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Psychological restoration in urban gardens related to garden type, biodiversity and garden-related stress

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A B S T R A C T

In the context of increasing urbanization, gardens as a form of urban greenspace are an important resource for the psychological restoration of urban dwellers, while underpinning urban biodiversity and delivering ecosystem services. However, the links between restoration, garden type and biodiversity are not fully understood. In this interdisciplinary study we aimed to identify how the self-reported restoration of gardeners was related to three factors: garden type (domestic vs. allotment gardens), number of plant species in the garden (a dimension of biodiversity) and garden-related stress for gardeners. We analyzed cross-sectional data of approx. 300 leisure gardeners in the city of Zurich, Switzerland, using an analysis of spatial autocorrelation, t-tests of differences of means between garden types and a structural equation model (SEM).

The results indicated that being an allotment gardener was associated with higher levels of restoration compared to domestic gardeners. The SEM suggested that restoration was positively related to the number of plant species by way of the perceived restorativeness of the garden. Garden-related stress or negative affect occurred among a number of gardeners and was negatively related to the restoration outcome. This suggests that the negative effects of gardening should be considered in future studies on greenspace and restoration.

In the face of shrinking urban greenspace, our study suggests that urban planners could better utilize the benefits of urban gardens, e.g. to reduce income-related health inequalities by providing gardens to residents with lower socio-economic status or to address public health and ecological issues by promoting plant-species rich gardens.

1. Introduction

As more people live in urbanized surroundings (United Nations, 2014), urban greenspaces offer residents increasingly important opportunities for recreation and restoration. Urban greenspaces are of major importance for a broad range of public health issues (Frumkin et al., 2017; Tzoulas et al., 2007), including stress reduction and the restoration of cognitive resources (Hartig, 2004). In many cities, domestic gardens (i.e. gardens which belong to single-occupancy houses) and allotment gardens (i.e. publicly provided gardening lots) constitute a large proportion of greenspace (Dewaelheyns, Gulinck, & Rogge, 2014), potentially making them important sites for psychological restoration. However, while the relevance of gardens for restoration has been analyzed, the influence of different forms and characteristics of gardens has not been sufficiently studied. In this interdisciplinary study combining perspectives from environmental psychology and urban ecology, we examine which characteristics of gardens contribute to the restoration of garden users.

In current European contexts where allotment gardens particularly are often under pressure from real-estate development (Haaland & van den Bosch, 2015) and loss of greenspace is a problem, identifying synergies among the restorative, social and ecological functions of urban greenspaces could help shape planning policies. One area with a potential for synergies is biodiversity. While urban greenspaces can harbor surprisingly high levels of biodiversity and provide essential ecosystem services in cities (Hall et al., 2017; Sattler, Arlettaz, Duelli, Moretti, & Obrist, 2010), research also suggests that higher biodiversity of greenspaces such as parks has a positive impact on restoration outcomes of users (Carrus et al., 2015; Fuller, Devine-Wright, Gaston, Irvine, & Warren, 2007). If this is also true for gardens, promoting biodiversity (such as the number of plant species) in gardens would fulfill multiple policy goals of cities. More generally, identifying which characteristics of gardens are conducive to restoration (and possibly offer synergies with other policy objectives) can help focus efforts to

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provide urban residents with garden spaces that generate the greatest benefits in regard to health, community building, wildlife conservation and other areas.

1.1. Theories of stress and restoration in greenspaces

Environmental psychology provides two particularly prominent theoretical frameworks for the positive effect of greenspace on well-being (Berto, 2014). The psycho-evolutionary Stress Recovery Theory asssumes that humans have a biologically determined propensity to show two responses to nature contact: a) preference for and attention to natural settings and b) restoration after stressful events (Ulrich et al., 1991). Attention Restoration Theory (Kaplan & Kaplan, 2005; Kaplan, 1995) suggests that greenspace ideally fulfills the conditions required for restoring the capacity for paying attention to cognitively demanding tasks (i.e. *directed* attention) by triggering effortless, *undirected* attention. Stress recovery and attention restoration, while distinct processes, share many features and both can be promoted by exposure to greenspaces (Li & Sullivan, 2016; von Lindern, Hartig, Bauer, Hunziker, & Frick, 2013). In this paper we employ a broad restoration concept encompassing both processes, rather than distinguishing between them.

The Perceived Restorativeness Scale (PRS) is often used to measure the restorative characteristics of a space. It distinguishes three dimensions of restorativeness: being away, fascination and compatibility (and others we do not discuss; Hartig, Korpela, Evans, & Garling, 1997, Kaplan, 1995). Hartig et al. (1997:176) note three aspects of being away: "One is to escape from unwanted distractions in the surroundings. Another is to distance oneself from one's usual work and reminders of it. The third is to suspend the pursuit of purposes." Geographical distance from everyday environments *per se* is neither a sufficient nor a necessary condition, but geographical distance can incur psychological distance from everyday distractions or worries, leading to a sense of being away (Hartig et al., 1997). A central aspect of the sense of being away is the *contrast* between environments (Hartig, 2004: 274), thus natural environments are often restorative for urban residents. Natural settings can also induce fascination or "effortless attention" (Kaplan, 1995:172). While some environmental cues (danger, blood) lead to "hard fascination", non-spectacular natural settings offer (the more restorative) "soft fascination" (Kaplan, 1995:170-172). Finally, compatibility means that the setting fits to the activity one is inclined to engage in, which implies such things as appropriate infrastructure and that the environment is easy to read and understand (Kaplan, 1995:173). Greenspaces and gardens can be called restorative to the extent they are perceived by users to feature these qualities. To clarify the distinction used in this study, the concept of perceived restorativeness captures the extent to which a scene is deemed to be restorative (thus answering a hypothetical question), while self-reported restoration captures a state a person is in, namely to which degree they currently experience the restorative effects of a scene or (when used in a summarizing, retrospective way) it captures the state a person habitually experienced after the factual contact with the respective scene.

1.2. Empirical evidence of the effects of greenspace on restoration

A wealth of studies gives empirical evidence of positive effects of nature contact on mental health, stress reduction and attention restoration (e.g. Alcock, Depledge, Fleming, Wheeler, & White, 2014, Ward Thompson et al., 2012, Mitchell & Popham, 2008). Exposure to greenspace is shown to be related to better recovery from stress and higher positive affect (Hartig, Davis, Evans, Gärling, & Jamner, 2003; Ulrich et al., 1991; van den Berg, Jorgensen, & Wilson, 2014), as well as to attention restoration (Hartig et al., 2003; van den Berg et al., 2014). Reviews take the evidence for an effect of nature on restoration to be strong (Berto, 2014; Hartig, Mitchell, Frumkin, & de Vries, 2014; Health Council of the Netherlands, 2004; Soga, Gaston, & Yamaura, 2017).

Many studies have focused on the antecedants and effects of perceived restorativeness and its dimensions. Von Lindern and co-authors have shown that similarities between a demanding environment and a restorative environment reduce the sense of being away, meaning people who work in natural environments have more difficulty relaxing there (von Lindern et al., 2013; von Lindern, 2017). Regarding fascination, one characteristic of natural scenes conducive to soft fascination and restorativeness is their visual complexity, particularly fractal-like complexity (Joye, Pals, Steg, & Unal, 2016; Van den Berg, Joye, & Koole, 2016). A few studies suggest a positive effect of PRS-dimensions (i.e. dimensions of the restorativeness of a space) on overall restoration and on physiological measures which imply restoration (Chang, Hammitt, Chen, Machnik, & Wei-Chia, 2008; von Lindern et al., 2013).

1.3. Biodiversity and restoration

A small number of studies attempt to test the association between the biodiversity of greenspaces (defined mostly as the number of species in that space) and restoration and well-being. The evidence is mixed. Natural images with higher biodiversity as opposed to those with lower biodiversity have been shown to be associated with brain activity patterns which suggest greater attention (Johansson, Gyllin, Küller, & Witzell, 2014) and thus higher fascination. The number of plant species in greenspaces is shown to be positively associated to "reflection", "distinct identity" (Fuller et al., 2007) and well-being of users (Carrus et al., 2015), but to be negatively related to well-being in another study (Dallimer et al., 2012). Carrus et al. (2015) also establish a link between the level of plant diversity and perceived restorativeness, which mediates self-reported psychological benefit. Perceived species richness of birds has been linked positively both to well-being (Dallimer et al., 2012), attachment (Fuller et al., 2007) and to negative emotions (Marselle, Irvine, Lorenzo-Arribas, & Warber, 2015). Fuller et al. (2007), who examine associations between psychological benefits and plant, bird and butterfly species richness, find stronger support for an effect of the number of plant species than for other taxons. They note that study participants had more accurate perceptions of plant species richness than of bird or butterfly richness, which are generally less easy to observe. This suggests that perception may drive the beneficial effect of plant species richness (Fuller et al., 2007). As far as we know there are no studies so far examining the effects of biodiversity on urban garden users as opposed to users of other greenspaces.

1.4. Restoration and stress in urban gardens

Far less work has been published on whether *gardens* rather than greenspace in general have positive effects on restoration. In descriptive studies, gardeners (we use the term 'gardener' to refer to garden users who tend their own garden, not to professional gardeners) report perceived psychological health benefits and describe the garden as a place of relaxation and escape from work or everyday problems, which resonates with the "being away" concept (Freeman, Dickinson, Porter, & van Heezik, 2012; Gross & Lane, 2007). Van den Berg, de Vries, van Dillen, and van Winsum-Westra (2010) present evidence for significantly higher health and well-being for a sample of allotment gardeners as opposed to non-gardeners living nearby. Socio-demographic variables have been shown to be associated with well-being outcomes and garden use. Age moderates the effects of gardening on the well-being of allotment gardeners with stronger effects for older gardeners (van den Berg et al., 2010), while the use and meaning of a domestic garden changes with age (Gross & Lane, 2007). Also, Cervinka et al. (2016) suggest that perceived restorativeness of gardens is lower for men than for women.

To our knowledge, the question whether allotments provide more or less restoration than domestic gardens has rarely been discussed (Cervinka et al., 2016; Milligan, Bingley, & Gatrell, 2004). Differences regarding ownership, geographical location and social organization of

these garden types may influence the mechanisms of restoration. As allotment gardens are at a distance from the home, the being away experience may be stronger among allotment gardeners, similar to the negative effects of interdependencies between work and leisure environments described above (von Lindern, 2017).

Van den Berg and Custers (2011) show that short-term stress (measured by salivary cortisol levels and self-reporting) is reduced significantly more by a gardening activity than by a control activity such as recreational reading. Stigsdotter and Grahn (2004) present evidence that domestic gardens reduce stress levels of their users. On the other hand, everyday experience suggests that a garden may constitute a stressor in itself. Many gardening tasks are determined by season and weather conditions and can therefore not be postponed indefinitely, potentially causing stress. We assume garden-related stress to be driven by the desire to conform to social norms of tidiness and to keep pace with gardening tasks. As Nassauer, Wang, and Dayrell (2009) show, social norms have a distinct effect on how people take care of a garden. Social norms may be stricter in the allotment garden communities with their more order-oriented norms than among domestic gardeners. However, there seems to be no research on garden-related stress, though see Milligan et al. (2004).

1.5. Research questions

Against this background, the present paper aims to answer the following research questions (RQs). First, are there differences between allotment and domestic gardeners regarding their levels of self-reported restoration (RQ 1a)? Furthermore, are there differences between users of the two garden types regarding levels of perceived restorativeness and its constituting variables, which might suggest possible causal mechansims between garden type and self-reported restoration (RQ 1b)? We expect garden type to influence self-reported restoration and perceived restorativeness and the sense of being away to be stronger among allotment gardeners. We also expect the level of garden-related stress to be higher among allotment gardeners, as we assume norms and their sanctioning to be more pronounced in allotment gardens.

Second, is the number of plant species, as a dimension of biodiversity, positively related to self-reported restoration of gardeners (RQ 2a)? Also, is the number of plant species related to perceived restorativeness and its constituting variables (RQ 2b)? We expect the number of plant species to have a positive association with self-reported restoration, perceived restorativeness and the fascination dimension of perceived restorativeness, suggesting a causal mechanism between the number of plant species and self-reported restoration.

Third, do gardeners experience the garden as a source of stress and how is stress related to self-reported restoration (RQ 3)? We expect garden-related stress to be negatively related to self-reported restoration.

2. Methods

This study was part of a larger project which examined several issues regarding social and ecological benefits of urban gardens. A randomly drawn sample of domestic and allotment gardeners was surveyed in Zurich, Switzerland using a questionnaire which included the variables used for the research questions we discuss here as well as variables regarding other research questions within the project. Zurich has approx. 400,000 inhabitants, placing it in the most common city-size class globally (United Nations, 2014). It is the center of the largest Swiss metropolitan agglomeration, which comprises about 1.3 million inhabitants (Federal Statistical Office, 2017). In Zurich, domestic gardens cover approx. 11% of settlement area and 25% of urban greenspace, while the 5,500 allotments cover approx. 3% of settlement area and 7% of urban greenspace (Grün Stadt Zürich, 2010; settlement area is the area of the municipality of Zurich excluding forests, agricultural land and water bodies). While domestic gardens provide private greenspace to those who can afford to buy or rent a house with a garden, allotments offer a gardening space for those who live in apartment accommodation, which is around 90% of Zurich's population. Allotment gardeners in Switzerland generally belong to a working-class, lower income, partly immigrant population (Frauenfelder, Delay, & Scalambrin, 2015; Table 3), though recently this has started to change as allotments become popular among more qualified and affluent social classes (Young, Frey, Moretti, & Bauer, 2019).

2.1. Sampling and surveying

Our sampling universe consisted of people with a domestic or an allotment garden in the city of Zurich. We considered a domestic garden to be a garden directly adjacent to a single-occupancy house, accessible only to its occupants. Our definition of allotment gardens encompassed gardens on land owned by the city, managed by associations and leased to gardeners for exclusive use in lots of 100 m^2 to 200 m^2, which is the typical allotment size in Zurich. In allotment gardens, formal rules prohibit many practices, such as the cultivation of plant species considered to be invasive, the construction of garden huts beyond a certain size, or living on the allotment.

We collected two sub-samples of the gardener population, one of allotment gardeners, one of domestic gardeners. The sample of allotment gardens was drawn in a two-stage probability-proportional-to-size sampling procedure (Schnell, Hill, & Esser, 1999) using maps showing each allotment which led to the selection of 225 allotment gardens. The response rate was 48%, resulting in a sample of 108 allotment gardeners. Our sample of domestic gardeners was drawn by the City of Zurich as a random sample from the total of individuals living in Zurich in a residential building occupied by only one household. This resulted in 743 addresses (see the supplementary online material for more details on sampling). The response rate was 27%, i.e. 202 cases. Among these, 9 respondents did not have a garden or did not tend to their garden themselves and were excluded. This resulted in a sample of domestic gardeners consisting of 193 persons.

We used distinct surveying strategies to take account of the specific characteristics of the two subpopulations. Surveying allotment gardeners is a challenge as the population includes many people with limited language skills in the local language (German) and little formal education. To ensure as representative a sample as possible, we used face-to-face surveying in the allotment grounds. We provided our 12-page questionnaire in German, Italian, Portuguese (languages commonly spoken by allotment gardeners) and French and employed multilingual surveyors. Questionnaires were translated from the German original. Surveying of allotments took place from August to October 2016 after prior agreement with the association officials. Participation was strictly voluntary. Surveyors visited the selected 225 allotments up to 15 times until they met someone on the allotment and could ask them to participate. At the 15th attempt and sometimes prior to that, a letter inviting participation and a questionnaire were left at the allotment. 19 allotment gardeners returned a questionnaire by post, the rest were interviewed on site. During face-to-face surveying, surveyors gave respondents the option to fill in the 12-page questionnaire themselves or to answer it in an interview situation where the surveyors read out the questions and filled in the questionnaire. Only one person per allotment garden was interviewed. Domestic gardeners were contacted by mail. They received the same questionnaire as allotment gardeners with minor adaptations, a postage-paid return envelope and a letter asking for the adult household member who tended the garden to fill in the questionnaire (if more than one person corresponded to this description, we asked for that person to respond whose birthday had occurred last). Respondents were also given the opportunity to receive the questionnaire in Italian, Portuguese or French if they preferred, rather than the German version they received initially.

Table 1
List of explanatory variables.

Variable	Measurement scale(s)
Perceived restorativeness	5-point Likert scales
Fascination	5-point Likert scales
Being away	5-point Likert scale
Compatibility	5-point Likert scales
Garden type	Dummy variable
Garden-related stress	5-point Likert scale
Number of plant species	Composite variable
Preference for tidiness of the garden	5-point Likert scale
Frequency of visits to the garden	5-point scale
Control variables	
Preference for biodiversity	5-point Likert scales
Age	8-point scale (10-year steps)
Gender	Dummy variable
Educational attainment	7 options
Employment status	Dummy variable
Job status	4-point ordinal scale

2.2. The outcome variable: self-reported restoration

Self-reported restoration, our dependent variable, was measured with a single item, as von Lindern et al. (2013) did. Participants indicated how rested they felt after having been in the garden on a five-point scale with the values "less rested than before", "neither more nor less rested", "a little more rested", "more rested", "much more rested". A "don't know" category was also offered and subsequently coded as missing.

2.3. Explanatory variables

Our study used a number of explanatory variables (listed in Table 1). The perceived restorativeness scale, one of our core explanatory variables, was applied with a reduced number of five items due to space constraints in the questionnaire. One item was used for the being-away dimension ("My garden gives me a good break from my day-to-day routine."), two for the fascination dimension (e.g. "In my garden my attention is drawn to many interesting things.") and two for the compatibility dimension (e.g. "I have a sense of oneness with my garden"). These were all measured on five-point Likert scales of dis/agreement ranging from "strongly agree" to "strongly disagree" (Cervinka et al., 2016; Hartig et al., 1997). Note that all questions and scales were worded in German initially and are given here as translations. The PRS dimension "extent/coherence" was omitted. For the descriptive statistics, perceived restorativeness, fascination and compatibility were calculated as additive indexes as explained here, whereas in the SEM they were calculated within the model as latent variables.

Garden-related stress was measured with a single item "I often feel under pressure when I think of the tasks that need doing in my garden." on a five-point Likert scale ("strongly agree" to "strongly disagree"). The aim was to measure stress caused by the responsibilities the garden incurs, as opposed to aspects such as neighbors.

A unique characteristic of our study is the way we estimated the number of plant species of each garden using two visual questions. Respondents indicated the presence/absence of 16 land-use types and garden features (e.g. lawn or pond) as well as assessing the similarity of their garden to illustrations which depicted different levels of the number of plant species. The predictive power of these variables was tested in a pilot study where the responses of 83 gardeners (not from our sample) were used to fit a multiple linear regression model to the actual number of plant species in their garden, which in turn was determined based on an exhaustive botanical survey Frey and Moretti (2019). A detailed description of this assessment method is given in Young et al. (2019).

Garden type was a simple dummy variable with the values 1 for allotment gardens and 0 for domestic gardens. We measured a preference for the tidiness of the garden with a single item ("It's important to me for my garden to look tidy.") on a 5-point Likert scale of dis/agreement. The frequency of visits to the garden was measured on a 5-point ordinal scale with the categories "daily", "several times a week", "once a week", "2–3 times a month" and "less frequently".

The variable indicating a preference for biodiversity was measured as an additive index of two items (e.g. "Having different plant and animal species in my garden is important to me."), each using a 5-point Likert scale of dis/agreement.

Job status level was measured as the level of marketable skills according to Oesch (2006), from low (e.g. machine operators, call center employees or shop assistants) to high (e.g. lawyers, mechanical engineers or journalists). The higher the level of the variable, the more the respondent's jobs skills are in demand on the labor market. Following Oesch (2006), we used this variable as a rough proxy for social class. In general, the social status associated with the job and the wage payed will correlate positively with the level of marketable skills. Educational attainment was measured with seven options and summarized in the four categories "compulsory education or less", "vocational education" (apprenticeships and similar), "post-secondary education" (baccalaureate and similar) and "tertiary education". We also included age, gender (male/female) and employment status (currently in employment or not) as control variables. More details on the variables are given in the supplementary online material (section S2).

2.4. Data analysis

We considered spatial effects on restoration, i.e. that the location of the garden was correlated with the level of self-reported restoration. This could be the case if certain spatial clusters of gardens were more restorative due to the fact that the area of Zurich they were in had for example less traffic or more general greenery. Potential spatial autocorrelation in the response variable (i.e. self-reported restoration), for each garden type separately and overall, was investigated by computing Moran's *I* autocorrelation indices and by using semivariograms (Pepesma, 2004; Popescu, Huber, & Paradis, 2012). As the exact locations of domestic gardens were not available, we generated a random point for each domestic garden within the postal code area it was located in to be able to analyze spatial autocorrelation. Similarly, random points for allotment gardens were generated within the allotment garden zone the garden was known to be located in.

In the next step, we examined differences between garden types regarding self-reported restoration, being away and garden-related stress. For this we looked at the distribution of Likert scores and performed Welch two-sided *t*-tests of the means.

The final step of analysis was to employ a structural equation model (SEM) to test for effects of garden type, biodiversity and garden-related stress on self-reported restoration in the garden, as SEMs allow the inclusion of latent variables and the examination of indirect effects (Kaplan, 2009). The model was calculated with the R package lavaan (Rosseel, 2012). We treated variables based on Likert-scales as continuous variables which is valid as Rhemtulla, Brosseau-Liard, and Savalei (2012) show. As tests showed that multivariate normality was not given in our data, we used a robust maximum-likelihood estimator (MLR) which calculates Huber-White robust standard errors. We dealt with missing values in the dataset by using full-information maximum likelihood (FIML) estimators. The variable with most missings was the level of job status (9%), followed by the item "I have a sense of oneness with my garden" (3%).

In the course of SEM specification, we first specified a measurement model for the latent variable perceived restorativeness and its three dimensions (fascination, being away and compatibility) using FIML and MLR (see supplementary online material for details). We then fitted the SEM with all the variables suggested by our hypotheses and theory,

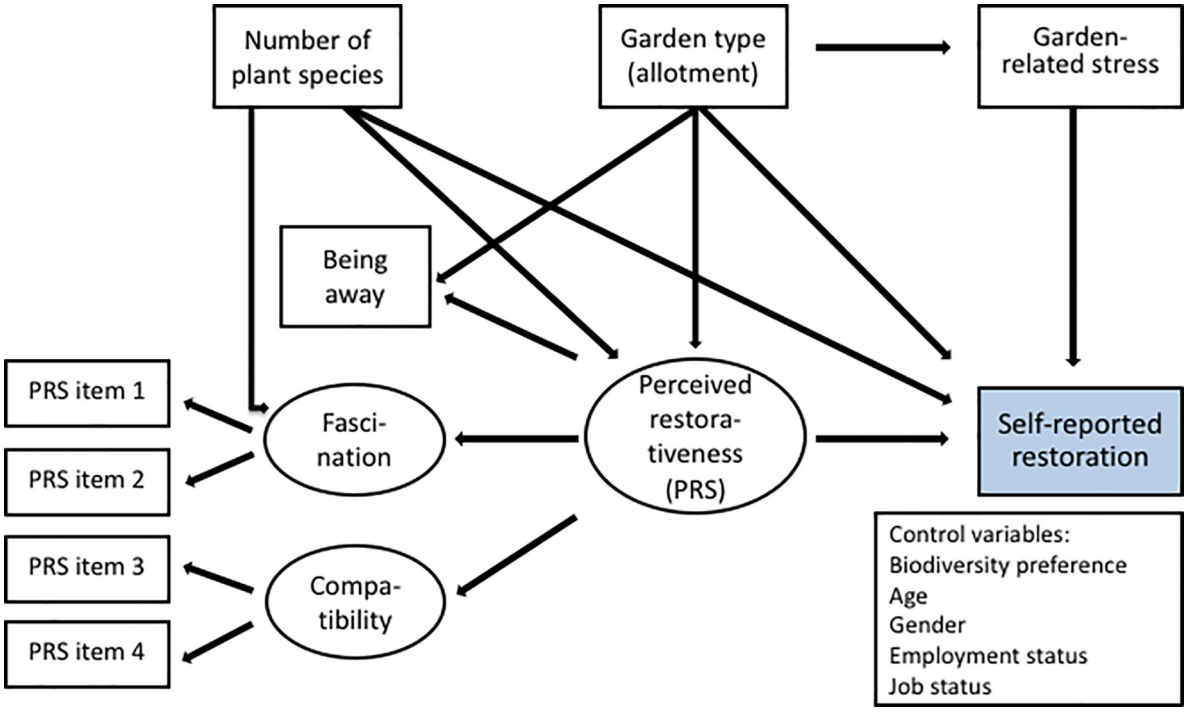

Fig. 1. Structural equation model. Observed variables are displayed in rectangular shapes, latent variables in oval shapes. Control variables are noted, but not shown in place, as this is not possible in this figure. See Table S2 in the supplementary online material for the exact specification of the model.

resulting in the proposed model as displayed in Fig. 1. To check robustness of results this model was reconstructed stepwise starting from a minimal model.

We were interested in the total and indirect effects of garden type and number of plant species on self-reported restoration, as well in 8 direct associations between concepts as shown in Table 2. The control variables age, sex, employment status and job skill level were included where the effect of garden type on the dependent variable was of interest (see equations 1, 2, 4 and 5 in Table S2 in the supplementary online material). This was done to control for the differences we identified between the two subsamples in regard to these socio-economic variables (see sample descriptives in Table 3).

Where the association of the number of plant species with the dependent variable was of interest a further control variable biodiversity preference was included (See equations 1, 2 and 3 in Table S2 in the supplementary online material). The rationale for this was that a higher number of plant species might improve psychological outcomes (restoration, restorativeness, fascination) to a greater extent for respondents who consciously value biodiversity. The aim was to control for this potential preference effect.

3. Results

3.1. Sample

The sample used for this study consisted of 301 cases. The two subsamples, allotment and domestic gardeners, displayed a number of substantial differences regarding socio-economic characteristics (see Table 3). Compared to the domestic gardeners, allotment gardeners were on average more likely to be men, were older, had less formal education and worked (or had worked) in lower-skill employment and thus could be assumed to have a less advantaged class position. They were also more likely to not be employed (mainly retired) and to have non-Swiss nationality or place of birth than domestic gardeners.

Though the location of respondents' gardens was not recorded exactly, the postal code area for each garden was available. In Fig. 2, the spatial distribution of the surveyed gardens by postal code area is shown separately for the two garden types.

Table 2
Associations of interest in the SEM.

Hypotheses regarding indirect and total effects		relates to research question no.
H1	Garden type – > self-reported restoration (+/-)	RQ 1a
H2	Number of plant species – > self-reported restoration (+)	RQ 2a
Hypotheses regarding direct effects		
H3	Garden type – > self-reported restoration (+/-)	RQ 1a
H4	Garden type – > perceived restorativeness (+/-)	RQ 1b
H5	Garden type – > being away (+)	RQ 1b
H6	Number of plant species – > self-reported restoration (+)	RQ 2a
H7	Number of plant species – > perceived restorativeness (+)	RQ 2b
H8	Number of plant species – > fascination (+)	RQ 2b
H9	Garden-related stress – > self-reported restoration (-)	RQ 3
*H*10	Garden type – > garden-related stress (+)	RQ 1b

(+) indicates we expected a positive and (-) a negative association. (+/-) indicates we had no hypothesis as to whether the effect would be negative or positive. The variable "Garden type" takes on the value 1 for allotment gardens, 0 for domestic gardens.

Table 3
Socio-economic characteristics of the sample.

	Allotment gardeners	Domestic gardeners	*t*-test for difference of means	
			T	*p*
N	108	193		
Women	48%	67%	3.2298	0.0014
Average age (years)	59	54	−2.877	0.0044
Educational attainment: vocational	31%	30%	−0.1788	0.8582
Educational. attainment: tertiary	29%	42%	2.3654	0.0189
In employment	51%	73%	3.8563	< 0.0001
Low/unskilled employment	21%	5%	−3.9782	0.0001
Swiss nationality	65%	93%	5.6015	< 0.0001
Born in Switzerland	48%	81%	5.7476	< 0.0001

Note: The table gives the percentage of each subsample (i.e. allotment or domestic gardeners) which falls into the respective category, e.g. 48% of allotment gardeners are women, while 67% of domestic gardeners are women. *t* and *p* refer to values from Welch's unequal variance *t*-test.

3.2. Analysis of spatial effects

As can be seen in Fig. 2, domestic gardens were distributed across the city in a fairly uniform fashion, while allotment gardens were surveyed in roughly half the postal code areas of the city. We detected no spatial autocorrelation of our outcome variable, self-reported restoration. The visual inspection of semivariograms for all gardens as well as for the two garden types separately did not reveal any values far below 1, i.e. values suggesting autocorrelation. A Moran's *I* test for all gardens did not indicate any spatial autocorrelation, as we could not reject the null hypothesis of no autocorrelation (p-value of 0.543), neither did the separate analyses for allotments (p = 0.587) and domestic gardens (p = 0.795).

3.3. Descriptive results

Levels of the outcome variable self-reported restoration in our sample were high. 57% of the respondents reported they felt "much more rested" (the highest score) after having spent time in the garden and 23% chose the second highest score. Allotment gardeners reported higher restoration on average (4.44, SD 0.95) than domestic gardeners (4.15, SD 1.09) (Fig. 3). According to a Welch two-sided *t*-test the difference in means was significant (t = -2.331, p = 0.021).

Perceived restorativeness was also high, with 56% of respondents reaching the highest of the 5 scores and 33% the second highest (Fig. 3). Allotment gardeners reported significantly higher values than domestic gardeners (4.72 [SD 0.47] and 4.28 [SD 0.79], Welch two-sided *t*-test: $t = -5.8059$, $p < 0.001$). Fascination and being away showed similar patterns. Fascination was higher for allotment gardeners than for domestic gardeners (4.42 [SD 0.69] and 4.04 [SD 0.94], Welch two-sided *t*-test: $t = -3.9019$, $p < 0.001$), just as was being away (4.74 [SD 0.67] and 4.29 [SD 0.91], Welch two-sided *t*-test: $t = -4.882$, $p < 0.001$). This last difference depends mainly on the highest point of the 5-point scale: 82% of allotment gardeners fully agreed that their garden was a place where they could distance themselves from their daily routine, while only 53% of domestic gardeners made the same statement (Fig. 3). On our five-point measure of garden-related stress, 16% of gardeners indicated they agreed or fully agreed with the statement that they often felt stressed by the garden (Fig. 3). Garden-related stress was significantly higher for domestic gardeners than for allotment gardeners. On the 5-point Likert scale, garden-related stress was moderate in both groups, with a mean of 2.54 (SD 1.05) for domestic gardeners and 2.15 (SD 1.23) for allotment gardeners (Welch two-sided *t*-test: $t = -2.75$, *p*-value = 0.007). The differences were mainly on the lower end of the scale, with 41% of allotment gardeners reporting no garden-related stress, but only 17% of domestic gardeners

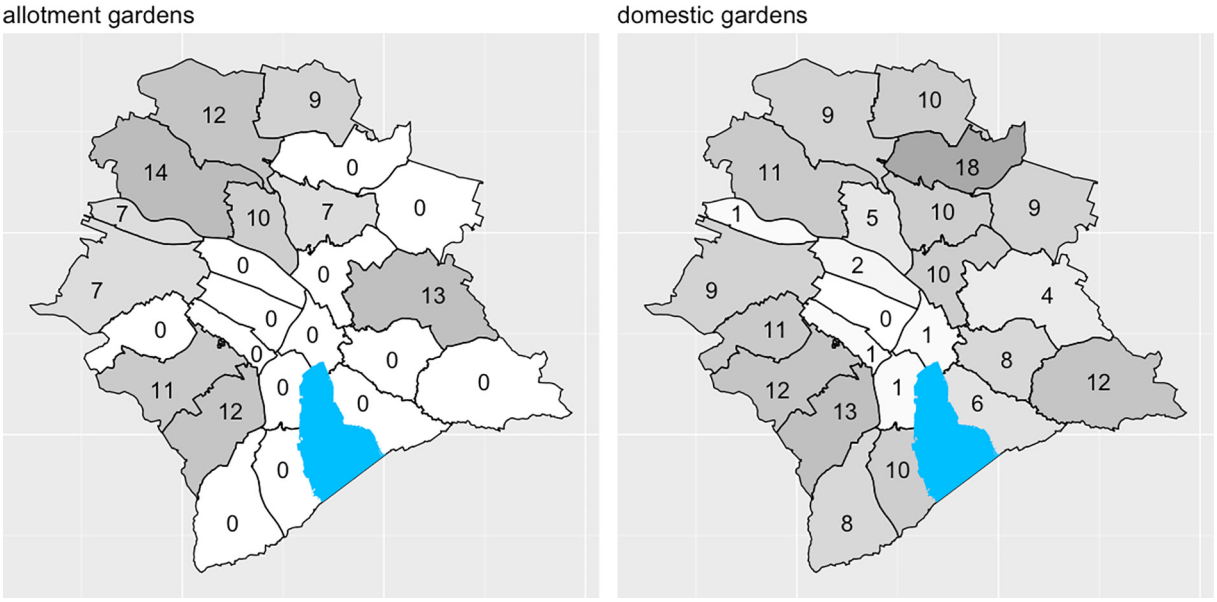

Fig. 2. Spatial distribution of surveyed gardens by postal code areas. The map shows the full area of the city of Zurich divided into postal code areas and a section of Lake Zurich in the lower center. Numbers in the postal code areas indicate the number of gardens in that area, shading is darker with higher numbers. Location data was missing totally for 6 allotment gardens and 11 domestic gardens.

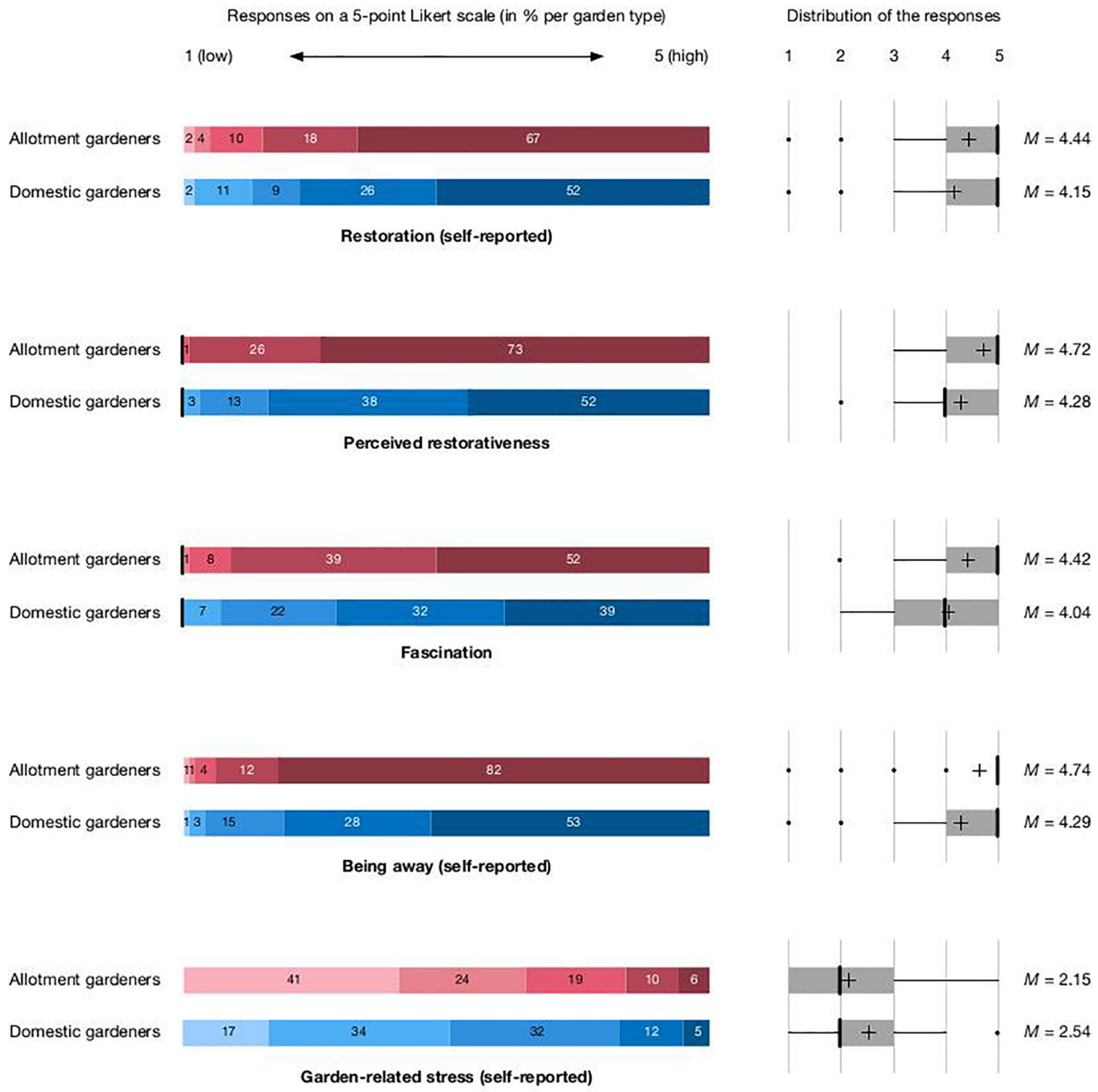

Fig. 3. Distributions of five key variables by garden type. Distribution of the variables self-reported restoration, perceived restorativeness, fascination, being away and garden-related stress for the two subsamples of allotment and domestic gardeners. The figures within the bars correspond to the percentage of gardeners within a garden type reporting this level of the variable. On one sbar the percentage add up to 101% due to round off. For the variables perceived restorativeness and fascination, the lower level(s) is (are) not displayed, as there were no cases in this level(s). In the boxplots to the right, the bold black line represents the median, the left and rights edges of the box the 25th and 75th percentile. Dots indicate outliers, the + indicates the mean which is also given as a number on the right (M =). For the variable being away, the very high proportion of allotment gardeners reporting the highest level causes the box to collapse into the median line.

choosing this category. Allotment gardeners had a significantly higher score regarding the preference for a tidy garden (mean: 4.33) than domestic gardeners (mean: 3.79, $t = -4.805$, $p < 0.001$, not shown in Fig. 3).

The estimated number of plant species per garden ranged from 58 to 199 (Fig. 4). The mean for allotment gardens was 114 [SD 20], for domestic gardens it was 121 [SD 29] species, which was a significant difference (Welch two-sided t-test: $t = 2.3347$, $p = 0.020$).

3.4. Structural equation model

The structural equation model (SEM) shows which variables were associated with self-reported restoration and through which paths (Fig. 5). The measurement model (which consists of five PRS items and three latent variables) had a good model fit (N: 301, chi^2-statistic = 4.8, df = 3, $p = 0.188$, robust CFI = 0.996, robust RMSEA = 0.048, SRMR = 0.015). Our SEM also displayed a relatively good fit with the data (N: 301, robust chi^2-statistic = 69.2, df = 35, $p < 0.001$, robust CFI = 0.945, robust RMSEA = 0.065, SRMR = 0.044). For all the fit indices and regression parameters, see Table S3 in the supplementary online material. The loadings of the manifest variables onto fascination and compatibility, and the loadings of fascination, compatibility and being away onto the second-order latent variable PRS were all positive, significant and equal to or larger than 0.697 (we report standardized coefficients throughout). As was our premise, perceived restorativeness was positively associated with self-reported restoration on a high significance level ($\beta = 0.567$, $p < 0.001$).

The indirect ($\beta = 0.227$, $p = < 0.001$) and total ($\beta = 0.182$, $p = 0.007$) effects of garden type on self-reported restoration were

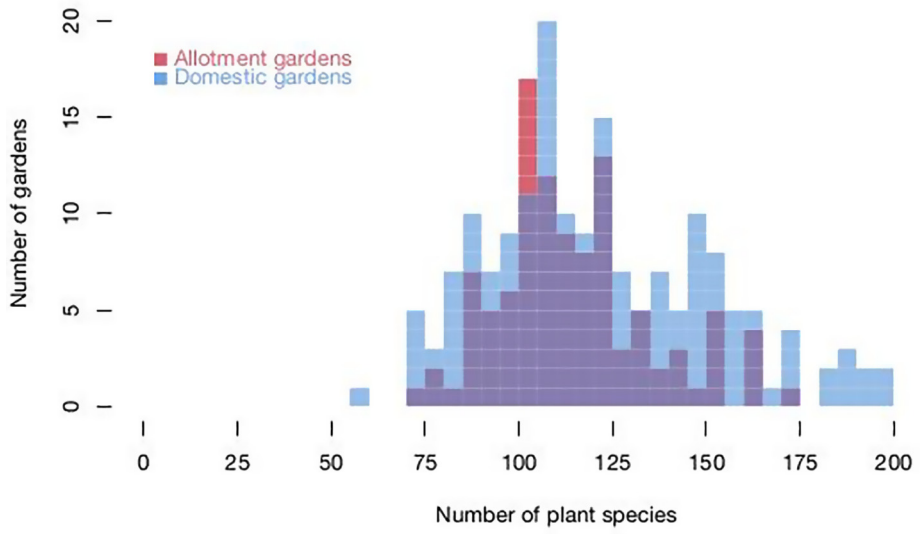

Fig. 4. Estimate of number of plant species per garden. Each square in the figure represents a garden. The darker squares indicate that there is both an allotment and a domestic garden with this number of plant species.

significant, indicating higher levels for allotment gardeners. There was neither a significant *direct* association between garden type and self-reported restoration nor between garden type and being away. Garden type showed a positive significant direct assocation with perceived restorativeness and a negative significant direct association with garden-related stress. This means that when controlling for socio-economic factors (age, gender, employment status and job status level), allotment gardeners on average reported higher levels of perceived restorativeness ($\beta = 0.362$, $p < 0.001$; see Table 4 for coefficients and p-values for all hypothesized associations).

The indirect effect of the number of plant species on self-reported restoration ($\beta = 0.104$, $p = 0.012$) was positive and significant, while for the total effect of the number of plant species on self-reported restoration the null hypothesis of no association could not be rejected ($\beta = 0.078$, $p = 0.171$). The number of plant species showed no *direct* association with the outcome variable self-reported restoration, nor with fascination. However, the number of plant species displayed a positive direct association with perceived restorativeness ($\beta = 0.184$, $p = 0.003$), while controlling for biodiversity preference.

Finally, garden-related stress was negatively associated with self-reported restoration ($\beta = -0.127$, $p = 0.044$). Allotment gardeners reported lower levels of garden-related stress than domestic gardeners ($\beta = -0.167$, $p = 0.013$) when controlling for the socio-economic control variables.

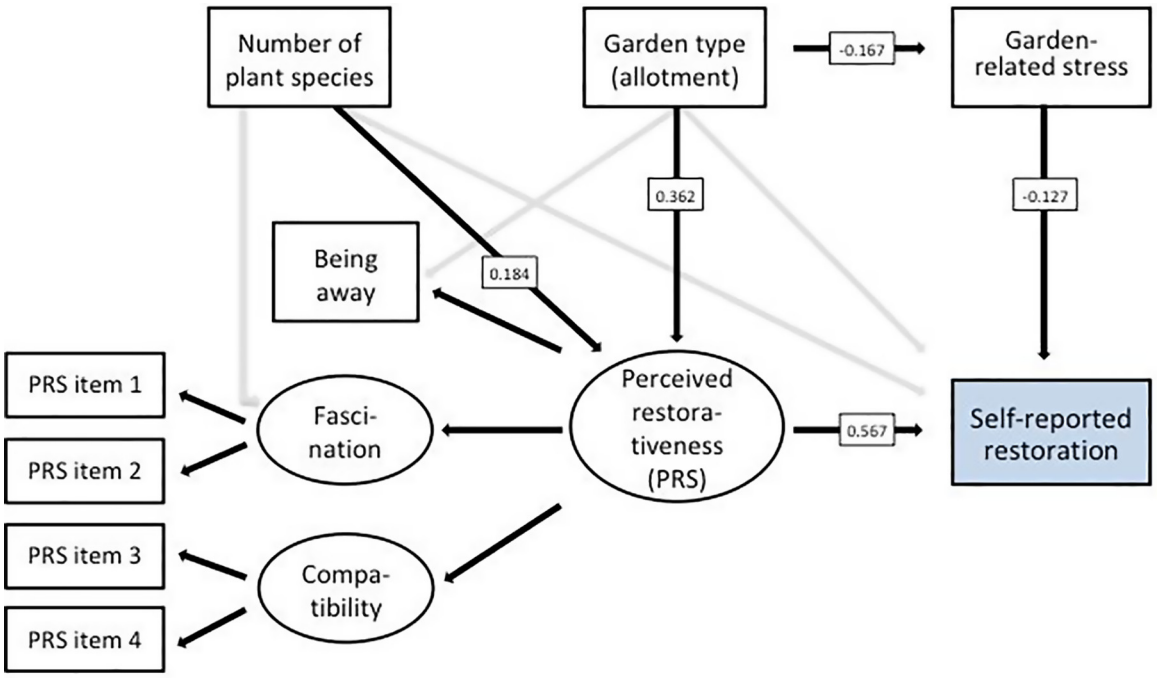

Fig. 5. Structural equation model with coefficients. Observed variables are displayed in rectangular shapes, latent variables in oval shapes. Latent variables cannot be measured directly but are assumed to cause the observable variables which can be used to estimate the level of the latent variable. Control variables are not shown. The black arrows indicate significant associations ($p < 0.05$); grey arrows non-significant ones. Coefficients given (values on the black arrows) are standardized β estimates. For more details about the statistics of the direct associations, see Table 4. See Table S3 in the supplementary online material for all coefficient estimates.

Table 4
Summary of hypothesized associations.

Association (numbering as in Table 2)		β	p	Result
Total effects				
H1	Garden type – > self-reported restoration (+/-)	0.182	0.007	supported
H2	Number of plant species – > self-reported restoration (+)	0.078	0.171	rejected
Indirect effects				
H1	Garden type – > self-reported restoration (+/-)	0.227	< 0.001	supported
H2	Number of plant species – > self-reported restoration (+)	0.104	0.012	supported
Direct associations				
H3	Garden type – > self-reported restoration (+/-)	−0.015	0.808	rejected
H4	Garden type – > perceived restorativeness (+/-)	0.362	greater than 0.001	supported
H5	Garden type – > being away (+)	−0.057	0.430	rejected
H6	Number of plant species – > self-reported restoration (+)	−0.029	0.633	rejected
H7	Number of plant species – > perceived restorativeness (+)	0.184	0.003	supported
H8	Number of plant species – > fascination (+)	0.063	0.253	rejected
H9	Garden-related stress – > self-reported restoration (-)	−0.127	0.044	supported
*H*10	Garden type – > garden-related stress (+)	−0.167	0.013	rejected

(+) indicates we expected a positive association. β is a standardized regression coefficient and p the p-value. The variable "Garden type" takes on the value 1 for allotment gardens, 0 for domestic gardens. Association 10 is significant, but the effect is the opposite to what we expected, so the hypothesis is rejected.

4. Discussion

In line with previous research (Cervinka et al., 2016; Stigsdotter & Grahn, 2004; van den Berg et al., 2010), our results show that both domestic and allotment gardeners experience their gardens as highly restorative, as is evidenced by the high levels of self-reported restoration and perceived restorativeness.

4.1. Differences in restoration for allotment and domestic gardeners

Concerning differences between garden types, several of our hypotheses were supported. While the higher level of self-reported restoration present among allotment gardeners in descriptive statistics did not translate into a *direct* association of garden type with self-reported restoration in the SEM, the *total* effect of garden type on self-reported restoration was significant. On average, this association indicated allotment gardeners scored approx. 0.4 points higher on the 5-point self-reported restoration variable than domestic gardeners. Thus, there were substantial differences between garden types, even after controlling for a number of socio-economic variables.

The descriptive statistics show that allotment gardeners report significantly higher levels of being away than domestic gardeners. However, the SEM rejected our hypothesis that garden type would have an effect on being away in the sense of allotment gardeners having higher levels. This suggests that (when including our control variables) domestic gardens are not subject to the spillover effect described by von Lindern and co-authors (von Lindern et al., 2013; von Lindern, 2017). We had expected to find this spillover effect which occurs when leisure settings are associated with work, reducing the sense of being away in the leisure setting. Nonetheless, future research could consider the difference between gardeners who do a major part of household work (and who might thus experience more spillover effects) and those who are less involved in this work.

Garden type was significantly associated with two further concepts we measured. The SEM showed a significant positive direct association between garden type and perceived restorativeness, with allotment gardens associated with higher values. This is contrary to findings by Cervinka et al. (2016) who found no significant differences between the perceived restorativeness of domestic and allotment gardens. In qualitative research, Milligan et al. (2004) found allotment gardens to support social contact more but did not contrast restoration outcomes. To our knowledge, these are the only two previous studies comparing garden types. Garden type was also significantly related to garden-related stress, as discussed below (4.3).

4.2. Mechanisms linking biodiversity to perceived restorativeness and restoration

Our study provides evidence that garden biodiversity - in our case number of plant species - is positively associated with psychological restoration. The (cumulated) indirect effect of number of plant species on self-reported restoration was significant in our model, though the total effect was not. The effect was relatively small: on average 10 additional plant species were associated with an increase of approx 0.040 points (approx. 1%) on a 5-point scale. While previous studies suggest an effect of biodiversity on restoration for other greenspace types (Carrus et al., 2015; Dallimer et al., 2012; Fuller et al., 2007; Marselle et al., 2015), our results are, to our knowledge, the first to demonstrate this link in the context of gardens.

Making assumptions about the mechanisms which link the number of plant species and self-reported restoration, however, proves more difficult. While the direct association between the number of plant species and self-reported restoration was not significant, there was an effect of the number of plant species on self-reported restoration mediated by perceived restorativeness. Our results are congruent with findings connecting visual complexity to attention restoration (Joye et al., 2016). A higher number of plant species (with different colours, heights, leaf shapes etc.) should in general result in higher visual complexity and thus higher attention restoration. Our confidence in this mechanism is additionally supported by the control variable biodiversity preference. Thanks to this variable we can to a certain extent rule out the possibility of the number of plant species having a positive effect on gardeners' restoration merely because it coincided with their preferences. As other studies describe, some gardeners gain much satisfaction from shaping the garden according to their preferences (Gross & Lane, 2007; Milligan et al., 2004). If gardeners actively aim to have a high number of plant species in their garden, achieving this could also have a positive effect on restoration. By controlling for biodiversity preference, we can argue that the association of the number of plant species with perceived restorativeness in our SEM was independent of gardeners achieving what they planned.

However, contrary to our hypothesis, there was no significant association between plant species richness and fascination. Theoretical considerations and research which link visual complexity and fascination (Van den Berg et al., 2016) led us to assume that the number of plant species would contribute to perceived restorativeness primarily by increasing the level of fascination. Our model did not support this, but it does leave the door open for future research, e.g. with larger samples, to consider this causal path further. Alternatively, the number of plant species could increase perceived restorativeness through the being-away or compatibility dimensions. It is not immediately obvious

how these mechanisms would work, but future research should consider these possibilities carefully.

4.3. Garden-related stress in relation to garden type

When the restorative effects of greenspace are studied, negative effects are rarely considered. Our results provide evidence that gardens which are managed by their users, in contrast to publicly managed greenspaces, can be a source of stress - while still being a source of restoration. Not distinguishing between garden types, 16% of our respondents considered their garden to cause them stress quite frequently. As far as we know, this is the first quantitative appraisal of garden-related stress. The result supports the sparse qualitative evidence available (Gross & Lane, 2007; Milligan et al., 2004). The SEM also shows the relevance to restoration outcomes, as garden-related stress had a significant negative association with self-reported restoration.

Our data show that domestic gardeners were significantly more likely to experience garden-related stress than allotment gardeners, which is contrary to what we expected. We hypothesized that the strict formal rules of allotment associations would cause more garden-related stress among allotment gardeners if they feel more under pressure to keep their garden tidy. One reason for the contrary finding may be that these rules do not put additional pressure on allotment gardeners because they prefer tidy gardens anyway as our variable designed to capture the preference for a tidy garden suggested. On the other hand, informal garden norms in a neighborhood can also put domestic gardeners under pressure (Nassauer et al., 2009), blurring differences between the two garden types in respect to rules.

Another possible explanation for this finding may be methodological. Allotment gardeners may on average be more committed or enthusiastic gardeners than domestic gardeners, as allotment gardeners who cease to enjoy gardening can give up their allotment quite easily. For domestic gardeners, the garden is usually tied to their home. This means that giving up the garden would involve much greater effort than for allotment gardeners e.g. requiring moving into an apartment without a garden. This amounts to a negative self-selection process for allotment gardeners who do not enjoy gardening or feel stressed by it. Allotment gardeners and domestic gardeners did not differ significantly in how frequently they spent time in their garden (allotment 17.6 days/month, domestic 15.8, $t = -1.525$, $p = 0.1285$) which initially could be interpreted as there being no difference in commitment between the groups. However, when one takes into account that getting to the garden on average takes far more time for allotment gardeners, the *lack* of difference supports the notion that allotment gardeners are more committed. Alternatively, it may also be the case that allotment gardens were indeed more restorative than domestic gardens.

4.4. Limitations

The results of this study must be considered in light of the limitations of the research design. One measurement limitation is that the data for restorativeness and self-reported restoration are retrospective. As the survey covered different research questions, the limited space available for the variables we use here forced us to work with only one item to measure self-reported restoration. While we see no reason to doubt the validity of our self-reported restoration measure, the reliability of a multi-item measure may have been greater (though this is not always the case for psychological constructs, see Gardner, Cummings, Dunham, & Pierce, 1998).

Furthermore, the cross-sectional data does not allow us to identify causal effects but rather reveals correlations which can suggest causal effects. Particularly the associations of garden type with other variables must be interpreted cautiously, as self-selection of certain types of individuals to garden types and structural constraints probably influence results. To further explore possible differences between garden types, other research designs (e.g., quasi-experimental field studies) would be desirable. In contrast to other similar studies, our samples are conceived as random samples of domestic and allotment gardeners. However, particularly among domestic gardeners with a response rate of 27%, there may be self-selection effects present in the sample as well. Conceivably, the people in our sample may have been more interested in gardening than non-respondents, but we have no information on this. The sample of allotment gardeners (48% response rate), on the other hand, can be taken to reasonably represent the respective population. The samples are also relatively small for running a SEM like ours and thus may result in false non-rejections of H0 (Type II errors).

5. Conclusion

In this cross-sectional study with approximately 300 leisure gardeners - both allotment and domestic gardeners - we show that gardeners in both garden types experience their gardens as places of relaxation and restoration. Specifically, we show (1) that being an allotment gardener on average was associated with higher levels of self-reported restoration and perceived restorativeness, (2) that there were significant though small effects of the number of plant species on self-reported restoration and on perceived restorativeness and (3) that there was a substantial minority of gardeners who reported garden-related stress and that these tended to be domestic rather than allotment gardeners.

Our results add to the evidence that gardens are an important resource for public health in cities. Urban gardens contribute to psychological restoration and stress reduction, which research has shown to be related to further positive health effects (Cohen et al., 2012; Thoits, 2010). As exposure to greenspace has been linked to smaller income-related health inequalities (Mitchell & Popham, 2008; Ward Thompson et al., 2012), providing gardens to populations with lower socio-economic status could be a policy measure to reduce income-related health inequalities. While our study cannot support this directly, we do show that (1) allotment gardeners were socio-economically less privileged than domestic gardeners and (2) that allotment gardeners benefited at least as much if not more than domestic gardeners in terms of restoration from time spent in the garden. This suggests that from a health equality perspective there are advantages of preserving allotment gardens or even of providing more gardening spaces which appeal specifically to socio-economically underprivileged urban residents.

The hypothesis of a positive effect of garden biodiversity on restoration was partly supported by our results. This means that conservation efforts in urban areas focusing on gardens can be win-win situations, with higher biodiversity leading both to positive results for human restoration and for conservation, for example by offering flower resources to insect pollinators (e.g. Hall et al., 2017). Future studies should investigate which elements of the garden flora (e.g. native vs. alien or functional flower traits) and garden designs contribute both to conservation and to restoration. Urban authorities should contribute to the overall value of both allotment and domestic gardens by developing and promoting garden designs which allow gardeners to maintain a diverse and restorative vegetation with limited management effort.

We also show that gardens have the potential to *cause* stress among users, reducing the restorative capacity of the garden. More research on the causes of this kind of negative affective response and the size of the effects would be important. It may be possible to reduce this stress through neighborhood programs to share gardens and garden tasks, simultaneously allowing more people to benefit from gardens and strengthen community networks. Indeed, the presence of garden-related stress for some gardeners must be weighed up against the known and potential advantages of gardening, e.g. for community building (Armstrong, 2000; Firth, Maye, & Pearson, 2011) or health (Berto, 2014; Hartig et al., 2014; Soga et al., 2017).

In the light of efforts to prevent urban sprawl, subsequent increases in urban densification and loss of garden spaces, policies aimed at

maximizing the diverse individual, ecological and social benefits from gardens are necessary. Integrating allotment gardens into planning policies will generally be easier than integrating domestic gardens, but innovative policies could target both. Future research could aim to identify which garden characteristics maximize psychological restoration as well as other benefits such as the growth of social capital in communities.

CRediT authorship contribution statement

Christopher Young: Writing - original draft, Methodology, Formal analysis, Investigation. **Mathias Hofmann:** Writing - review & editing, Visualization, Formal analysis. **David Frey:** Writing - review & editing, Methodology, Formal analysis. **Marco Moretti:** Writing - review & editing, Investigation. **Nicole Bauer:** Supervision, Project administration, Funding acquisition, Conceptualization, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2020.103777.

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