A socio-ecological approach to investigate the perception of green walls in cities: A comparative analysis of case studies in Turin and Lisbon

Nature-Based Solutions 6 (2024) 100175

Contents lists available at ScienceDirect

Nature-Based Solutions

journal homepage: www.elsevier.com/locate/nbsj

A socio-ecological approach to investigate the perception of green walls in cities: A comparative analysis of case studies in Turin and Lisbon

Matilde Molari [a,*], Laura Dominici [a], Maria Manso [b], Cristina Matos Silva [c], Elena Comino [a]

[a] Department of Environment, Land and Infrastructure Engineering (DIATI), Politecnico di Torino, 10129, Turin, Italy
[b] Department of Civil Engineering, Universidade Lusófona—Centro Universitário de Lisboa, 1749-024, Lisbon, Portugal
[c] Department of Civil Engineering, Architecture and Georesources Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisbon, Portugal

ARTICLE INFO

Keywords:
Living wall systems
Perceived Restorativeness Scale
Socio-ecological benefits
Urban ecology
Biophilic design

ABSTRACT

New urban greening practices are increasingly adopted to contrast and mitigate critical issues of urban areas. These strategies involve *nature-inspired* solutions to increase sustainability and restore natural processes in cities. In this framework, green walls play a pivotal role to reintroduce nature and provide both environmental and socio-cultural benefits in high densely cities. Despite green walls contribute to increase the aesthetic value of buildings and people's consideration of the area, methodologies to effectively assess their social benefits are still lacking.

This study proposes a place-based approach to investigate the Restorative capacity of two outdoor green walls: a modular living walls system covering two facades of a public university building in Turin (Italy) and a plastic planter boxes based living wall located in an inner courtyard of a cultural centre in Lisbon (Portugal). Firstly, the two living walls were characterised through direct observation considering technical, spatial, and social aspects that influence the fruition and the biophilic perception of these public spaces. Then, a self-rating questionnaire based on the Perceived Restorativeness Scale model was given on-site to participants to investigate the influence of green walls on people's cognitive perception and well-being. The novel Green Wall Perceived Restorativeness Scale consists of 17 items that evaluate individuals' perceptions of green walls, emphasising their attractiveness, integrative role in the environment and contribution to the overall appeal and comfort of space. Similar results between sites suggest that common features such as development at maximum building height, symmetrical disposition, element repetition and plant variety are drivers of citizens perception of green walls. Outcomes support the recognised link between citizens aesthetic appreciation of green walls and their perceived sense of comfort and mental relief, related to the Being away factor. The spontaneous social gathering and citizens resting near both green walls creates evidence of the attractiveness of this nature-based solution as a landmark in the urban environment. These conclusions demonstrate the pivotal role of urban biophilic design to combine natural and artificial elements in architectural and landscape design creating an opportunity to increase the use of green walls to contribute to citizens well-being in urban settings.

1. Introduction

The increasing urbanisation trend causes environmental and social concerns that are compromising human well-being and challenging the sustainability of cities. New urban greening concepts are being developed to mitigate these problems through sustainable and *nature-inspired* strategies [18]. The use of these solutions can contribute to re-introduce nature into daily urban life, recreating a lost connection with natural elements which is increasingly affecting citizens physical and psychological well-being [15]. Defined as nature-based solutions, these technologies show a very diverse range of typologies with the common characteristics to "address societal challenges such as climate change, disaster risks, food and water security, and human health by protecting, sustainably managing or restoring natural ecosystems" [21,36]. As a typology of nature-based solutions, green walls are assuming a crucial role in the design, construction and renovation of buildings or neighbourhoods, contributing to the definition of a new concept of urban green areas. Green walls are vertical structures that support vegetation, and they can be categorised according to their components and their support system into green facades and living wall systems [48]. Green

* Corresponding author at: Politecnico di Torino, corso Duca degli Abruzzi, 24, 10129, Turin, Italy.
E-mail address: matilde.molari@polito.it (M. Molari).

https://doi.org/10.1016/j.nbsj.2024.100175
Received 22 December 2023; Received in revised form 29 July 2024; Accepted 26 August 2024
Available online 18 September 2024

facades include climbing plants growing directly on the wall or indirectly using a support system [91]. In the past, green facades with climbing plants were popular in the Mediterranean region and Central Europe [41]. Instead, living walls are more complex systems that assure uniform vegetation covering but they require frequent irrigation and supply of nutrients [26,27]. Living wall systems are composed of a supporting structure that contains the growing medium and they are subdivided into modular or continuous systems [67]. As a part of nature-based solutions, green walls are multifunctional alternative infrastructures that can simultaneously provide multi-dimensional environmental and social benefits [22]. As stated by numerous academic works, they can support the recovery of ecosystemic processes such as regulating, provisioning and cultural ecosystem services [72]. They can improve air quality [30,40,69,85], increase urban biodiversity [45,71,83], absorb traffic and urban noise [59,77], ameliorate the urban microclimate [14,73] and improve the psychological well-being and social relationships of citizens [4,13,57]. Nowadays green walls can be considered as crucial tools for the application of a regenerative design in cities [52].

Many studies focus on green walls benefits at the building and neighbourhood scale related to regulating ecosystem services [12,64,96]. Anyway, in the framework of high densely cities, green walls are considered as flexible nature-based solutions that enhance the increasingly large vertical surfaces of buildings [19,86]. Moreover, in the last ten years the interest on green walls ability to support cultural ecosystem services has been growing [10,42,58]. Thanks to the worldwide endeavour towards the green and sustainable transition of urban environments [1,29,79], the liveability of cities and the health and well-being of their inhabitants is now globally considered a matter of urgent concern for an efficient systemic transformation [24,78]. In this framework, the biophilic perspective adopts a more holistic approach to the design and management of urban spaces using nature and vegetations as instruments to increase psychological benefits of citizens [7]. Through these types of applications, the daily interaction with natural elements and processes are recognised in their effectiveness for human well-being and consciously introduced in urban design. Due to the difficulty of assessing intangible benefits offered by green infrastructure, i.e. psychological well-being, monitoring and quantification of social impacts of green walls is still an innovative research field [12]. Indeed, green walls are technological greenery and they cannot be compared as traditional interventions of urban greenery such as parks [20], thus their impacts on people's perception require specific investigation in order to guide a more efficient biophilic design. For instance, as demonstrated by Anderson et al. [2] and Dai et al. [16], the social and community acceptance is essential for implementing successful and effective NBSs.

Increasing academic studies performed in the last ten years focus on people's perceived well-being from direct or indirect interactions with green walls. In many cases, the target people analysed are homogeneous categories, such as university students, schoolchildren and patients of clinics and hospitals [65,88]. Some studies focus on the quantitative assessment of stress reduction by monitoring biometric parameters such as heart rate, blood pressure and salivary alpha-amylase to evaluate the health status of participants [25,74,93,95]. While others investigate the perceived well-being qualitatively, through questionnaires or face-to-face interviews [28,31,54,81,89]. In this case, qualitative indicators such as pleasantness, liveability, perceived mental relief, sense of connection with nature, sense of place are taken into account to assess the perceived well-being of participants while interacting with vegetation. Magliocco & Perini [46] highlight the importance of people's aesthetic appreciation in the process of acceptance and affiliation with green wall systems and applications. While Petra et al. (2022) demonstrated how a person's visual perception of green wall biodiversity increases its aesthetic appreciation and sense of pleasantness. Lotfi et al. [44] and Timm et al. [84] propose to use a qualitative method via questionnaire to quantify psycho-physiological benefits using the Perceived Restorativeness Scale (PRS), a well-established method in the field of social and natural sciences to detect the sense of comfort and mental relief deriving from the fruition of a specific context. As stated by Ziesel [97], the direct experience of a natural environment can be evaluated as behavioural information and the importance to assess psychological effects of the direct experience of green infrastructures is confirmed by the increasing number of studies [43,51,94]. The PRS can be adopted as self-rating tool based on a semi-qualitative scale, i.e. Likert scale, to investigate people's perception about green walls in a real environment, providing crucial information to assess their social benefits in order to improve the design of nature-based solutions [32,56].

Given the significant research gap in assessing the social benefits of green infrastructures [9], this study focuses on the Perceived Restorativeness of green walls as a crucial element in biophilic and sustainable urban transformations.

This research adopts a socio-ecological assessment approach to:

- investigate the Perceived Restorativeness of green walls, evaluating how green walls in urban spaces contribute to individuals' perceptions of Restorativeness and well-being;
- analyse and compare data on Perceived Restorativeness from two urban settings with green walls: one in Turin (Italy) and one in Lisbon (Portugal);
- based on citizen perceptions, determine which design and spatial features of green walls influence the perception of Restorative capacity;

The present study aims to:

- enhance understanding of how integrating the socio-ecological dimension in urban design can promote biophilic approaches for resilient cities;
- propose a new methodology for evaluating the social benefits offered by green walls, aiming to: (1) support the spread of *evidence-based* biophilic design and (2) include psychological benefits in the impact assessment of green walls and other nature-based solutions.

2. Materials and Methods

This study was performed through a mixed method consisting of on-site inspections based on naturalistic observation [11] and survey investigation (Fig. 1). This place-based approach has been applied to understand people's behaviours, patterns of urban life and socio-ecological relationships [55,103] between people and green walls in two selected sites in Turin (Italy) and Lisbon (Portugal) (Fig. 2). To identify the perceptions of participants in relation to the living walls of

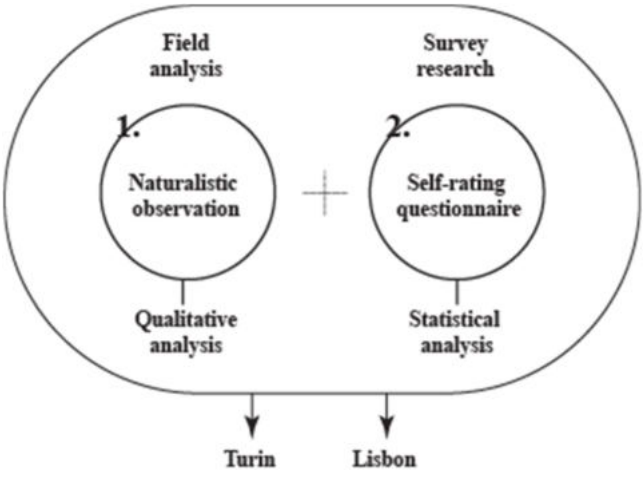

Fig. 1. Methodological scheme.

Fig. 2. The front face of the Complesso Aldo Moro (left) and the Centro Cultural de Belem (right).

the two sites, a questionnaire has been constructed following the model of the Perceived Restorative Scale (PRS), which has been used extensively to understand if physical environments - natural, urban or rural - would likely result in Restorative capacity [8]. Proposed by Hartig et al. [33], this tool is based on the principles of the Attention Restoration Theory [38], presenting scientific reliability that poses it as a significant tool in the detection of complex psycho-physiological constructs related to well-being. Moreover, the PRS has been refined over time through empirical evidence (Table 1), leading to the development of various versions of the scale according to the investigated environment and target of respondents [33,44,47,61,98,102,104] modified according to targets and locations, adding, compacting or eliminating elements. Through self-rating assessments, PRS allows to define in a quali-quantitative way the sense of relief and restoration perceived by a person in response to a specific environment.

The integration of naturalistic observation to the self-rating questionnaires aimed to counterbalance the occurrence of the agreement bias in participants' answers through the detection of visible information of the socio-ecological relationship between people and green walls in the urban space. Furthermore, socio-demographic data and contextual information have been included into the questionnaire to investigate the target of respondents and interpret their responses [105]. Site inspections and questionnaire distribution were organised in Turin and Lisbon between November 2022 and May 2023. The data collected were analysed and validated using statistical analysis, following the method applied by other recent studies on PRS [75].

2.1. Sites description

The Complesso Aldo Moro (CAM) was the selected site in Turin, it is a building complex that hosts offices, student spaces, university residences and commercial activities. The CAM is located within the historic centre of the city, close to the main building of the Department of Foreign Languages, Literatures and Modern Cultures of the University of Turin and to some of the most famous architectural landmarks of the city. This is a strategic area with several university sites where students usually gather. The building complex is the result of the redevelopment plan of the university area whose purpose was to create an urban campus model in which university buildings become open structures, integrated and spread throughout the city fabric. An internal courtyard in between of the buildings was integrated for the organisation of cultural events and meeting occasions. In the CAM, two living walls have been placed on the facades of the two main buildings of the complex that create the entrance of the open courtyard (Fig. 3). The two living walls are made of a modular system based on non-woven fabric pockets filled with growing medium. Both measure around 144 m^2 and show a great number of plants and plant species.

The placement of these two green walls can be related to two different topics largely developed in urban renewal projects. From one hand, the intervention deals with the insertion of green infrastructures in educational institutions, conceived to improve the physical and cognitive health of students and workers [53]. On the other hand, the intervention deals with the renovation of urban areas, planning the insertion of green infrastructure as a valuable element for urban liveability [17].

The selected site in Lisbon is the Centro Cultural de Belém (CCB), a cultural centre located in the neighbourhood of Belém, western Lisbon. This parish is famous for its cultural heritage as it is home of many of the most important Portuguese monuments at city and national level. The CCB hosts: a conference centre and commercial activities, two auditoriums and four galleries for exhibitions. In its inner courtyard, two living walls, easily visible from the entrance, are placed on the sides of the ticket office (Fig. 2). The placement of these green walls is related to the topic of sustainability in museums, being implemented within the framework of Lisbon European Green Capital 2020 and adopting an irrigation system finalised at the minimum use of water. The integration of green infrastructures in museums deals with a new way to conceive cultural spaces and is currently a global increasing trend [35] affecting the museum governance. The two living walls are based on plastic planter boxes covering part of the building envelope at the entrance of the exhibition areas. They create two vegetated coverages of 125 m^2 each, showing a dense disposition of plants and flowers (Fig. 4).

Fig. 2 shows the two green walls placed at the Complesso Aldo Moro, in the historic centre of Turin (Italy), and the two green walls placed at the entrance courtyard of the Centro Cultural de Belém, located in the Belém parish of Lisbon (Portugal).

2.2. Naturalistic observation of the sites

On-site inspections at CAM and at CCB were carried out to characterise the two sites in which the green walls are placed. A naturalistic observation method was chosen since it is efficient in reaching information of the real target that lives and frequents a context in an unobtrusive way [97]. Site inspections have been developed to identify similarities and differences useful to characterise each site and help the interpretation of the Green wall Perceived Restorativeness Scale (GwPRS) results. The analysis investigates technical, spatial and social aspects in order to register elements that can influence the fruition and perception of the space [70]. Thus, technical observations were developed on the (i) typology of the green walls and their spatial relation with the (ii) building and (iii) the context in which they are inserted. Moreover, qualitative observations on the users (iv) flows and fruition of the place and (v) interaction with the green walls have been registered. These multiple layers of analyses [37] are relevant to characterise the two different sites of Lisbon and Turin and develop an effective comparative study.

Table 1
The table summarises the most relevant PRS versions, showing characteristics and underlying strengths and weaknesses.

Authors	Items n°	Factors (items n°)	Evaluation	Comments
Hartig et al. [33]	16	Being away (2) Fascination (5) Extent (4) Compatibility (5)	5-Likert Scale	Time-efficient thanks to small number of items and short evaluation scale.
Pasini et al. [61]	11	Being away (3) Fascination (3) Coherence (3) Scope (2)	11-Likert Scale	Critical reliability of evaluation due to long evaluation scale.
Berto et al. [102]	17	Being away (4) Fascination (4) Coherence (4) Scope (4) (Environmental) Preference (1)	5-Likert Scale	Simple language for complex perceptions. Time-efficient thanks to short evaluation scale. Takes into account personal appreciation of the space.
Takayama et al. [98]	29	Familiarity (1) Being away (6) Fascination (7) Coherence (4) Scope (4) Compatibility (5) Preference (2)	11-Likert Scale	Long filling-in process due to the high number of items and long evaluation scale. Take into account the previous relation to the place. Tackle automatisation in response, presenting items not ordered according to factors.
Kim et al. [104]	16	Being Away (5) Fascination (3) Coherence (2) Compatibility (6)	11-Likert Scale	Critical reliability of evaluations due to the long evaluation scale.
Timm et al. [84]	14	Being away (5) Fascination (3) Coherence (2) Compatibility (6)	5-Likert Scale	Tackle automatisation in response adopting negative sense. Time-efficient thanks to small number of items and short evaluation scale. Language focused on the visual stimuli.
Lotfi et al. [44]	15	Being away (2) Fascination (4) Extent (4) - negative sense Compatibility (5)	5-Likert Scale	Tackle automatisation in response adopting negative sense. Time-efficient thanks to small number of items and short evaluation scale.
Mani et al. [47]	21	Being away (5) Fascination (7) Extent (4) - Coherence and Scope Compatibility (5)	5-Likert Scale	Long filling-in process due to the high number of items. Simple language for complex perceptions.

2.3. Questionnaire preparation and distribution

The questionnaire has been composed of three sections seeking different information: (i) contextual information to assess the knowledge of participants about the analysed green walls and their relation to the selected cities; (ii) general socio-demographic data to characterise and interpret the interviewees' answers [49]; and (iii) a PRS-based section. For each site the questionnaire was adapted to the national language - Italian and Portuguese - and English, allowing to include foreign people in the study. According to participants convenience questionnaires have been distributed on printed version or online version, through QR code scanning. Microsoft Forms has been used to build the online version of the questionnaire. The protocol of the questionnaire distribution has been prepared taking care to guarantee the anonymity of respondents. According to several works applying PRS, questionnaires have been distributed and filled in situ [68,92], close to the green walls, allowing to obtain more reliable answers on the effective perception of participants [8]. The factors included in the GwPRS are Familiarity (F), composed of one item, Fascination (Fa), Being Away (BA), both composed of 4 items, Extent and Coherence (EC), composed of five items and Preference (P), composed of three items. Moreover, to easen the fill in during a face-to-face questionnaire, the work of Pasini et al. [61] was taken as reference, considering the small number of items, which makes the completion more agile than the original PRS [33]. Moreover, since the PRS tool has been developed to deal with landscape and open context and not specific elements or parts of the built environment [63], some of the original PRS items are considered as not effective in informing about the Restorative capacity of green walls. In the present work the original items have been revised to focus on the impact of green walls on citizens' perception of a space. Since interaction with green walls is mainly visual, Lotfi et al. [44] and Takayama et al. [98] were taken as reference for their items referring to the sight and the visual attraction of greenery. Fig. 5 shows the structure and components of the GwPRS. Participants have responded using a 5-point Likert scale (from "I more than agree" to " I more than disagree") to indicate the extent to which the given statement describes their experience in the setting. After data collection, these evaluations have been translated into numerical values for the development of statistical analysis (2.4) and the quantification of Perceived Restorativeness in each site.

2.4. Statistical analysis

The Analysis of Variance (ANOVA) has been used to assess the effects on participants' Perceived Restorativeness between the CCB site and the CAM site [76]. So, a Two way ANOVA has been developed using sites and GwPRS factors as factors of the statistical analysis, respectively with two (CAM and CCB) and five (Familiarity, Fascination, Being away, Extent and Coherence and Preference) levels. The averages and variances of each factor for both sites have been compared. Moreover, variations and statistical consistency have been investigated within and between the two sites' factors values [50]. The Pearson correlation [8] was calculated on the totality of evaluations of the items in order to identify connections within them and the relative GwPRS factors.

The Pearson correlation measures the linear relationship between two continuous variables, quantifying the degree to which the variables change together. The correlation coefficient ranges from -1, indicating a perfect negative linear relationship, to 1, indicating a perfect positive linear relationship. A correlation equal to 0 indicates no linear relationship. The Pearson correlation is calculated using the covariance of the variables divided by the product of their standard deviations. This statistical analysis assumes that the relationship between the considered variables is linear and that the data is normally distributed [99].

The Cronbach's alpha test has been used to assess the reliability and accountability of the GwPRS [61] for both sites. Cronbach's alpha is a measure of internal consistency, indicating how well a set of items or variables measures a single and unidimensional latent construct. It is commonly used in psychology and social sciences to assess the reliability of scales and questionnaires. The value of Cronbach's alpha ranges from 0 to 1. A Cronbach's alpha value of 0.7 or higher is generally considered acceptable, indicating good internal consistency. Lower values suggest

Fig. 3. Green walls in CAM.

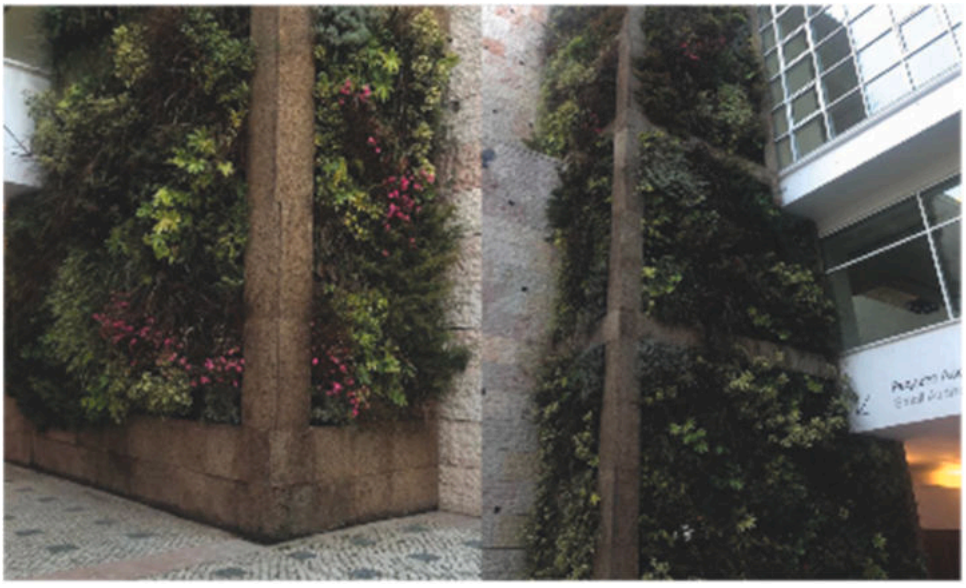

Fig. 4. Green walls in CCB.

that the items may not be well correlated and may not be measuring the same underlying concept. Higher values indicate that the items are more closely related and therefore more reliable. Cronbach's alpha is calculated based on the average inter-item correlation and the number of items in the scale [100].

Statistical procedures were carried out using Excel. Statistical analysis has been developed to obtain consistent results in support of the qualitative observations.

3. Results

The following sections present the results obtained by the naturalistic observations and the questionnaire responses for the CAM and CCB sites. Thus, the results are organised into qualitative observations of the two sites describing their technical, spatial and social characteristics and the quali-quantitative responses of participants to the questionnaire - contextual information, GwPRS and socio-demographic data - focused on the two contexts in which green walls are placed.

3.1. Characterisation of the sites derived from naturalistic observation

The two green walls placed at the CAM are continuous living wall systems and cover the facades of the two buildings at the entrance of the

Questionnaire structure

Contextual information		Were you aware of the presence of these green walls?
		Is this the only geen wall sute you have visited?
		What is your connection to this city?
Socio-demgraphic information		Age
		Gender
		Nationality
		Occupation
		Sector
GwPRS	**Familiarity** Familiarity with the place (Berto, 2018)	1. I often visit this place
	Fascination The wealth of stimuli offered by the green wall.	2. Passing through this area I take a look at the green wall
		3. When I am here, I dwell to observe the details and changes in the green wall
		4. Green walls offer fascinating views of the area
		5. I have curiosity to explore the space I see beyond the green walls
	Being away Sense of mental relief and freedom from daily stress or routine.	6. During a break (from work, study, etc.) I choose/would choose to stand in a spot where I can observe these green walls
		7. I find it relaxing to look at these green walls
		8. The presence of the green walls enhances the feeling of comfort of fered by this place
		9. When I am/ if I were on a break (from work, study, etc.), the presence of these green walls gives/ would give me a feeling of mental refreshment.
	Extent and Coh. The "naturalness" of the green wall and its fitting in the space.	10. In this place, nature takes back its space
		11. It seems that the vegetation coexists with the building
		12. Green walls are the characterising element of this place
		13. The green walls fit well with the surroundings
		14. The physical arrangement of the area (buildings, roads, vegetation, pavements, etc.) is well or ganised
	Preference Pleasantness of the green wall and the place	15. I like that the green walls were included in this courtyard
		16. I like this courtyard
		17. Green walls are my favorite element in this space

Fig. 5. Structure of the questionnaire, composed of contextual information, Green Wall Perceived Restorativeness Scale and socio-demographic information.

building complex. Each green wall presents a vegetated area of almost 144 m^2 (12 m x 12 m) and both are disposed at the second level above the ground, over the two glazed commercial plinths. Each module composing the living walls consists of a first layer of double non-woven fabric with 12 pockets, each containing 1 litre of substrate, followed by one layer of felt cloth, one layer of PVC foil and finally one layer of Oriented Strand Board (OSB). The living walls have a dripping irrigation system. The vegetation contained in both green walls is composed of

melliferous, hanging and aromatic plants, showing a dense coverage of leaves and the use of different shades of greens and colours. The disposition of the varied plants and plant species is clearly defined according to a designed pattern to obtain dynamic effect of the coverage and return a sense of controlled naturalness. The non-woven fabric layer that sustains the plants' rooting systems development is barely visible just in restricted parts of the green walls, where vegetation shows lower density of foliage. Both green walls are encased in the facades including a projecting profile that frames them. The only structural element that is visible is the eaves at the bottom side of the two green walls. Looking at the spatial distribution of the site in which the CAM is placed, the facades with green walls delimit a widening in the pedestrian way introducing to the internal courtyard beyond them. The main flows of people are shown in Fig. 6 and come from the two roads crossing in front of the entrance of the CAM. The site is crowded in the morning when people pass through to reach university and work and at the lunch break when people go to the restaurants and sit at the outdoor tables of the cafe. However, during the morning and the afternoon many students meet and talk in front of the University and the CAM, some of them sitting at the external steps of the entrances of these two buildings.

The two green walls placed at the CCB are living wall systems based on planter boxes and cover the surface of the narrow volumes at the end of the entrance courtyard. They are placed before the ticket office and the stairs leading to the exhibition spaces. These two green walls are composed of 7524 planter boxes creating a vegetated area of almost 250 m^2 covering two faces of each volume of 17 m height. These two green walls present a vegetated area of almost 80 m^2 each (20 m x 4 m) covering two faces of each volume. The living walls have a dripping irrigation system. Both green walls are disposed starting from a height of 1 m and covering the entire height of the two volumes. Melliferous, hanging and aromatic plants composed the vegetation of both green walls that present an homogeneous coverage of greenery with different shades of greens and use of colourful flowers. Planter boxes have a circular form of about 20 cm diameter and contain one plant each. They are disposed very close to each other, The planter boxes that form the green walls are not visible from the centre of the courtyard but are clearly evident observing the systems closely. Both green walls appear encased in the narrow volumes and are attached in a recessed space within them. Looking at the spatial distribution of the entrance courtyard of CCB, it can be seen that the space offers a double function, from one hand containing commercial services and meeting and relaxation spaces with chairs and coffee tables while on the other hand introducing the cultural spaces. As shown in Fig. 7, the main flows of people move along the entrance and exit way of the CCB. The site is mainly crowded during the holiday periods and during the weekends, mainly after the lunch break, with a peak during the afternoon. During the week CCB is not very frequented but some people use the courtyard to rest and take a break at the cafes or sitting at the tables near the green walls. Sometimes

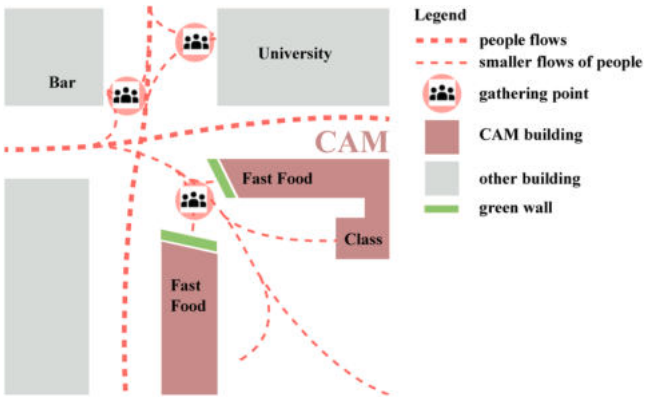

Fig. 6. People's flows and fruition of place in the CAM.

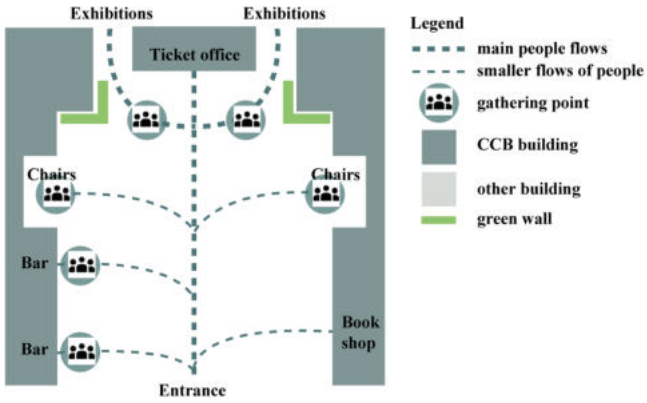

Fig. 7. People's flows and fruition of place in the CCB.

tables have been moved by visitors and placed very close to the two green walls in order to rest beside them. During the site inspections it was possible to observe that almost all the visitors observed the green walls passing through the courtyard. A good part of visitors took some minutes to stare at the green walls, observing, touching or taking pictures of them.

3.2. Comparative results: target composition in CAM and CCB

The GwPRS were submitted to 230 participants, 115 in Turin and 115 in Lisbon.

The large majority of the CAM target is composed of Italians (95,4%), with a small number of Romanian (3,7%) and French (0,9%). The 73% are women and the 27% men, most of them (89,6%) living, working or studying in the city. Only the 9,1% live outside Turin but frequent it in their leisure time and just the 1% are tourists. More than half of the participants are between 18 and 24 years old (52,2%) and more than a fifth is between 25 and 34 years old (22,9%). For what concerns the relation of the target with the CAM, 61,2% of participants are aware of the presence of the two green walls and this is not the first time that they saw the system while the 21,7% were aware of them but it was the first time they saw a green wall. For 44,0% of participants the CAM was the first site in which they saw a green wall system.

The Lisbon target of participants is composed, for the large majority, of Portuguese (44,4%), with a relevant number of French (10,4%) and British (7,8%). The 59,7% are women and the 40,3% men, most of them (50,8%) are tourists while the 46,0% live, work or study in the city. Only the 3,2% live outside Lisbon but frequent it in their leisure time. A slight majority of the participants are between 25 and 34 years old (35,5%) while 33,3% are between 18 and 24 years old. For what concerns the relation of the target with the CCB, 59,7% of participants are aware of the presence of the two green walls and for the 51,6% it was not the first time that they saw the system. For the 48,4% of the visitors the CCB was the first site in which they saw a green wall system. Fig. 8 synthetases the information on the target composition in CAM and CCB.

3.3. Green walls Perceived restorativeness: comparing reliability and GwPRS values in the two sites

Below the results of the performed repeated Two-way ANOVA are presented, comparing the factors and items' mean values and variances between CAM and CCB.

The between-subjects factor was restorativeness of the place, with five levels (F, Fa, BA, EC, P), and the within-subject factor with two levels (CAM and CCB). The between-subjects factor and the within-subjects factor show statistically significant effects.

As a general overview (Fig. 9), the average of the total value of the CCB GwPRS (67.9) is slightly higher than the CAM one (66.5). CCB

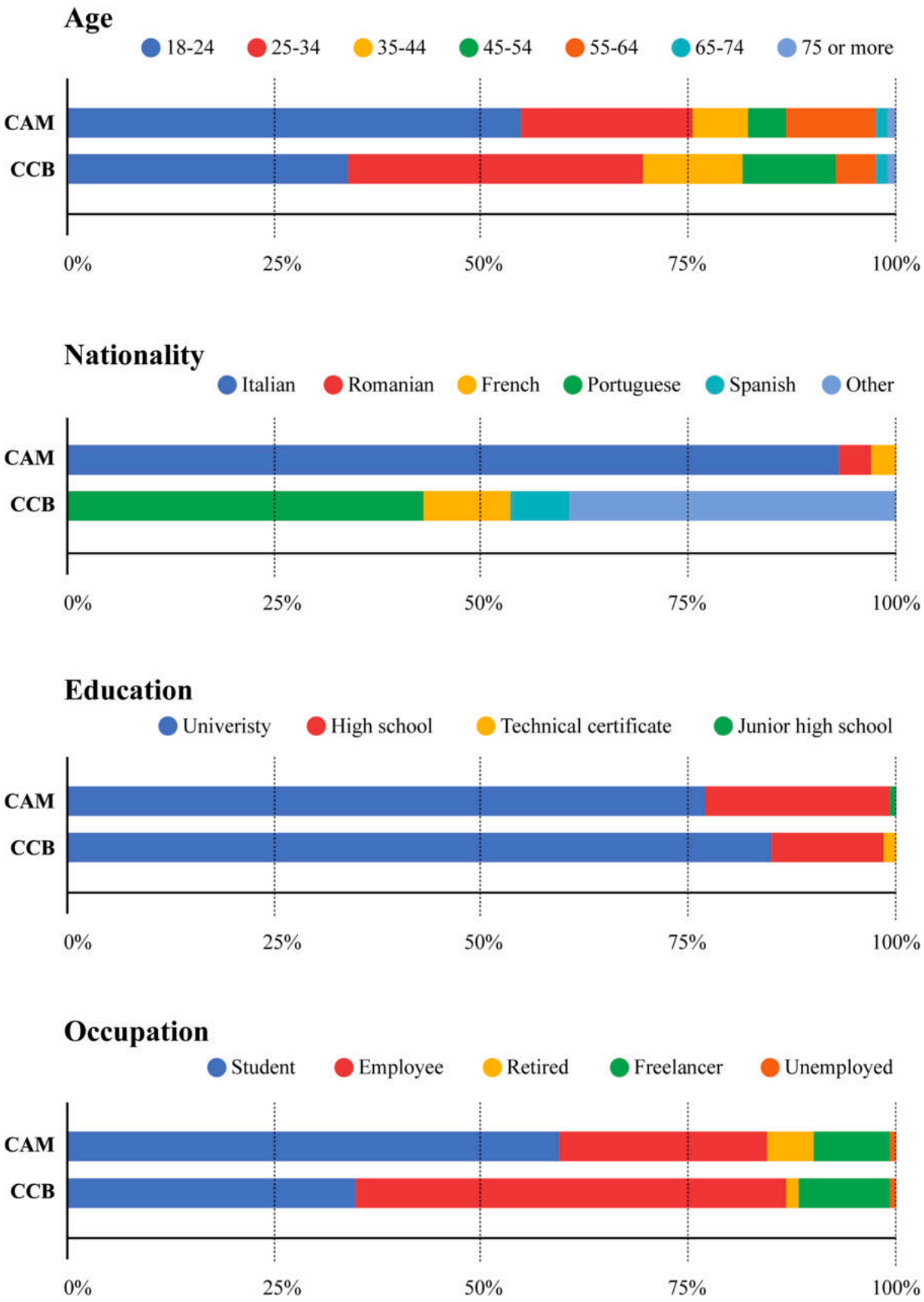

Fig. 8. Target composition of CAM and CCB.

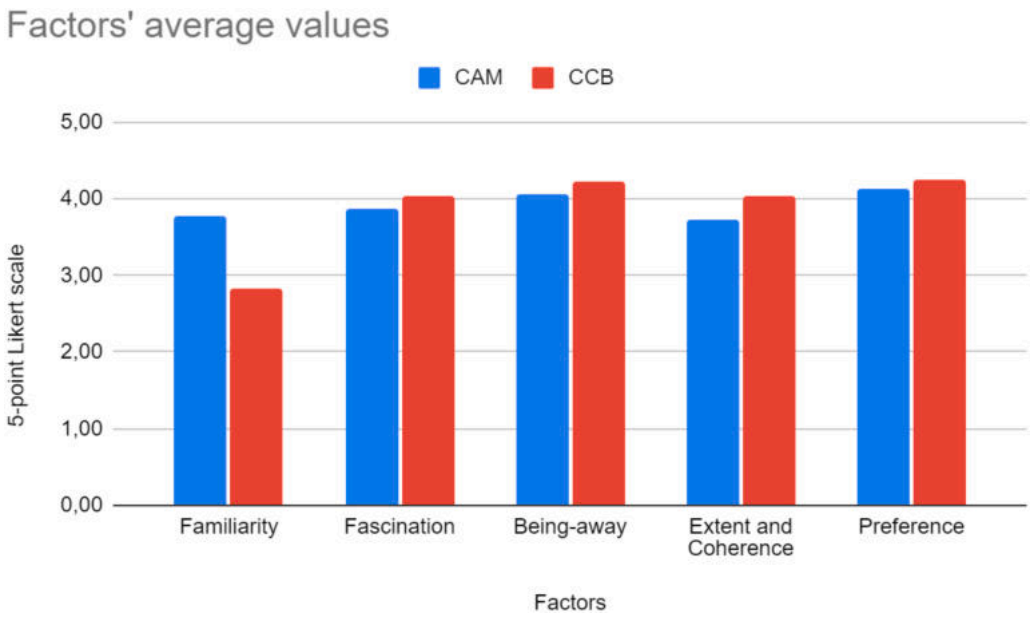

Fig. 9. GwPRS factors values for both CAM and CCB.

factors are higher than CAM factors except for the F factor. The highest factor is P for both sites, CCB P has the highest value among all the factors and sites. BA and P mean values are very similar between the two sites and are the closest among all the factors. F is the factor that shows the highest difference between the two sites.

Detailed results of the factors are presented below (Table 2). The F mean value of CAM (3.78) is higher than CCB (2.98) with a difference of almost 1.00, the highest difference among all the other factors' mean values. Variance is relevant, the highest between all the factors. In particular, CCB shows higher variance (2.08) of CAM (1.38) and presents the highest variance of all the other factors in both sites.

The Fa mean value of CAM (3.88) is higher than CCB (3.12) with a relevant difference of 0.76. CAM has a higher Fa variance (0.57) than CCB (0.29) with a slight difference of 0,28. Fa values and differences between variances are very similar to those of the BA factor. The BA mean value of CCB (4.19) is higher than CAM (4.05) with a very small difference of 0.14. CAM BA has a higher variance (0.53) than CCB (0.28) with a slight difference of 0.27. As noted above, values and differences between variances are very similar to those of the Fa factor. The EC mean value of CCB (3.73) is higher than CAM (4.00) with a difference of almost 0.27. The variance between the two sites is very similar, CAM (0.32) is higher than CCB (0.31) for just 0,01. The P mean value of the two sites is very similar, the CCB (4.21) mean value is higher than CAM (4.12) with a difference of almost 0.09, the lowest difference among all the couple of factors. Moreover, the P mean value of CCB is the highest among all the other factors. Variance of the two sites is the same (0.32). If we consider the total variance of each factor, i.e. the average variance of the variances of the GwPRS factors for each site, we see that F has the highest variance (1.92), followed by Fa (0.57) and EC (0.50).

The Cronbach's alpha test assessed the high accountability of the results obtained. In fact, the GwPRS performed at the CAM site obtained a 0.88 while the one performed at the CCB site 0.78 ($\alpha > 0.70$) [61].

For what concerns the evaluations distribution of the two green walls sites, it can be clearly noticed from Fig. 10 that mean values of items are quite aligned between and within CAM and CCB, except for the evaluations of the item 1. (CAM = 3.78; CCB = 2.82).

Regarding the items, both sites achieved most of the average ratings above 4 ('I agree'). The CCB ratings are always higher than those of CAM except for item 1., item 2., and item 17. The items that show the greatest difference in ratings between the two sites are: item 1. (CAM = 3.78; CCB = 2.82; d = 1.92); item 13. (CAM = 3.90; CCB = 4.35; d = 0.45); item 14. (CAM = 3.88; CCB = 4.26; d = 0.38); and item 16. (CAM = 4.01; CCB = 4.35; d = 0.34). Only item 1. (CAM = 3.78; CCB = 2.82), item 2. (CAM = 4.14; CCB = 4.01) and item 17. (CAM = 3.98; CCB = 3.84) received higher results in CAM than in CCB. Item 15. received the highest evaluations for both CAM (4.39) and CCB (4.53). In particular, CAM received higher evaluations for item 8. (4.29), item 7. and item 2. (4.15), while lower evaluations have been received for item 10., item 12. (3.54) and item 3. (3,55). On the other hand, CCB received higher evaluations for item 7. (4.40), item 8. (4.38), item 13. and 16. (4.35) and item 14 (4.26), while lower evaluations have been received for item 1. (2.82), item and item 3. and item 12. (3.60).

The Pearson correlations' matrices of the five factors and the seventeen items of the Perceived Restorativeness Scale were calculated based on the average evaluation given by all the interviewed in CAM and CCB sites. Thus, four Pearson correlations have been developed, two within items tested in CAM and in CCB, and two within factors tested in CAM and CCB. For what concerns the Pearson correlation within items

Table 2
Two-way ANOVA and Cronbach's alpha test results of CAM and CCB.

	Mean value		Variance			Cronbach's alpha		
Factor	CAM	CCB	CAM	CCB	Total	CAM	CCB	Reference
Familiarity	3,78	2,89	1,38	2,08	1,92			
Fascination	3,88	3,12	0,57	0,30	0,57			
Being-away	4,05	4,19	0,53	0,28	0,41			
Extent and Coherence	3,73	4,00	0,32	0,31	0,50			
Preference	4,13	4,21	0,32	0,32	0,32			
GwPRS total	66,5	67,9	0,71	0,97	-	0,88	0,78	> 0,70

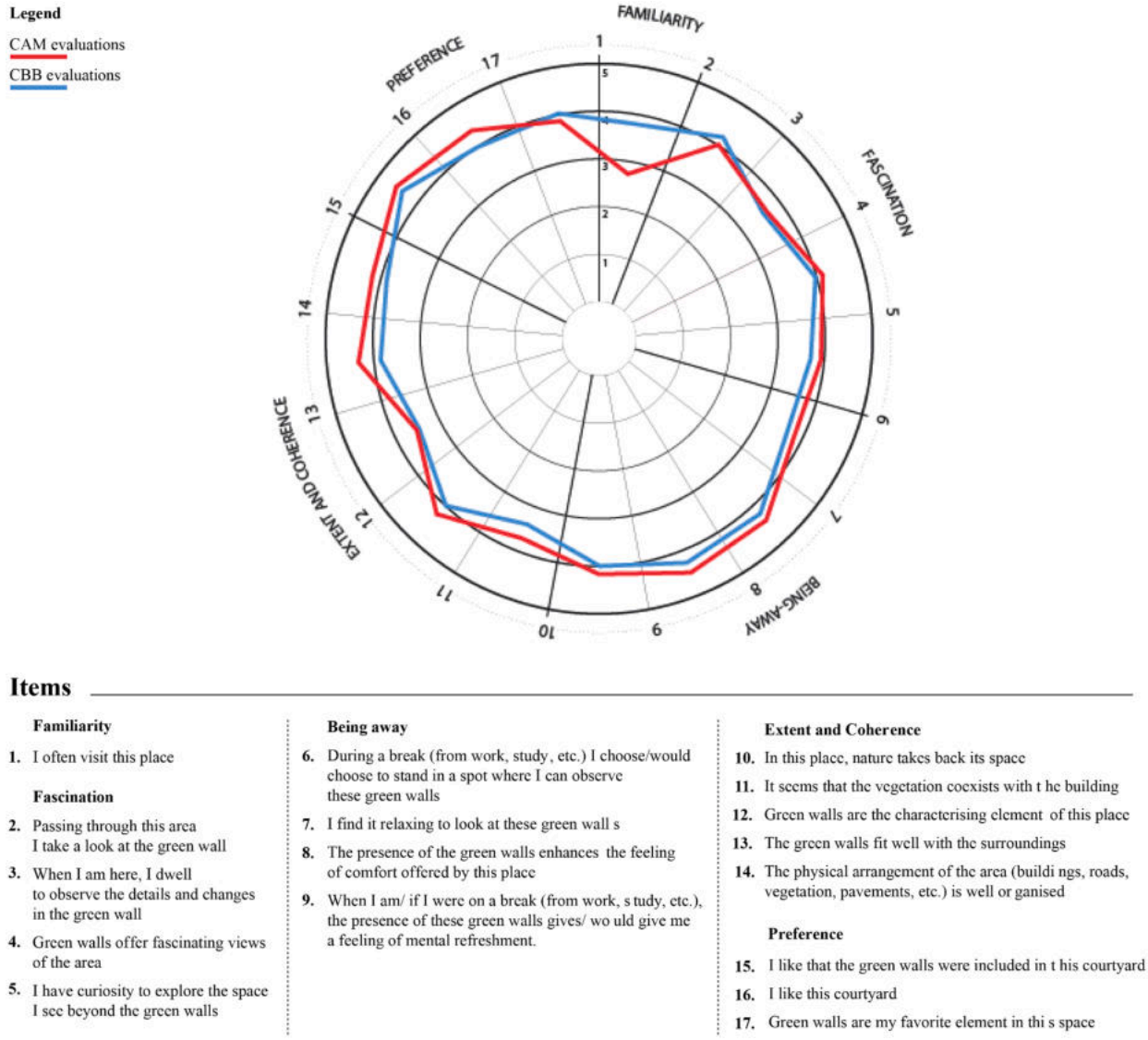

Fig. 10. Distribution of participants' evaluations of GwPRS in CAM and CCB. The red line refers to CAM results while the blue one refers to CCB results.

in both sites, correlations in the questionnaire answers of CAM are more and higher than those in CCB. For a detailed analysis of the results, Tables 5 and 6 summarise the Pearson correlations of the GwPRS items in CAM and CCB and can be found in the "Supplementary materials''. For what concerns the Pearson correlation within factors, it is interesting to note that results from CAM (Table 3) show very high correlation between Fa and BA (0.73) and EC and P (0.74). Lower correlations have been found between Fa and EC (0.60), BA and EC (0.53), P and Fa (0.53) and P and BA (0.59). On the other hand, CCB factors correlations appear very different (Table 4). The highest correlation found is between P and EC (0.64), while lower correlations are between EC and BA (0.50) and P and BA (0.51).

4. Discussions

Crossing the data collected from the naturalistic observations and the

Table 3
Factors' Pearson linear correlations for CAM. Good correlations are highlighted in yellow (> 0.50), while very high correlations are in orange (> 0.70).

	Familiairty	*Fascination*	*Being Away*	*Ext. and Co.*	*Preference*
Familiairty	1				
Fascination	-0.33	1			
Being Away	-0.41	0.73	1		
Ext. and Co.	-0.29	0.60	0.53	1	
Preference	-0.12	0.53	0.59	0.74	1

Table 4
Factors' Pearson linear correlations for CCB. Good correlations are highlighted in yellow (> 0.50), while very high correlations are in orange (> 0.70).

	Familiairty	*Fascination*	*Being Away*	*Ext. and Co.*	*Preference*
Familiairty	1				
Fascination	0.17	1			
Being Away	-0.01	0.49	1		
Ext. and Co.	0.19	0.46	0.50	1	
Preference	-0.04	0.45	0.51	0.64	1

questionnaire leads to a detailed overview about the influence of green walls on the perception of space. Information are the results obtained from qualitative and quali-quantitative data, thus the following section mixes information from the evidence collected on field and information elaborated from statistical analysis to better explain the socio-ecological relationship between people, urban space and green walls [80].

4.1. Restorative capacity of green walls in CAM and CCB

Green walls of both sites show high average values for all GwPRS factors and a high and very similar total GwPRS value. Thus, despite differences between CAM and CCB such as the size of vegetated area (Timm et al., 2017), the level of accessibility to the green wall [5], the target participants [82] and the space use, the influence of green walls on the participants' Perceived Restorativeness is extremely similar between the two sites. As anticipated by Lotfi et al. [44], this first result suggests the occurrence of a common intrinsic Restorativeness value of this nature-based solution perceived by participants in both sites. This result can also be interpreted as evidence of the occurrence of the biophilic process in relation to a technological green system such as green walls. This is crucial information for urban planning to recognise the validity of green walls as a bio-based technological unit capable of influencing urban liveability [22].

The answer distribution in fact is very similar on both sites, although the CCB shows slightly higher values than the CAM for all items. However, considering the very small difference between the values (except for item 1), it is not recognised a marked difference in Perceived Restorativeness between the two sites. These outcomes lead to suggest that the common features of the two green walls are the drivers of this perceptual process. According to scientific literature, it can be suggested that these characteristics are: the development at the maximum height of the building [66], the symmetrical disposition of green walls that create a plurality of vegetated elements fitting the design of the urban space [9] and the specific type of green wall, characterised by a rich variety of visual stimuli due to the plant variety [23].

The two sites show similarities in the results of BA and Fa and EC and P, with very high average values and correlations. This result supports the recognised link between people's aesthetic appreciation of the green wall and their perceived sense of comfort and mental relief - strictly related to the BA factor - and thus support the pivotal role of urban biophilic design to create a coherent urban context that combines natural and artificial elements. As argued by Barbiero et al. [6], these results highlight the crucial role of the aesthetic function of green walls as a co-dependent aspect to the creation of psycho-physiological reactions. The high values of BA in both sites prove the strong role of green walls as architectural elements improving the comfort of an urban space. Moreover, the high correlation of EC and P suggests the importance of integrating green walls as part of the landscape design, as well as architectural elements at the building level. Interestingly, only for CAM the Fa factor correlates with BA, EC and P (Table 4). A greater number of linear correlations in the CAM results are also visible when considering the items (Table 5). Considering the fundamental importance of the Fa factor [38], the absence of correlation in the CCB results is certainly an interesting element to be analysed.

Looking at the items for which each site received the highest values as indications of their strengths, it can be seen that both CCB and CAM green walls offer a high sense of comfort and relaxation (item 7 and item 8). For CCB, this may be the result of the arrangement of the inner courtyard, separated from the street access and quiet [63], and the positioning of the green wall whose development of the vegetated surface from the ground to cover the entire height of the building creates a continuous effect that evokes the sense of refuge [39]. Furthermore, the possibility of very close access to the plant species, both visual and physical, is certainly another decisive characteristic that allows for emotional contact with the visitors [34]. As far as CAM is concerned, being a public open space, this aspect may be due to the feeling of refuge and perspective [9] created by the heights and inclination of the two green walls, which form a green barrier surrounding the square and leading towards the inner courtyard.

Despite the positive GwPRS values, it is useful to dwell on the main differences in the results of the two sites. Looking at the factors (Fig. 6), it can be seen that the CAM site obtains a higher value than CCB only for the F factor, which as seen above, shows no correlation with any of the other GwPRS factors. Although some works deny the importance of this factor within the PRS [101], in this work its importance is recognised as it offers additional information on the impact the green wall may have on a possible community of people. As highlighted by the results, in fact, this factor becomes significant as a further evaluation of people's relationship with the space, namely the sense of place of the people who frequent the site. This is a concept of relevant importance, influencing the liveability of urban places [90]. In fact, although the total GwPRS values are high for both sites, the F value of CCB shows that the overall incidence of the sense of place for the target community of the site (mostly tourists) is low. On the contrary, for CAM, whose reference community is local, a high average value is obtained. Although evident from the nature of the two spaces, this information highlights the relevance of the sense of appropriation of the analysed site in the assessment of the GwPRS.

Bearing in mind the results just discussed as proof of the influence of green walls on the Restorative capacity of an urban space, one evident result concerns the spontaneous creation of gathering and resting points near green walls in both CAM and CCB (Fig. 4 and Fig. 5). This is practical evidence of the attractiveness of this nature-based solution. In particular, in CCB visitors moved by their own chairs close to the two living walls in order to rest and chat near the vegetation. It is particularly interesting to note that in CAM an aggregation point is created in front of the two green walls where the space is not used for gathering or rest. In fact, this point corresponds to the entrance of the stairs leading to the lower level of the building complex. Moreover, no benches or free chairs are placed in this point. In response to the works of Parker & Simpson [60] and Peschardt & Stigsdotter [68] on urban green infrastructures and spaces, this observation is first empirical evidence of the

attractiveness of the green walls, which can influence the behaviour in the urban context and create privileged points for people gathering, even where the space is not set aside. This result suggests that the living walls in CAM are perceived as a landmark.

Results obtained allowed the gathering of interesting data and the proposing of relevant information, nevertheless, this is the first study for a comparative and replicable methodology in green walls social benefits detection. As such, limitations are present in the study and have to be recognised to improve reliability and applicability of the methodology. As other similar studies investigating Perceived Restorativeness in real environment [62,75], the number of participants is limited due to the time-consuming nature of the survey activity and the dependance on the daily fluxes of people. A longer period of survey should be performed in order to reach a higher number of respondents and at the same time provide a longer observation of the influence of green walls on urban vitality.

Moreover, the study allows to have a first look at the response of a very varied target of people just linked by the interaction with the green walls. To strengthen the reliability of data obtained, more homogeneous targets should be reached in order to consistently compare their responses within the target and with other targets.

Although the integration of socio-demographic data and contextual information to the proposed GwPRS, more information should be obtained to better define the cultural and subjective profile of respondents as pivotal aspects in Restorativeness perception [24]. Effective open-ended questions may be crucial for the comprehension of the complex personal perceptions and responses to green walls interaction.

5. Conclusions

This study demonstrates the importance of punctual natural areas to improve citizens' liveability perception of urban public spaces in high densely cities. The study contributes to fill the gap in the scientific literature about the ability of green walls to increase citizens well-being and implement cultural ecology at local scale by producing social benefits [3].

The study:

- shows that despite differences between sites and green walls, the values of Perceived Restorativeness are extremely similar, showing very close values trends in the responses of participants in CAM and CCB;
- ascertains the occurrence of very high values of Perceived Restorativeness - overcoming the value 4 for the majority of items of the GwPRS - in both sites thanks to the presence of green walls
- identifies evidence of the biophilic attraction of green walls, indicating their ability to draw people and encourage social aggregation.
- based on results, proposes green wall typology, its height, its symmetrical disposition, the elements repetition and the plants variety as influencing drivers for Perceived Restorativeness.

Results suggest considering green walls as promising tools to cope with other green infrastructure to effectively re-introduce vegetation in cities and create a "green" network at city scale. Outcomes provided by this investigation remarks the socio-cultural implications of urban greening interventions to move towards a more sustainable and holistic management of the built environment.

Therefore, this study proposes a methodology that includes the socio-ecological dimension as fundamental design driver in the biophilic transformation of the built environment. In this sense, the use of a well-established tool, the PRS, was the basis for the development of an *ad hoc* tool for the assessment of the socio-cultural value of green walls, adapting and modifying factors and items to evaluate the effectiveness of vertical greening. The methodology proposed in this article can be easily adapted to other infrastructures that combine nature and technology to assess the social sustainability of other types of nature-based solutions. Further investigations performed using this methodology should take into account the cultural diversity and subjectivity of the respondents to the questionnaire, adding open-ended questions to gain more insight into people's perceptions and reasons behind their answers. More homogeneous respondents should be targeted to allow a comparative analysis of their answers on the basis of the internal common characteristics of the targets being compared. To obtain an increasingly accurate definition of the impacts of green walls, it is important to provide a longer observation and questionnaire submission period, which allows the influence of the green wall throughout the year to be mapped.

To improve the reliability of the GwPRS, this methodology should be replicated in other green wall sites to obtain more information on the variables influencing the Restorative capacity of a green wall in an urban space. The systematic collection of such results can constitute a first step to guide *evidence-based* biophilic design through the integration of socio-cultural, ecological and technological perspectives of the built environment. Data about the socio-ecological perspective of citizens on nature-based solutions are crucial for policy-making processes in the development of resilient and biophilic cities responding to the request expressed by the SDG 11 "Make cities inclusive, safe, resilient and sustainable" [87]. Moreover, the positive response and acceptance rate provided by participants suggests the opportunity to increase the use of green walls as tools to contribute to the urban metabolism and to recover ecological processes in cities. At the end, data related to the cultural ecosystem services of green walls are essential for a complete definition of their sustainability in cities, including social benefits in the assessment of their impacts.

CRediT authorship contribution statement

Matilde Molari: Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Laura Dominici:** Writing – review & editing, Validation, Methodology, Conceptualization. **Maria Manso:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Cristina Matos Silva:** Validation, Supervision, Methodology, Conceptualization. **Elena Comino:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgement

This contribution contains the contents of the PhD research of M. Molari under the supervision of Prof. M. Manso, Prof. C. Matos Silva, Prof. E. Comino and PhD L. Dominici. The questionnaire draft was revised by PhD C. Caprioli, from the Interuniversity Department of Regional and Urban Studies and Planning of the Politecnico di Torino, to check its consistency and accountability. The research was partly developed at the Universidade Lusófona de Humanidades e Tecnologias of Lisbon as abroad research period of the PhD programme of M. Molari.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nbsj.2024.100175.

References

[1] Adams, E.; Cartalis, C.; Lievens, R.; d'Antonio, S. (2022) Cities, Jobs and Just Transitions - Context, Urban Innovation Action https://uia-initiative.eu/en/just-urban-transitions/skill-green-future/cities-jobs-and-just-transitions.

[2] C.C. Anderson, F.G. Renaud, S. Hanscomb, K.E. Munro, A. Gonzalez-Ollauri, C. S. Thomson, E. Pouta, K. Soini, M. Loupis, D. Panga, M. Stefanopoulou, Public acceptance of nature-based solutions for natural hazard risk reduction: survey findings from three study sites in Europe, Front. Environ. Sci. 9 (2021).

[3] F. Ascione, R.F. De Masi, M. Mastellone, S. Ruggiero, G.P. Vanoli, Green walls, a critical review: knowledge gaps, design parameters, thermal performances and multi-criteria design approaches, Energies. (Basel) 13 (9) (2020) 2296.

[4] A. Assem, D.K. Hassan, Biophilia in the workpla ce: Apilot project for a li ving wall usi ng an intera ctive parame tri c desi gn approach, Architect. Engineering 9 (1) (2024) 3–16.

[5] In: N. Agnolio, M. Molari, L. Dominici, E. Comino, Outdoor Green Walls: Multi-perspective Methodology for Assessing Urban Sites Based on Socio-environmental Aspects, in: F. Calabrò, L. Della Spina, M.J. Piñeira Mantiñán (Eds.), New Metropolitan Perspectives. Post COVID Dynamics: Green and Digital, Transition, Between Metropolitan and Return to Villages Perspectives, 1905-1915, Springer, Berlin/Heidelberg, 2022.

[6] G. Barbiero, R. Berto, A. Venturella, N. Maculan, Bracing Biophilia: When biophilic Design Promotes Pupil's Attentional performance, Perceived Restorativeness and Affiliation With Nature, Environment, Development and Sustainability, 2021.

[7] R. Berto, G. Barbiero, J.L. Nasar, Editorial: Biophilic design rationale: Theory, methods, and applications, Front. Psychol. 13 (2022).

[8] R. Berto, G. Barbiero, P. Barbiero, G. Senes, An Individual's Connection to Nature Can Affect Perceived Restorativeness of Natural Environments Some Observations about Biophilia, Behavioural Science 8 (3) (2018) 34.

[9] W.D. Browning, C.O. Ryan, J.O. Clancy, 14 Patterns of Biophilic Design, Terrapin Bright Green llc, New York, 2014.

[10] R.A. Bustami, R. Rawlings, S. Beecham, J. Ward, D.Y.S. Mah, Living walls in the city: community values and expectations, International J. Integrated Engineering 15 (9) (2023) 79–86.

[11] J. Byrne, Observation for Data Collection in Urban Studies and Urban Analysis, Methods in Urban Analysis (2021) 127–149.

[12] M. Chàfer, L. Cabeza, A. Pisello, C. Tan, N. Wong, Trends and gaps in global research of greenery systems through a bibliometric analysis, Trends and gaps in global research of greenery systems through a bibliometric analysis, Sustain. Cities. Soc. 65 (2021) 102608.

[13] W. Chung, M. Lin, C. Chau, M. Masullo, A. Pascale, T. Leung, M. Xu, On the study of the psychological effects of blocked views on dwellers in high dense urban environments, Landsc. Urban. Plan. (2022) 221.

[14] C. Ciacci, N. Banti, V. Di Naso, R. Montechiaro, F. Bazzocchi, Experimentation of Mitigation Strategies to Contrast the Urban Heat Island Effect: A Case Study of an Industrial District in Italy to Implement Environmental Codes, Atmosphere (Basel) 13 (2022) 1808.

[15] J. Colding, M. Giusti, A. Haga, M. Wallhagen, S. Barthel, Enabling Relationships with, Nature in Cities. Sustainability 12 (2020) 4394.

[16] L. Dai, Q. Han, B. de Vries, Y. Wang, Applying Bayesian Belief Network to explore key determinants for nature-based solutions' acceptance of local stakeholders, J. Clean. Prod. (2021) 310.

[17] G.S. Dantas, I.R.B. Nagy, P.B. Nogueira, Implementation of Green Infrastructure in Existing Urban Structures: Tracking Changes in Ferencváros, Budapest, Land 11 (2022) 644.

[18] H. Dorst, A. van der Jagt, R. Raven, H. Runhaar, Urban greening through nature-based solutions – Key characteristics of an emerging concept, Sustain. Cities. Soc. 49 (2019) 101620.

[19] A. Douglas, A. Morgan, E. Rogers, P. Irga, F. Torpy, Evaluating and comparing the green wall retrofit suitability across major Australian cities, J. Environ. Manage (2021) 298.

[20] J.W. Dover, Green Infrastructure. Incorporating Plants and Enhancing Biodiversity in Buildings and Urban Environments, Routledge, London, 2015.

[21] European Environment Agency (2023) Scaling nature-based solutions for climate resilience and nature restoration, Publications Office of the European Union.

[22] M. Goel, B. Jha, S. Khan, Living walls enhancing the urban realm: a review, Environmental Science and Pollution Research 29 (26) (2022) 38715–38734.

[23] P. Gonçalves, K. Vierikko, B. Elands, D. Haase, A.C. Luz, M. Santos-Reis, Biocultural diversity in an urban context: An indicator-based decision support tool to guide the planning and management of green infrastructure, Environmental and Sustainability Indicators 11 (2021) 100131.

[24] C. Gong, R. Yang, S. Li, The role of urban green space in promoting health and well-being is related to nature connectedness and biodiversity: Evidence from a two-factor mixed-design experiment, Landsc. Urban. Plan. 245 (2024) 105020.

[25] G. Grilli, S. Sacchelli, Health Benefits Derived from Forest: A Review, Int. J. Environ. Res. Public Health 17 (2020) 6125.

[26] K. Gunawardena, K. Steemers, Urban living walls: reporting on maintenance challenges from a review of European installations, Archit. Sci. Rev. 63 (6) (2020) 526–535.

[27] K. Gunawardena, K. Steemers, Living walls in indoor environments, Build. Environ. 148 (2019) 478–487.

[28] C. Gunn, M. Vahdati, M. Shahrestani, Green walls in schools - The potential well-being benefits, Build. Environ. 224 (1) (2022) 109560.

[29] European Environment Agency, Urban adaptation in Europe: what works? Implementing climate action in European cities (2023).

[30] C. Falzone, H. Jupsin, M. El Jarroudi, A. Romain, Advancing Methodologies for Investigating PM2.5 Removal Using Green Wall System, Plants 13 (12) (2024) 1633, https://doi.org/10.3390/plants13121633.

[31] F. Fonseca, M. Paschoalino, L. Silva, Health and Well-Being Benefits of Outdoor and Indoor Vertical Greening Systems: A Review, Sustainability. 15 (5) (2023) 4107.

[32] In: T. Hartig, Restoration in Nature: Beyond the Conventional Narrative (eds), in: A.R. Schutte, J.C. Torquati, J.R. Stevens (Eds.), Restoration in Nature: Beyond the Conventional Narrative, Nature and Psychology. Nebraska Symposium on Motivation 67 (2021).

[33] T. Hartig, K. Korpela, G.W. Evans, T. Gärling, Validation of a measure of perceived environmental restorativeness, Göteb. Psychol. Rep. 26 (1997) 1–64.

[34] N.H. Hefnawy, The Effect of Using Green Walls in Enhancing the Imageability of Urban Spaces, IOP Conference Series Earth and Environmental Science 1113 (1) (2022) 012007.

[35] International Council of Museums, (2018), Annual Report 2018.

[36] IUCN, IUCN Global Standard for Nature-based Solutions. A User-Friendly Framework For the verification, Design and Scaling Up of NbS, First edition, 2020.

[37] S. Jalaladdini, D. Oktay, Urban Public Spaces and Vitality: A Socio-Spatial Analysis in the Streets of Cypriot Towns, Procedia - Social and Behavioral Sciences 35 (2012) 664–674.

[38] R. Kaplan, S. Kaplan, The Experience of Nature: A Psychological Perspective, Cambridge University Press, Cambridge, 1989.

[39] S.R. Kellert, Nature By Design: The Practice of Biophilic Design, Yale University Press, New Haven, 2018.

[40] K. Koch, K. Wuyts, S. Denys, R. Samson, The influence of plant species, leaf morphology, height and season on PM capture efficiency in living wall systems, Science of the Total Environment 905 (2023).

[41] M. Köhler, Green facades—a view back and some visions, Urban. Ecosyst. 11 (2008) 423–436.

[42] T.-Y. Ling, W.-K. Hung, C.-T. Lin, M. Lu, Dealing with green gentrification and vertical green-related urban well-being: A contextual-based design framework, Sustainability. 12 (23) (2020) 10020, 1-24.

[43] M. Llaguno-Munitxa, M. Edwards, S. Grade, M. Vander Meulen, C. Letesson, E. Agudo Sierra, S. Altomonte, E. Lacroix, B. Bogosian, M. Kris, E. Macagno, Quantifying stress level reduction induced by urban greenery perception, IOP Conf. Ser.: Earth Environ. Sci. (2022) 1122.

[44] A. Lotfi, M. Refaat, M. El Attar, A. Salam, Vertical gardens as a restorative tool in urban spaces of New Cairo, Ain Shams Engineering Journal 11 (3) (2020) 839–848.

[45] F. Madre, P. Clergeau, N. Machon, A. Vergnes, Building biodiversity: Vegetated façades as habitats for spider and beetle assemblages, Glob. Ecol. Conserv. 3 (2015) 222–233.

[46] A. Magliocco, K. Perini, The perception of green integrated into architecture: installation of a green facade in Genoa, Italy, AIMS. Environ. Sci. 2 (4) (2015) 899–909.

[47] M. Mani, H. Woolley, J. Russell, A New Perceived Restorativeness Scale for Children's Everyday Environment (PRS-ChEE): Evaluating the Restorative Potential of Orphanages' Outdoor Spaces from the Viewpoint of Children, Child Youth. Environ. 33 (2) (2023) 130–152.

[48] M. Manso, J. Castro-Gomes, Green wall systems: A review of their characteristics, Renewable and Sustainable Energy Reviews 41 (2015) 863–871.

[49] A. Maron, F. Ramirez, Social Perception of Living Walls in Quito: A Study of Four Vertical Gardens, IOP Conf. Ser. Earth Environ. Sci. 503 (2020) 012095.

[50] M. Masullo, A. Ozcevik Bilen, R.A. Toma, G. Akin Guler, L. Maffei, The Restorativeness of Outdoor Historical Sites in Urban Areas: Physical and Perceptual Correlations, Sustainability. 13 (2021) 5603.

[51] C. Matos Silva, F. Bernardo, M. Manso, I. Loupa Ramos, Green Spaces over a Roof or on the Ground, Does It Matter? The Perception of Ecosystem Services and Potential Restorative Effects, Sustainability. 15 (2023) 5334.

[52] I. Mell, Examining the Role of Green Infrastructure as an Advocate for Regeneration, Front. Sustain. Cities 4 (2022) 731975.

[53] M.B. McCullough, M.D. Martin, M.A. Sajady, Implementing Green Walls in Schools, Front. Psychol. 9 (2018) 619.

[54] Z. Minova, A. Turcovská, P. Kapalo, Z. Vranayova, The Effect of Green Walls on Humidity, Air Temperature, Co2 and Well-Being of People, Environ. Sci. Proc. 2 (1) (2020) 56.

[55] A.V. Mirti Chand, Place Based Approach to plan for Resilient Cities: a local government perspective, Procedia Eng. 212 (2018) 157–164.

[56] K. Mouratidis, W. Poortinga, Built environment, urban vitality and social cohesion: Do vibrant neighborhoods foster strong communities? Landsc. Urban. Plan. 204 (2020) 103951.

[57] M.M. Nevárez-Favela, J.C. García-Albarado, A. QuevedoNolasco, A. López-Pérez, M.A. Bolaños-González, Perception of green infrastructure systems: green walls and green roofs, Agrociencia 57 (8) (2023) 1746–1759.

[58] A. Ode Sang, P. Thorpert, A.M. Fransson, Planning, Designing, and Managing Green Roofs and Green Walls for Public Health – An Ecosystem Services Approach, Front. Ecol. Evol. 10 (2022).

[59] V. Oquendo-Di Cosola, F. Olivieri, L. Ruiz-García, A systematic review of the impact of green walls on urban comfort: temperature reduction and noise attenuation, Renewable and Sustainable Energy Reviews 16 (2022) 112463.

[60] J. Parker, G.D. Simpson, Public Green Infrastructure Contributes to City Livability: A Systematic Quantitative Review, Land. (Basel) 7 (4) (2018) 161.

[61] M. Pasini, R. Berto, M. Brondino, R. Hall, C. Ortner, How to Measure the Restorative Quality of Environments: The PRS-11, Procedia - Social and Behavioral Sciences 159 (2014) 293–297.
[62] S.R. Payne, C. Guastavino, Exploring the Validity of the Perceived Restorativeness Soundscape Scale: A Psycholinguistic Approach, Front. Psychol. 9 (2018) 2224.
[63] F. Pazzaglia, L. Tizi, Che Cos'è Il Restorative Design, Carocci Editore, Roma, 2022.
[64] L. Péréz-Urréstarazu, Building integrated vegetation systems – another way for greening densely built cities, Acta Hortic. 1374 (2023) 1–13.
[65] L. Pérez-Urrestarazu, R. Fernández-Cañero, A. Franco-Salas, G. Egea, Vertical Greening Systems and Sustainable Cities, J. Urban. Technol. 22 (4) (2015) 65–85.
[66] K. Perini, M. Ottelé, Designing Green Façades And Living Wall Systems For Sustainable Constructions, Int. J. of Design & Nature and Ecodynamics 9 (1) (2014) 31–46.
[67] K. Perini, M. Ottelé, E. Haas, R. Raiteri, Vertical greening systems, a process tree for green façades and living walls, Urban. Ecosyst. 16 (2) (2013) 265–277.
[68] K.K. Peschardt, U.K. Stigsdotter, Associations between park characteristics and perceived restorativeness of small public urban green spaces, Landsc. Urban. Plan. 112 (2013) 26–39.
[69] T. Pettit, P. Irga, N. Surawski, F. Torpy, An assessment of the suitability of active green walls for NO2 reduction in green buildings using a closed-loop flow reactor, Atmosphere (Basel) 10 (12) (2019).
[70] In: J. Rocha, M. Costa, Urban vitality in Madureira: Field observation and recording (eds), in: P. Janeiro (Ed.), Drawing (...) City (...) Body, Dwelling on Earth Imagined-Architectures: Architectural Graphic Representation and Other Images, Routledge, London, 2019.
[71] A. Salisbury, T. Blanusa, H. Bostock, J.N. Perry, Careful plant choice can deliver more biodiverse vertical greening (green façades), Urban. For. Urban. Green. 89 (2023).
[72] K. K. Sangha, I.J. Gordon, R. Costanza, Ecosystem Services and Human Wellbeing-Based Approaches Can Help Transform Our Economies Front. Ecol. Evol. 10 (2022) 841215.
[73] L. Schibuola, C. Tambani, A monthly performance comparison of green infrastructures enhancing urban outdoor thermal comfort, Energy Build. 273 (2022) 112368.
[74] R. A. Sedghikhanshir, Y. Zhu, M. Beck, A. Jafari, The Impact of Visual Stimuli and Properties on Restorative Effect and Human Stress: A Literature Review Buildings 12 (11) (2022) 1781.
[75] E. Sella, C. Meneghetti, V. Muffato, E. Borella, E. Carbone, R. Cavalli, F. Pazzaglia, The influence of individual characteristics on perceived restorativeness and benefits associated with exposure to nature in a garden, Front. Psychol. 14 (2023) 1130915.
[76] J. Simkin, A. Ojala, L. Tyrväinen, The Perceived Restorativeness of Differently Managed Forests and Its Association with Forest Qualities and Individual Variables: A Field Experiment, Int. J. Environ. Res. Public Health 18 (2021) 422.
[77] N. Shushunova, E. Korol, E. Luzay, D. Shafieva, P. Bevilacqua, Ensuring the Safety of Buildings by Reducing the Noise Impact through the Use of Green Wall Systems, Energies. (Basel) 15 (2022) 8097.
[78] M. Soga, K.J. Gaston, Global synthesis reveals heterogeneous changes in connection of humans to nature, One Earth. 6 (2) (2023) 131–138.
[79] S. Sugandha, R. Freestone, P. Favaro, The social sustainability of smart cities: A conceptual framework, City Culture and Society 29 (1) (2022) 100460.
[80] R. Sutton, Aesthetics for green roofs and green walls, Journal of Living Architecture 1 (2) (2014) 1–20.
[81] O. Tarboush, B. Asilsoy, Ç. Çağnan, Evaluation of perception with regards to green wall systems application in Nicosia, N. Cyprus, International Journal of Advanced and Applied Sciences 7 (3) (2020) 24–36.
[82] I. Teotonio, C. Matos Silva, C. Oliveira Cruz, Economics of green roofs and green walls: A literature review, Sustain. Cities. Soc. 69 (2021) 102781.
[83] P.; Tiago, A.I. Leal, C. Matos Silva, Assessing Ecological Gains: A Review of How Arthropods, Bats and Birds Benefit from Green Roofs and Walls, Environments. 11 (4) (2024) 76.
[84] S. Timm, L. Dearborn, J. Pomeroy, Nature and the City: Measuring the Attention Restoration Benefits of Singapore's Urban Vertical Greenery, Technology Architecture and Design 2 (2018) 240–249.
[85] M. Tomson, P. Kumar, K.V. Abhijith, J.F. Watts, Exploring the interplay between particulate matter capture, wash-off, and leaf traits in green wall species, Science of the Total Environment (2024) 921.
[86] M. Treder, V. Joedeck, K. Schweikert, P. Rosenkranz, U. Ruttensperger, K. Traynor, Vertical greening systems serve as effective means to promote pollinators: Experimental comparison of vertical and horizontal plantings, Landsc. Urban. Plan. 243 (2024) 104951.
[87] United Nations General Assembly (2015). Transforming our world: The 2030 agenda for sustainable development. Retrieved from http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.
[88] A. Van den Berg, From Green Space to Green Prescriptions: Challenges and Opportunities for Research and Practice, Front. Psychol. 8 (2017) 268.
[89] N. van den Bogerd, S.C. Dijkstra, K. Tanja-Dijkstra, M.R. de Boer, J.C. Seidell, S. L. Koole, J. Maas, Greening the classroom: Three field experiments on the effects of indoor nature on students' attention, well-being, and perceived environmental quality, Build. Environ. 171 (2020) 106675.
[90] M. van Dinter, M. Kools, G. Dane, M. Weijs-Perrée, K. Chamilothori, E. van Leeuwen, A. Borgers, P. van den Berg, Urban Green Parks for Long-Term Subjective Well-Being: Empirical Relationships between Personal Characteristics, Park Characteristics, Park Use, Sense of Place, and Satisfaction with Life in The Netherlands, Sustainability. 14 (9) (2022) 4911.
[91] G. Vox, I. Blanco, E. Schettin, Green façades to control wall surface temperature in buildings, Build. Environ. 129 (2018) 154–166.
[92] S. Wang, A. Li, Demographic Groups' Differences in Restorative Perception of Urban Public Spaces in COVID-19, Buildings 12 (2022) 869.
[93] S. Xiaoxue, X. Huang, Promoting stress and anxiety recovery in older adults: assessing the therapeutic influence of biophilic green walls and outdoor view, Front. Public Health (2024).
[94] S. Yau-Huo, R. Ready, B. Orland, S. Echols, How Do Visual Representations Influence Survey Responses? Evidence from a Choice Experiment on Landscape Attributes of Green Infrastructure, Ecological Economics 156 (2019) 375–386.
[95] S. Yeom, H. Kim, T. Hong, Psychological and physiological effects of a green wall on occupants: A cross-over study in virtual reality, Build. Environ. 204 (2021) 108134.
[96] J. Zhao, Q. Rao, C. Sun, R.M.A. Ikram, C. Fan, J. Li, M. Wang, D. Zhang, A Systematic Review of the Vertical Green System for Balancing Ecology and Urbanity, Water. (Basel) 16 (2024) 1472.
[97] J. Ziesel, Inquiry By design: Tools for Environment-Behavior Research, Brooks/Cole Pub. Co., Salt Lake City, 1981.
[98] N. Takayama, A. Fujiwara, H. Saito, M. Horiuchi, Management Effectiveness of a Secondary Coniferous Forest for Landscape Appreciation and Psychological Restoration, Int. J. Environ. Health Res. 14 (7) (2017) 800, https://doi.org/10.3390/ijerph14070800.
[99] H. Akoglu, User's guide to correlation coefficients, Turkish journal of emergency medicine 18 (3) (2018) 91–93, https://doi.org/10.1016/j.tjem.2018.08.001.
[100] K.S. Taber, The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education, Res. Sci. Educ. 48 (2018) 1273–1296, https://doi.org/10.1007/s11165-016-9602-2.
[101] B. MHernandez, C. Hidalgo, R. Berto, E. Peron, The Role of Familiarity on the Restorative Value of a Place: Research on a Spanish Sample, IAPS Bull. Environ. Cogn. Mem. Mimma Peron. 18 (2001) 22–24.
[102] R Berto, M. Pasini, G. Barbiero, How does Psychological Restoration Work in Children? An Exploratory Study, J. Child Adolesc. Behav. 3 (2015) 200, https://doi.org/10.4172/2375-4494.1000200.
[103] Y Yin, Y. Shao, Y. Meng, Y. Hao, The effects of the natural visual-aural attributes of urban green spaces on human behavior and emotional response, Front. Psychol. 14 (2023) 1186806, https://doi.org/10.3389/fpsyg.2023.1186806.
[104] M. Kim, T.H.T. Gim, J.S. Sung, Applying the concept of perceived restoration to the case of Cheonggyecheon stream park in Seoul, Korea, Sustainability 9 (2017) 1368.
[105] P. Kuldna, H. Poltimäe, H. Tuhkanen, Perceived importance of and satisfaction with nature observation activities in urban green areas, J. Outdoor Recreat. Tour. 29 (2020) 100227.