palsdottir and colleagues [57] found in a study that Serene, Natural, Open, Shelter, and Cohesive, with little or no presence of Social, were the most essential supporting qualities of a rehabilitation garden for people suffering from stress-related mental illness. In an epidemiological study by Björk and colleagues [55], the researchers found that if the residents had a good range of all PSDs in their neighbourhood, they experienced better neighbourhood satisfaction, devoted themselves more to physical activity, and had a lower BMI.

Through reviewing literature, it can be concluded that there are diverse and sometimes contradictory results around the restorative effect of the eight PSDs. This raises the question: Do all the eight PSDs provide some kind of restorative experience? In order to explore the restorative capacity of PSDs, this study aims to test the restorative potential of each PSD through conducting an experiment including pre-test and post-test. The following hypotheses have been formulated with the purpose of enriching the understanding of the impact of PSDs on psychological status regarding restorative state: (1) That all PSDs encompass the restorative potential to improve psychological status, and (2) There are distinct differences in effectiveness among eight PSDs in terms of psychological restoration.

2. Materials and Methods

2.1. Methodological Considerations

The object was to study which PSDs best enable recovery after a stressful event. The eight PSDs include several senses, such as sight, hearing, olfaction, balance, proprioception, temperature, distance calculations, etc. Therefore, it is best if studies can be done in real environments to investigate how a person reacts to different PSDs. However, in field studies, it is difficult to control for disturbances in the form of, for example, temperature, sound, and light conditions. In order to assess and carry out measurements of all subjects equally, it is, therefore, an advantage if the experimental situation can be standardised insofar as possible.

Photo-based studies have consequently been the dominant method in preference studies of both large-scale rural areas and green areas in urban environments. Several studies have been conducted to examine the reliability of photo-based studies, and the results are positive [31,60,61]. However, it is an advantage if the experimental situation can use the two distance senses, sight and hearing. Research has shown that hearing largely defines restorative environments [62–64], and studies show that the combination of sound and image probably provides more reliable results than pictures alone, when it comes to investigating how exposure to natural environments affects physiological changes in stress in subjects [65]. The combination of sound and image has also been used in similar studies [66]. For these reasons, we chose in this study to use pictures and sounds in combination that may represent different PSDs.

In similar studies [66], films have been chosen as stressors. After consultation with psychological experts, we acquired a film about accidents, which has proven to work well as stressor.

We chose a population, young adults at Golestan University, who at group level can be assumed not yet to be overly affected by various diseases. The experiment was conducted at Golestan University, Gorgan, Iran, during the latter part of the students' spring semester, April/May, and the data processing and writing of the manuscript was conducted during the autumn and winter of 2020/2021.

According to communication from the ethics committee at Golestan University, no ethical approval was required for this study because the participants were not in a depen-

dent relationship with the test leaders, no invasive procedures were performed, such as blood sampling, nor were any invasive or sensitive questions asked. However, to follow good ethical research standards, all participants were provided with informed consent in accordance with the WMA Declaration of Helsinki regarding ethical principles in research [67]. The participants were informed that they could end their participation in the study at any time without reason. Each participant was asked for their written consent to participate in the study, which was gained from all included participants. At the start of each session, the sequence of experimental procedures was explained to the participants briefly. Then, they were asked to give informed consent and told that they were free to leave at any time during the experiment. Subsequently, participants completed the first part of the questionnaire, which encompassed questions regarding gender, age, and field of study.

2.2. Participants

Participants were 157 university students (55 males, 88 females, 14 not indicated), ranging in age from 18 to 26 years (mean age: 21.2 years). Participation was voluntary and participants did not receive financial remuneration for their time. The study consisted of a laboratory experiment in which participants were recruited via announcements at the University of Golestan.

2.3. Stimulus Material

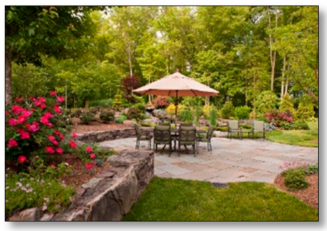
2.3.1. Video Clip as Stressor

In this type of study, videos showing accidents have been used as stressors with good results (e.g., [68,69]). According to Jiang and colleagues [70], the time in which showing a video as stressor results in physiological and psychological changes ranges from two to ten minutes. In this study, the five-minute video including suspenseful sequences depicting extremes of human emotion during an ominous roller-coaster accident was shown to be an affective stressor.

2.3.2. The Presentation of PSD Environments

The current research was conducted through a photo-questionnaire. The eight PSDs were employed to represent eight different natural settings to evaluate the potential of natural environments in stress restoration. The procedure for the selection of pictures follows a routine according to, among others, [71,72]. The first selection of pictures was performed by the first author based on the descriptions of the PSDs in the references. The selection was made after careful assessment and interpretation of the description of the eight PSDs. Hundreds of photos were taken in different green areas in and around Gorgan, and hundreds of additional photos were chosen from the Internet, since urban green areas in Gorgan lack clear examples of several PSDs. After rejecting a large number of pictures, 400 remained, 50 per PSD. The first and second authors performed a second sorting. Subsequently, 80 candidate pictures (8 to 12 photos per PSD) were sent to an expert panel deeply familiarised and experienced with PSDs. After an initial assessment, they requested more suitable pictures for the PSDs Social and Shelter. Finally, the panel ranked the four best pictures representing each of the eight PSDs. Table 1 represents a sample of photo assigned to each PSDs.

Table 1. Sample of photos for each PSDs.

PSDs	Sample of Photo	PSDs	Sample of Photo
Natural [1]		Cultural [73]	
Open [74]		Social [75]	
Cohesive [1]		Diverse [76]	
Shelter [77]		Serene [78]	

[1] Photo credit: author.

The chosen pictures were supplemented with appropriate and compatible audio recordings, selected by the first and second author. For example, the picture associated with Serene is accompanied by a natural sound of water and a soft breeze that makes gentle waves in the water surface.

2.3.3. Counterconditioning

Counterconditioning describe an intervention causing an undesirable feeling to not only disappear, but be replaced by a desirable feeling. Studies have shown that certain images or situations not only reduce fear, but replace fear with another desirable feeling. The image of a laughing baby has been used in such contexts [79].

2.4. Measures

The Restorative State Scale (RSS) is a self-assessment tool developed by van den Berg and colleagues [68] that has also been used in similar studies (e.g., [80]) with good results. RSS examines changes in restorations over time. The advantage of the instrument is that it does not focus on current objects in the environments. In addition, RSS includes both feelings of stress and the ability to think (see items in Table 2). In this study, the manual regarding the use of the standard version of the RSS scale has been followed, and the items in the instrument follow the order accordingly.

Table 2. The Restorative State Scale (RSS) [68]. Each of the items were rated on a scale from 1 to 7. Response options ranged from 1 = 'Do not feel at all', to 7 = 'Feel very strongly'.

Item	Phrasing
1	My mind is not invaded by stressful thoughts.
2	I can take time out from a busy life.
3	I can lose all sense of time.
4	I am thinking about everything and nothing at the same time.
5	I can make space to think about my problems.
6	I can leave all my problems behind me.
7	My mind just wanders in infinity.
8	I can imagine myself as part of the larger cyclical process of living.
9	I feel connected to the natural world.

Thus, it is suitable for capturing changes in psychological status that are consistent with the purpose of this study. The Persian version of RSS with nine items has been used, and has proven to be sufficiently reliable, with a Cronbach's alpha of 0.87. Response options ranged from 1 = 'Do not feel at all', to 7 = 'Feel very strongly'.

2.5. Procedure

Twenty sessions (including two or three fifteen-minute sessions for each presentation of the eight PSDs) were run with independent groups ranging from 2 to 16 members on a day at the university outside of the testing period. Therefore, academic examinations and the associated stress play no role in measuring baseline RSS.

Following baseline measure of participants' RSS (presented as T1 in this study), participants were exposed to an affective stressor. The stressor was followed by the measurement of RSS for the second time (presented as T2 in this study.) After randomly assigning all participants into eight groups, participants were instructed to watch a slide show presenting one of the PSDs, and imagine themselves in the depicted setting. In other words, each presentation showed one PSD. The eight PSDs required eight presentations and eight groups. Each group responded to only one presentation about a certain PSD.

Each group was exposed to a set of four sample photos presenting one of the PSDs with an appropriate sound. Each of the four photos was presented seriatim for 15 s while the associated sound was played. The last slide of presentation projected the four photos at once. The presentation was followed by the measurement of RSS for the third time (presented as T3 in this study), and, while participants responded to the questionnaire, the final slide was continuously projected. Then, participants were asked to give feedback and make suggestions. Finally, the video of a laughing baby was shown to ensure that all side effects from viewing the stressor were completely eliminated.

T1, T2, and T3 are separate and sequential steps whose order did not vary. First, the baseline measure of the participants' stress level, T1, was determined by asking the participants to respond to RSS, without stimuli, prior to stressor exposure. Therefore, the result at T1 is considered the stress level at the baseline. In the next step, T2, participants were exposed to the stressor and then responded to the RSS for the second time. In step three, T3, participants were exposed to the PSDs, visually and audibly, and then responded to RSS for the third time. Since it is a controlled experiment, T1, T2, and T3 were performed consecutively on the same day. By doing this, it can be argued that the recovery from the stress response was caused by audio/visual exposure to the experiment's stimuli (images and sounds related to different PSDs).

2.6. Statistical Analysis

As the eight groups tested in this experimental study were independent, comparison of the groups required verification that no noticeable difference existed in participants' baseline stress levels between the eight different groups. Thus, this study used One-way

ANOVA analysis of variance to compare the means of the eight independent groups in order to determine whether any difference between the associated population means was statistically significant. Homogeneity of variance was investigated through Levene's test.

Moreover, this study analysed the data from Repeated Measures experiments considering three conditions (T1, T2, T3) and eight groups (Natural, Cultural, Open, Social, Cohesive, Diverse, Shelter, Serene). In so doing, the null hypothesis was investigated with Mauchly's Test of Sphericity, and the Box's M value, to see whether the variances of the differences are equal for the purposes of the Repeated Measures. Finally, tests of Within-Subjects Effects and Between-Subjects Effect were used to prove the significant difference between the means of different conditions in each group, and significant RSS differences among the eight groups, respectively

3. Results

3.1. Descriptive Statistics

Table 3 presents the descriptive statistics, including three sets of scores (Mean, Standard deviation, Number). Exploring the descriptive statistics table shows that the mean values make sense, given the scale that was used. In all eight groups, the stressor leads to reduction in RSS among respondents, and view nature scenes has a positive effect, improving restorative state as measured by RSS. Therefore, the reported mean of RSS attributed to T3 is higher than the reported mean of RSS attributed to T2, and even T1 as baseline, in all eight groups due to the restorative effect of PSDs.

Table 3. Descriptive Statistics: Unadjusted means and standard deviations for outcome measures by group and condition of measurement.

Mean of Restorative State (1–7)	Marginal Means1	Baseline T1	Pre-Test T2	Post-Test T3	N
Natural	4.50 (0.083)	4.29 (0.66)	3.40 (0.39)	5.29 (0.50)	18
Serene	4.32 (0.081)	4.33 (0.79)	3.47 (0.37)	5.15 (0.52)	19
Diverse	4.06 (0.079)	4.43 (0.56)	3.62 (0.46)	4.52 (0.89)	20
Open	3.96 (0.083)	4.18 (0.74)	3.21 (0.41)	4.63 (0.56)	18
Shelter	3.94 (0.079)	4.32 (0.68)	3.37 (0.30)	4.48 (0.70)	20
Cohesive	4.08 (0.082)	4.09 (0.43)	3.33 (0.45)	4.73 (0.64)	19
Cultural	4.14 (0.075)	4.53 (0.72)	3.42 (0.26)	4.90 (0.64)	22
Social	4.12 (.077)	4.57 (0.66)	3.42 (0.33)	4.88 (0.60)	21

Covariates are evaluated at the following values: RSS.BASE = 4.3560.

According to Table 3, the highest RSS value in each PSD group is that of T3, which indicates the value of the restorative state after participants have viewed PSD photos. The lowest RSS value in each PSD group, on the other hand, is specified for the restorative state after viewing the video clips of the accidents, defined as T2.

3.2. One-Way ANOVA

Levene's test revealed that the homogeneity of variances is not violated, and there is not a statistically significant difference between groups after analysing one-way ANOVA. $F(7149) = 1.205$, $p = 0.304$. Consequently, there is no noticeable difference in the participants' baseline stress levels between the eight different groups that can affect the results. Thus, the eight independent groups are comparable.

3.3. Repeated Measures

Mauchly's Test of Sphericity has indicated that the assumption of sphericity is violated, $\chi 2(2) = 4.185$, $p = 0.123$. The null hypothesis is not rejected. Therefore, the variances of the differences are equal.

The Box's M value of 57.61 was associated with a p value of 0.106, $p < 0.005$, which is interpreted as non-significant [81]. Therefore, the covariance matrices among eight groups are

assumed to be equal for the purposes of the Repeated Measures. Consequently, although the groups were independent, it is possible to compare them with each other. In addition, Levene's test indicated equal variances of dependent variable (Restorative State) among eight groups for T2 (pre-test, F = 1.571, p = 0.148), and T3 (post-test, F = 1.095, p = 0.369).

3.3.1. Within-Subject Main Effects and Interactions

The results regarding Tests of Within-Subjects Effects revealed that there is an overall significant difference between the means of the different conditions as main effect, F(1, 148) = 4.462, p = 0.036, ηp2 = 0.029. It can be concluded that there is a statistically significant effect for two conditions (pre-test T2, and post-test T3) in this study. The results indicated that there is a significant change in RSS values between two conditions (T2 and T3). Moreover, the effect of the two-way interaction of group and condition is significant, F(7, 148) = 2.165, p = 0.040, ηp2 = 0.093. Results indicated that not only two different conditions, but also the interaction effect between conditions and groups, influences the RSS values.

In this study, the effect size that is identified as partial eta-squared for condition is 0.029. According to the commonly used guidelines (0.01 = small effect, 0.06 = moderate effect, 0.14 = large effect) proposed by Cohen [82], this result suggests an approximately small effect. The eta squared value for interaction between conditions (T2 and T3) and groups (PSDs) is 0.093, which is interpreted as a moderate effect size. Taking into account the effect size of condition and interaction between condition and group, the interaction influences the restorative state much more than the condition type as a within-subjects factor.

3.3.2. Between-Subjects Effect

The between-groups test indicated that there are significant differences in the RSS among the eight groups, F(7, 148) = 5.311, p = 0.000, ηp2 = 0.201. In fact, the eight independent groups are different in terms of RSS value in the different conditions of T2 and T3. Consequently, in the graph (Figure 2) the lines are not parallel and rather far apart. Moreover, the partial eta-squared value of the between-subject effect for groups in this study is 0.201, a very large effect. The differences in restorative impacts measured as RSS value among the eight natural settings reflect the different restorative impacts of PSDs. However, the function of a common (visual) trigger of restoration is inherent to all these natural stimuli and settings. Therefore, based on the findings, it can be concluded that although some PSDs provide greater recovery from stress, all PSDs include properties that improve the psychological state. It means that the eight PSDs should be considered as a whole, important for improving various parts of public health.

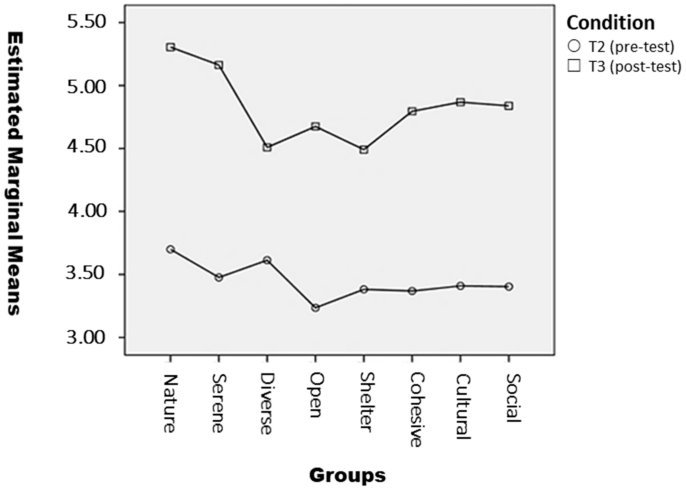


Figure 2. Estimated means of restorative state values in two conditions and among eight groups.

4. Discussion and Conclusions

In this study, the results indicated that all PSDs are restorative, but the eight PSDs showed clear differences in the intensity of their restorative effects. The results show that Natural and Serene have the greatest restorative effect. Memari and colleagues [51] also showed that Natural and Serene had the greatest restorative effect. Similarly, other studies show that Natural and Serene have powerful restorative effects [37,56]. These PSDs are, therefore, in high demand by stressed city dwellers, and this is especially true of Serene [37,64].

The importance of Serene is demonstrated not least by van den Bosch and colleagues [59], who showed that if people move to urban areas with high levels of Serene, it can prevent the development of mental illness. PSD Serene is characterised not least by its ability to make people feel safe. Stress levels drop rapidly in connection with experiencing an area as safe [6,7]. The security created by the character Serene depends on a number of things, such as good maintenance of urban green areas and the absence of disturbing noise. Herzog and colleagues [83] also showed that the degree of maintenance had a significant impact on an area's restoration properties. Yet Serene is not just about the absence of noise, but there should be soothing, calm sounds [64]. This PSD is, therefore, extremely sensitive to disturbances, but important for the city's green structure's health-promoting function [84].

A study by Weimann and colleagues [85] showed that perceived safety is a basic prerequisite for associating the PSDs with the use of green areas. People with long-term stress-related mental illness, such as burnout and depression, were rehabilitated in the Swedish University of Agricultural Sciences' experimental Alnarp Rehabilitation Garden. The garden of just under two hectares is designed with a number of garden rooms that together offer all eight PSDs [57]. Initial demand was highest for Serene and Shelter, followed by Natural, and varied towards the end of the rehabilitation to include all PSDs. The studies showed that it took time for participants with stress-related mental illness to find security in the rehabilitation garden, and to use all the PSDs [39,86,87].

4.1. The Supportive Environment Theory as a Framework for PSDs

There seems to be a fundamental need for green areas that convey an impression of safety and security, values linked to Serene and Shelter. With regard to the other PSDs, as reported in the introduction, studies disagree regarding which PSDs are most restorative. In general, regarding sufferers from long-term or severe stress, such as those with stress-related mental illness, Natural, Shelter, Serene, and Cohesive appear to be restorative while Cultural, Open, and Social are not regarded as restorative, and Social in some studies even is assumed to have a negative impact on stress [37,51,56,57]. If, on the other hand, the studies are aimed at the general population or at young people, Social and Cultural are proposed to be restorative, with some studies also highlighting these PSDs as the most restorative [53,58]. This study involved healthy young people acutely exposed to a stressful event, and many PSDs appear to have worked restoratively.

The Supportive Environment Theory (SET) states that specific qualities of green environments are supportive of psychological restoration [7,39]. These qualities correspond to different human needs for support, including the needs for rest, exercise, socialising, or pleasure. SET explains the relationships among the individual's mental strength, the need for supportive environments, and the PSDs [39]. This theoretical framework has been suggested as a cornerstone for the evaluation and design of green areas [45,56].

The relationship between the need for support and mental strength is usually illustrated as a hierarchy of needs (see Figure 3). The X-axis illustrates the need for support, while the Y-axis illustrates the person's mental strength. The figure also includes four levels, which reflect the needs for support the person experiences [7]. This model has been tested and developed in several studies, for example, at the Alnarp rehabilitation garden, in which participants were severely stressed or ill [57,87].

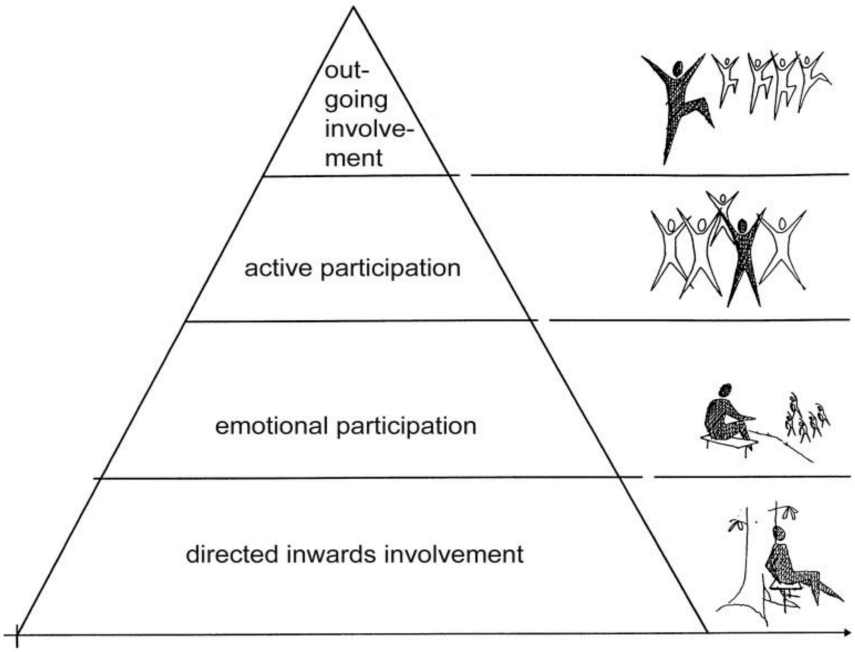


Figure 3. The model of supportive environments (SET): It explains the relationships among the individual's mental Scheme [56]. In this tool, the Y-axis, in addition to indicating the participants' mental strength, also describes the degree of challenges that participants can cope with or need. The Y-axis is then called the "Gradient of challenge". The lowest level of the hierarchy of needs, directed inwards involvement, was proposed to reflect the needs of Serene, Natural, and Shelter. The next level, emotional participation, was proposed to reflect the needs of Cohesive and Diverse. The third level was proposed to reflect the needs of Open and Cultural, while the top level, outgoing involvement, was proposed to reflect the needs of Social. The more sensitive the user group, the greater the impact the environment has on its health and well-being. Depending on the user group's characteristics related to gender, age, disability, mood, interests, etc., different PSDs along the challenge gradient will be most crucial.

After a review of studies with different types of users, Bengtsson [88] found that the need for green areas with Social, Cultural, and Open could sometimes be great in nursing homes. This applied to users who may have a physical disability, but remain mentally alert. They often felt isolated and desired social contact, attractive natural scenery, and cultural-historical experiences. Ulrich [89] also describes the sensitivity, stress, and needs of long-term and short-term patients. Ulrich claims that stress in short-term patients emanates from anxiety related to acute illness. They suffer from too much social contact, are overstimulated, and need to feel seclusion as well as peace and quiet. This contrasts to the tedium and lack of stimulation and social interaction that cause stress and depression in people with chronic illnesses who undergo long-term hospital stays, e.g., in nursing homes [89]. Bengtsson [88], therefore, suggested that the pyramid of needs in such cases should be reversed. However, a study in the Alnarp rehabilitation garden, where participants suffered from long-term stress-related illness, showed that some participants, even at the beginning of the rehabilitation, sometimes looked for environments with the PSDs Social and Cultural. They sought out these social environments to de-stress following difficult and stressful conversations with a psychotherapist [90].

4.2. Using the Restorative Potential of all Eight PSDs

As the results of this study confirm, all eight PSDs have a restorative potential. Their capacity differs statistically. We interpret this difference as a reflection of each PDS's independent and unique effect on the restoration process. Studies also show that all these PSDs are perceived distinctly [37,38,51]. Like many other studies, this study suggests that Serene and Natural have good restorative effects. The restorative capacity of the other PSDs should,

however, not be underestimated. The review in the introduction suggests that all PSDs are needed. Among other effects, studies show that a good supply of all PSDs is correlated with better neighbourhood satisfaction among residents [55,84], engagement in physical activity, and lower BMI [55].

The needs of the study population for psychological restoration at our disposal may vary across PSDs. When we interpret the results in relation to other studies, we find the following: Serene and Shelter seem to be fundamental PSDs that provide security and, together with Natural, they are most effective in aiding recovery from high stress levels. Cohesive, Diverse, and Open are PSDs that can be related to theories of restorative qualities, put forward by, e.g., Pasini et al. [27], Dallimer et al. [30], and Ulrich [16], respectively. However, these PSDs are not unequivocally linked to stress recovery. Open can be experienced as demanding, as Memari et al. [51] have shown. Stigsdotter et al. [40] suggest that Open and Cohesive have some social properties, related to being active. Studies also show that these qualities are important for perceived well-being in residential areas, and for physical activity [55,84], and possess important qualities linked to rather large parks [91]. Social and Culture seem to be important for those who seek urban social life and energy, design, historical artefacts, etc. These factors are especially important for the health and well-being of those who feel isolated [88].

It can be misleading to nominate the most restorative and health-promoting qualities of green areas, based on studies of people with severe stress-related mental problems. Some qualities will be highlighted, while others are diminished in importance or completely ignored. The densification of cities, coupled with the high maintenance costs of green spaces, may accelerate the creation of some PSDs, but PSDs requiring abundant space or sensitivity, such as Cohesive and Natural, do not receive the attention they deserve.

Studies in, e.g., China and Russia show a large shortage of green areas containing PSDs Serene, Natural, and Shelter, and a surplus of green areas with PSDs Social, Cultural, and especially Open [92]. In Figure 1, Serene, Natural, and Shelter are shown at left, while Social, Cultural, and Open are shown opposite right. There is, thus, a surplus of the three most urban PSDs, often linked to the smallest green areas. It is also possible that larger green areas are designed to contain, for example, the PSD Open, of which there is the largest surplus. In that case, we suggest that some of these large green areas with large lawns should be redesigned to contain PSDs Serene, Natural, and Shelter.

In fact, the great need for restorative qualities such as Shelter, Natural and Serene in urban environments may be due to urban lifestyle demanding for diligence and perfection. In addition, urban dwellers are flooded with information and impressions that give a supersaturation they have difficulties coping with. People who do not actively participate in city life, including residents of retirement homes, or those who live in smaller cities and communities, may instead need cultural stimulation, and a social atmosphere in urban parks and green spaces, to feel well.

The qualities Serene and Shelter are the PSDs most strongly associated with perceived security. Both PSDs are located in the left-hand part of Figure 1, and are linked to large green areas. However, an important part of PSD Shelter is that people do not feel exposed, in contrast to PSD Open. An important part of PSD Serene is that the relevant area is well maintained and cleaned, without weeds, litter, or graffiti. These aspects of the two PSDs may well be found in smaller green areas with fairly simple design interventions and a higher degree of care and maintenance.

The eight PSDs should be considered important as a whole for improving various parts of public health. Implementing physical characteristics of all PSDs in urban green spaces can consequently be a feasible way to satisfy the varied demands of citizens for restoration and improvement of wellbeing and quality of life. A great need for urban green areas of differing qualities, recreational opportunities, recovery, and well-being has been demonstrated, not least during the COVID-19 pandemic.

4.3. Limitation

There are several limitations to the current study. First, we used a study based on photos supplemented with sound environments. Photo-based studies have been the dominant method in environmental psychological preference studies of green areas in the city as well as in the countryside. This offers many advantages, in that the studies can be carried out under controlled conditions. One disadvantage is that the eight PSDs stimulate such other senses such as balance, temperature, proprioception, etc. However, as far as we know, no study has shown the inappropriateness of using photo-based methods as a substitute for site-based ones [31,60,61]. In this study, we have also supplemented the photo study with sound environments, which provide another aspect that strengthens the environmental perception [62,65]. One PSD that may be particularly difficult to study in this type of image-sound study is Shelter. It has been highlighted as a very important stress-reducing PSD in studies of therapy gardens (e.g., [57]). One of the most important features of this PSD is that people can seek out places where they can feel safely surrounded by vegetation, and can have control over the surroundings. This feeling is a whole-body quality. Possibly, this experience can be created by Virtual Reality (VR) or Augmented Reality (AR). However, given that PSDs involve so many senses, we suggest that this study be supplemented with a site-based study, VR, or AR to investigate the difference in restorative potential between different PSDs.

Second, we have used one validated instrument to measure stress recovery, the Restorative State Scale (RSS). We found that RSS worked well, as it is comprehensive and does not focus on stress or directed attention fatigue, nor does it focus on the characteristics of the green areas currently being evaluated. In a future study, however, we suggest that this instrument be supplemented with other self-assessment instruments and physiological measurements of, for example, heart rate, blood pressure, HRV, and salivary cortisol.

Third, our study population was homogeneous in terms of, for example, age (18–26 years) and education. We sought to examine this population as a contrast to the many studies that focused on nursing homes, hospitals, the elderly, and those affected by various types of illness and disorders, such as stress-related illness. However, future studies should include a study population with a broader background, e.g., in terms of age and socioeconomics. This kind of research is needed to explore the benefits of PSD in a broader public health perspective not limited to, but of course including, certain types of ill-health such as high levels of stress. This can lead to an increased understanding of the restorative potential of different PSDs.

Author Contributions: Conceptualization, S.M., M.P. and P.G.; methodology, S.M., M.P. and P.G.; software, S.M.; validation, M.P. and P.G.; formal analysis, P.G.; investigation, S.M. and M.P.; resources, S.M., M.P. and P.G.; data curation, S.M.; writing—original draft preparation, S.M.; writing—review and editing, M.P., P.G.; supervision, M.P., P.G.; project administration, S.M.; funding acquisition, P.G. All authors have read and agreed to the published version of the manuscript.

Funding: Part of this study has been funded by the FORMAS Research Council; the project 'Sustainable outdoor living environments—systematic interdisciplinary studies of health effects and impact on social inequalities' (D-nr 2019-01916) and the NORDGREEN: Smart Planning for Healthy and Green Nordic Cities project (ID-nr 95322), which is funded by NordForsk, an organisation under the Nordic Council of Ministers that provides funding for and facilitates Nordic cooperation on research and research infrastructure.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to thank the expert group who donate time to select the images attributed to eight PSDs, which included Frederik Tauchnitz, Nina Oher, and Anna Bengtsson, working with evidence-based health design at the Swedish University of Agricultural Sciences,

Alnarp, Sweden. This article has been inspired from first author's master's thesis in architecture, entitled "Design of Healing Garden Approach Stress Restoration through Nature Based Therapy (NBT)", completed at the Department of Engineering, Faculty of Architecture, Golestan University.

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

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