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Virtual Garden Computer Program for use in Exploring the Elements of Biodiversity People want in Cities

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Abstract: *Urban ecology is emerging as an integrative science that explores the interactions of people and biodiversity in cities. Interdisciplinary research requires the creation of new tools that allow the investigation of relations between people and biodiversity. It has been established that access to green spaces or nature benefits city dwellers, but the role of species diversity in providing psychological benefits remains poorly studied. We developed a user-friendly 3-dimensional computer program (Virtual Garden [www.tinyurl.com/3DVirtualGarden]) that allows people to design their own public or private green spaces with 95 biotic and abiotic features. Virtual Garden allows researchers to explore what elements of biodiversity people would like to have in their nearby green spaces while accounting for other functions that people value in urban green spaces. In 2011, 732 participants used our Virtual Garden program to design their ideal small public garden. On average gardens contained 5 different animals, 8 flowers, and 5 woody plant species. Although the mathematical distribution of flower and woody plant richness (i.e., number of species per garden) appeared to be similar to what would be expected by random selection of features, 30% of participants did not place any animal species in their gardens. Among those who placed animals in their gardens, 94% selected colorful species (e.g., ladybug [*Coccinella septempunctata*], Great Tit [*Parus major*], and goldfish), 53% selected herptiles or large mammals, and 67% selected non-native species. Older participants with a higher level of education and participants with a greater concern for nature designed gardens with relatively higher species richness and more native species. If cities are to be planned for the mutual benefit of people and biodiversity and to provide people meaningful experiences with urban nature, it is important to investigate people's relations with biodiversity further. Virtual Garden offers a standardized tool with which to explore these relations in different environments, cultures, and countries. It can also be used by stakeholders (e.g., city planners) to consider people's opinions of local design.*

Keywords: city dwellers, connection to nature, conservation psychology, ecosystem services, perceptions, species diversity, urban ecology

Programa de Computadora de Jardín Virtual para Uso en la Exploración de los Elementos de Biodiversidad que la Gente Desea en las Ciudades

Resumen: *La ecología urbana está emergiendo como una ciencia integradora que explora las interacciones de la gente y la biodiversidad en las ciudades. La investigación interdisciplinaria requiere la creación de nuevas herramientas que permitan la investigación de las relaciones entre la gente y la biodiversidad. Se ha establecido que el acceso a áreas verdes o a la naturaleza beneficia a los habitantes de ciudades, pero el papel específico de la diversidad de especies para proveer beneficios psicológicos permanece poco estudiado. Desarrollamos un programa de computadora amable con el usuario y en tercera dimensión (Virtual Garden [www.tinyurl.com/3DVirtualGarden]) que permite a las personas diseñar áreas verdes propias o públicas*

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*con 96 rasgos bióticos y abióticos. Virtual Garden permite a los investigadores determinar los elementos de la biodiversidad que a la gente le gustaría tener en las áreas verdes cercanas al mismo tiempo que se toman en cuenta otras funciones que la gente valora en esas zonas. En 2011, 732 participantes utilizaron nuestro programa Virtual Garden para diseñar su jardín público ideal. En promedio, los jardines contenían 5 animales diferentes, 8 flores y 5 especies de plantas leñosas. Aunque la distribución matemática de la riqueza de flores y plantas leñosas (p. ej.: número de especies por jardín) pareció ser similar a lo que se esperaría de una selección aleatoria de rasgos, el 30% de los participantes no colocó especies animales en su jardín. Entre los que colocaron especies animales en sus jardines, el 94% seleccionó especies coloridas (p. ej.: mariquita o catarina [*Coccinella septempunctata*], carbonero común [*Parus major*] y peces dorados), el 53% seleccionó reptiles o mamíferos grandes, y el 67% seleccionó especies no-nativas. Los participantes mayores y con un nivel más alto de educación y los participantes con una mayor preocupación por la naturaleza diseñaron jardines con una riqueza de especies relativamente mayor y más especies nativas. Si las ciudades se diseñarán para el beneficio mutuo de las personas y la biodiversidad y para proporcionarle a la gente experiencias significativas con la naturaleza urbana, es importante investigar más a fondo las relaciones entre la gente y la biodiversidad. Virtual Garden ofrece una herramienta estandarizada con la cual se pueden explorar estas relaciones en diferentes ambientes, culturas y países. También puede ser usada por las partes interesadas (p. ej.: planeadores urbanos) para considerar la opinión de las personas en el diseño local.*

Palabras Clave: conexión con la naturaleza, diversidad de especies, ecología urbana, habitantes de ciudades, percepciones, psicología de la conservación, servicios ecosistémicos

Introduction

Sprawling urban environments pose a growing problem for conservation of biodiversity (McKinney 2002) and increase the separation of the world's population from nature (Turner et al. 2004). The latter could affect people's life directly (Dye 2008) and conservation efforts indirectly because this extinction of experience (Miller 2005) could affect the way people value nature (Chawla 1999) and their willingness to protect nature and to allocate funds for conservation (Stokes 2007). Understanding how to design and manage urban environments to favor wildlife could help alleviate some of the detrimental effects of urbanization on people and wildlife. Although conservation professionals have devoted much effort to studying how to conserve biodiversity in cities, less attention has been devoted to understanding the relation between people and this biodiversity (Lindemann-Matthies et al. 2010).

The psychological benefits people attain from exposure to a diversity of species (hereafter biodiversity) in cities are commonly evoked as one of the motivations for conserving urban biodiversity (Dearborn & Kark 2010). To date, most research has focused on the positive relation between several measures of people's well being and exposure to nature or green spaces (Tzoulas et al. 2007; Matsuoka & Kaplan 2008) regardless of their quality (e.g., in terms of species diversity). For instance, exposure to green spaces or nature can improve self-reported mental health (de Vries et al. 2003), reduce levels of stress and mental fatigue (Ulrich 1984; Kuo 2001), and is associated with quicker recovery from surgery (Ulrich 1984). However, exposure to green spaces does not necessarily mean people are exposed to biodiversity and benefit from it. The first research to investigate the relation between people and different components of biodiversity revealed its complexity (Fuller et al. 2007; Luck et al. 2011; Dallimer et al. 2012). On the one hand, people from different socioeconomic backgrounds appreciate biodiversity and relate biodiversity to their well being (e.g., Lindemann-Matthies et al. 2010; Dallimer et al. 2012). On the other hand, attempts to relate specific components of biodiversity (e.g., species richness) to measures of well-being provide contradictory results. Among green-space users a positive relation between plant species richness and well being or aesthetic appreciation has been demonstrated (Fuller et al. 2007; Lindemann-Matthies et al. 2010). However, results for other taxonomic groups (e.g., birds, butterflies) or other locations (e.g., riparian green spaces, neighborhoods) do not show a consistent relation between people's well being and sampled species diversity (Fuller et al. 2007; Luck et al. 2011; Dallimer et al. 2012).

The inconsistency between the need people say they have for green spaces and nature and the biodiversity they experience and appreciate in their lives may be explained by their lack of ecological expertise. For instance, people tend to underestimate species richness and fail to recognize even common species (e.g., Dallimer et al. 2012; Shwartz 2012). Lack of knowledge could limit the ability of people to consciously experience biodiversity, despite their declared intent. As a first step in understanding the psychological benefits biodiversity can deliver to city dwellers, it is important to examine people's preferences for species diversity in their daily lives. Information on the interplay between socioeconomic and socioenvironmental factors is also needed to fully understand how these factors affect people's choices. Socioeconomic variables are related to plant diversity in urban areas (Hope et al. 2003) and affect people's preferences for biodiversity (e.g., Kellert 1984; Palmer & Suggate 1996; Lindemann-

Matthies & Bose 2008). Luck et al. (2011) demonstrated that disregarding socioeconomic variables could strongly bias the understanding of the people-biodiversity relation. A common quantitative way to explore this question is via questionnaires. However, it is argued that the wording and complexity of questions could have a large effect on the results (e.g., Filion 1981; Luck et al. 2011). People often judge the value of organisms through subjective criteria such as their aesthetics and usefulness (Lindemann-Matthies 2005), which could be difficult to capture in the words of a questionnaire. Thus, when aiming to explore the preference of people for biodiversity, a more visual approach could be useful (Bayne et al. 2012).

For that reason we developed a user-friendly 3-dimensional computer program (Virtual Garden) that allows people to design their ideal public garden with a set of selected species and abiotic features. Virtual Garden allows the researcher to explore participants' perceptions of biodiversity without using this or related words in questions; thus, it reduces bias. The software registers each step in the creation of the garden and computes several diversity indexes and garden measures. Although the use of virtual software has not yet reached its full scientific potential, virtual methods are increasingly used in education and movement psychology with different groups of people, from children to the elderly (Abe et al. 2005; Foreman et al. 2005). In 2011, we surveyed over 700 participants in Paris, France. We used the Virtual Garden program (available online from www.tinyurl.com/3DVirtualGarden) to explore which elements of biodiversity people want to see in small public gardens close to their homes and how people's socioeconomic status and environmental stance affect those preferences. Understanding people's affinity for particular species and the social variables that affect this affinity is important because these social factors may affect biodiversity directly (Hope et al. 2003) and indirectly through people's awareness of and concern for nature (Stokes 2007).

Methods

Virtual Garden

The main objective behind the creation of the Virtual Garden program was to develop a user-friendly and attractive tool to investigate people's choice of biodiversity in green spaces. The Virtual Garden program is freeware and was designed to ensure administrators to adapt the software to their needs. The version we used was programmed (in **C#**) to allow users to design small public urban gardens of about 1 ha, but it can be adjusted easily to represent other types of green spaces (e.g., domestic gardens, green roofs).

Double clicking on the software icon opened an image that introduced the location the participant would design (e.g., public urban garden; Fig. 1a). This image was important because there were no other elements to connect the garden to any specific context (e.g., regarding size or location [urban or not] or whether the green space was public or private) in the rest of the working space (i.e., the space in which participants created their gardens; Fig. 1b). Double clicking on the image opened a window that was divided into 4 sections (Fig. 1b): a central working space; above, software commands (e.g., undo, save, and print); on the left, design and view commands (e.g., delete, move, rotate, and view); and on the right, drop-down menus of the main features participants could click to get access to the features.

Altogether, the software contained 95 features that were grouped into 7 drop-down menus (animals, flowers, lawn and cover, sport and playing, trees and bushes, water and other [see Supporting Information for a full list of features]). For the biotic features ($n = 74$), we used a selection of native, domestic, and non-native species that occur commonly in the Paris region (exceptions were 3 non-native animal species and a palm tree; Table 1). The biotic features included 36 animals, 23 ornamental flowers, 15 tree and bush species (hereafter woody species). The rationale behind the species we selected was to provide participants with choices they would likely already be aware of, either because those species are common in the Paris region or because those species tend to attract attention (colorful, scary; e.g., Kellert 1993; Driscoll 1995). Each time the software is opened, the order of items in the drop-down menus and icons within each tab were shuffled to prevent order-selection bias.

To design the garden, users browsed through the icons and selected features they wanted in their gardens. When the user moved the pointer to an icon, the image was enlarged and the feature could be selected by left clicking on the icon (Fig. 1c). Once selected, the user placed the feature anywhere in the working space (each left click placed one feature). The user could change the location or orientation of a feature later with the design and view commands. The Virtual Garden program allowed users to view the garden from various angles by scrolling (zoom in and out), right clicking (change view angle), and right and left clicking together (inclination). Thus, the user could design the garden in plan view and later virtually stroll in the garden to get a better impression of its design. It was difficult to create realistic 3-dimensional models of animals that move and could be seen in the context of the garden (some animals are very small). Therefore, icons of the selected animals were at the top of the working space (Fig. 1d). The Virtual Garden registered each step of the creation of the garden and computed several diversity indexes and structural measures at the garden level (e.g., animal richness and lawn cover). A short questionnaire was integrated into the software to collect information on participants.

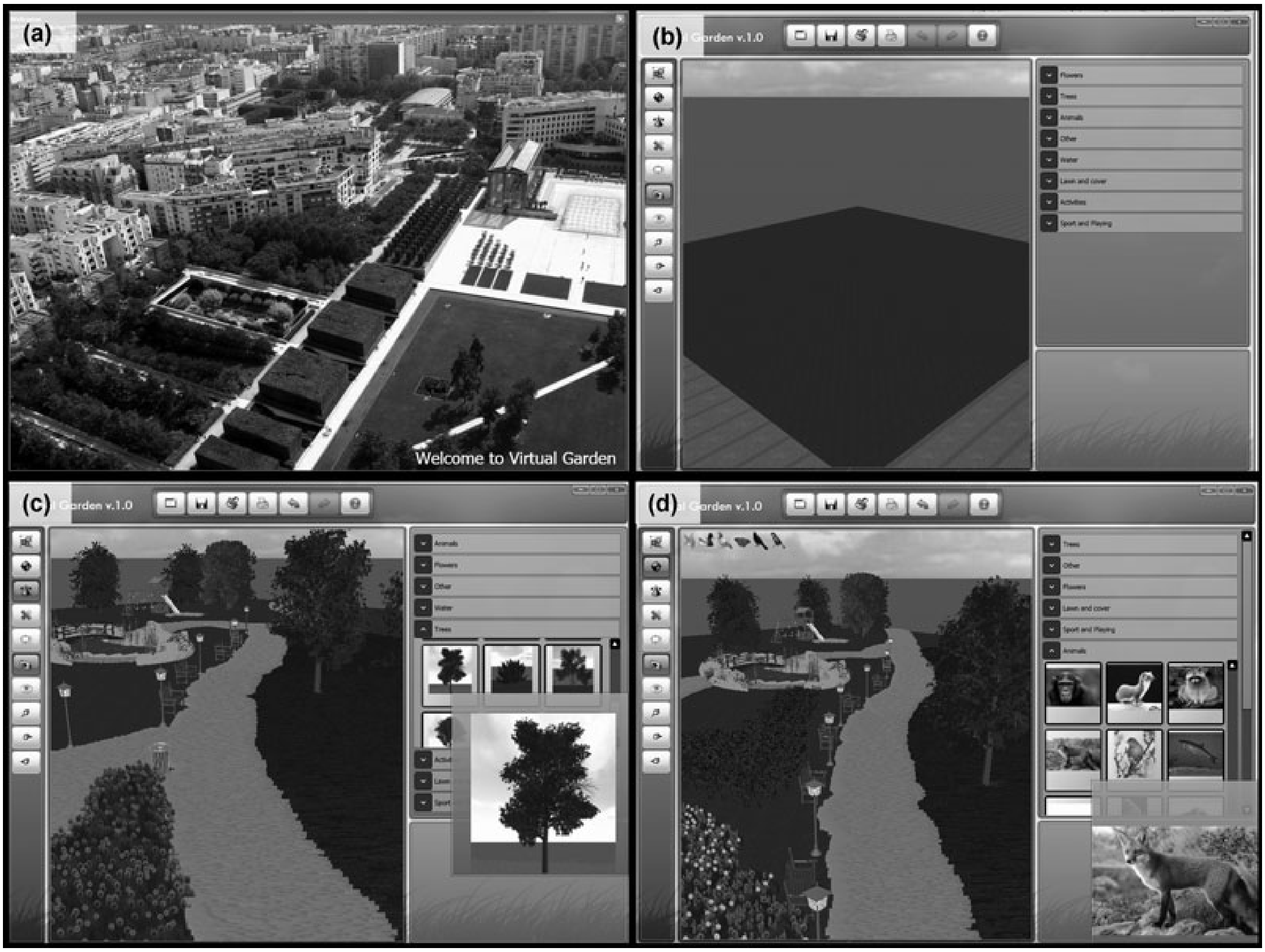

Figure 1. Four screen shots of the Virtual Garden program: (a) first screen, shows the location context, (b) garden working space and commands, (c) example of garden at the eye-level view and selection of one tree species, and (d) top view of the same garden with animals.

Data Collection

From March to August 2011, we conducted a survey of adult participants (≥18 years old) in 12 different Parisian hospitals. We sought out participants in hospitals because we expected to find a socioeconomically unbiased population that would have time to participate in our survey. To avoid influencing participants' choices regarding biodiversity, we presented ourselves as geographers who study garden design and asked people whether they would like to participate in the research and design their ideal garden. Participation was voluntary and the entire process of participation was strictly anonymous. After a short introduction, which included an explanation of the virtual research location of the garden (see above) and of use of the software, we gave participants about 30 minutes to design their gardens. While they created the gardens, we recorded creation time, participant type (patient, visitor, or staff), and aptitude for use of the software. These 3 variables could affect participants' work with the software (hereafter software variables) (Table 2). If a participant was unable to operate the computer mouse ($n = 167$), we designed the garden following their instructions carefully and ensuring that we did not affect the participant's decision making. While participants were working, we encouraged them to view the garden from different angles once every few minutes. When a participant finished creating the garden, we verified the participant was satisfied with the result. We then asked the participant to complete the short questionnaire (Supporting Information). The questionnaire contained 17 questions related to people's socioeconomic status, environmental stance, activities they would like to do in their ideal garden, and public gardens they visit frequently. These questions were drawn from a previous study conducted in small public gardens of Paris (Shwartz 2012).

We used 8 of these questions to measure people's socioeconomic status and environmental stance (Table 2). There are several recognized scales in environmental psychology that are used to measure people's environmental stance (e.g., Nisbet et al. 2009). However,

Table 1. The different animal species available to participants to place in their virtual gardens, ranked by order of preference calculated on the basis of the proportion of gardens containing each species.

Rank	*Species group*	*Common name*	*Scientific name*	*Proportion of gardens*
1	invertebrates	ladybug	*Coccinellidae* sp.	0.31
2	butterflies	European Peacock	*Inachis io*	0.27
3	birds	great tit	*Parus major*	0.27
4	fish[a]	gold fish	*Carassius auratus auratus*	0.25
5	birds	mallard	*Anas platyrhynchos*	0.24
6	birds	European Robin	*Erithacus rubecula*	0.24
7	butterflies	painted lady	*Vanessa cardui*	0.23
8	birds	house sparrow	*Passer domesticus*	0.18
9	butterflies	small white	*Pieris rapae*	0.17
10	mammals	red squirrel	*Sciurus vulgaris*	0.17
11	invertebrates	bumblebee	*Bombus* sp.	0.17
12	herptiles	green frog	*Pelophylax* kl. *esculentus*	0.16
13	invertebrates	garden snail	*Helix aspersa*	0.15
14	birds	magpie	*Pica pica*	0.15
15	birds	nightingale	*Luscinia megarhynchos*	0.15
16	birds[a]	mandarin duck	*Aix galericulata*	0.15
17	birds	barn swallow	*Hirundo rustica*	0.14
18	mammals	rabbit	*Oryctolagus cuniculus*	0.14
19	birds	blackbird	*Turdus merula*	0.14
20	fish	European chub	*Squalius cephalus*	0.13
21	herptiles[a]	red eared slider	*Trachemys scripta elegans*	0.13
22	mammals	common hedgehog	*Erinaceus europaeus*	0.13
23	mammals[a]	cat	*Felis catus*	0.12
24	birds	feral pigeon	*Columba livia*	0.11
25	herptiles	common midwife toad	*Alytes obstetricans*	0.11
26	herptiles	wall lizard	*Podarcis muralis*	0.09
27	mammals[a]	northern palm squirrel	*Funambulus pennantii*	0.08
28	birds[a]	Canada goose	*Branta canadensis*	0.08
29	birds[a]	rose ringed parakeet	*Psittacula krameri*	0.08
30	invertebrate	domestic house spider	*Tegenaria domestica*	0.07
31	mammals	beech marten	*Martes foina*	0.05
32	mammals[a]	raccoon	*Procyon lotor*	0.04
33	birds	herring gull	*Larus argentatus*	0.04
34	mammals	common pipistrelle	*Pipistrellus pipistrellus*	0.04
35	mammals[a]	chimpanzee	*Pan troglodytes*	0.03
36	mammals	red fox	*Vulpes vulpes*	0.02

[a]*Nonnative or domestic species.*

each of those scales measures something slightly different, and to our knowledge none of them directly addresses concern for biodiversity conservation. Because we wanted to keep our questionnaire brief and relative to urban conservation issues, we measured participants' environmental stance on the basis of 3 questions, which we drew from a previous study conducted in small public gardens of Paris (Shwartz 2012). We measured participant's desire to interact with nature on the basis of the activities they mentioned they would like to do in their ideal gardens. This variable served as a proxy for proenvironmental behaviors. Test trials of questions in the previous study (Shwartz 2012) demonstrated that people's concern for the disappearance of bees in Europe represented well people's environmental stance (i.e., people who cared about the disappearance of bees demonstrated proenvironmental stances). Therefore, we used this variable as a proxy for concern and knowledge of conservation issues. Because sensitivity of people to the environment relates to people's interaction with nature during childhood (e.g., Palmer & Suggate 1996), we also recorded where participants spent the majority of their childhoods (Table 2).

Data Analyses

We excluded from analyses all gardens that were unfinished and finished gardens participants were unsatisfied with ($n = 110$). Because we aimed to explore participants' preferences for diversity in public gardens, we compared the mathematical distribution of species richness in each garden (i.e., how many gardens placed 0–36 different animal species, 0–23 different flower species, and 0–15 different woody species; Fig. 2) with expected richness distributions in randomly created gardens. The expected distributions (Fig. 2) were calculated on the basis of the assumption that each feature had the same probability of being chosen, given the observed

Table 2. Qualitative and quantitative descriptions of the 16 socioeconomic, proenvironmental, software, and garden variables used in our study of 732 participants in the Virtual Garden survey.

Variables	*Details*	*Descriptions*
Socioeconomic		
gender	male or female	44% (male), 56% (female)
age	age of participant in years	44.06, 15.74, 18–87 (mean, SD, range)
marital status	single or couple	34.4% (single), 65.6% (couple)
income[a]	participants' perception of their income on a scale of 0 (low) to 10 (high)	8.4% (0–2), 18.3% (3–4), 28.2% (5), 36.7% (6–7), 8.4% (8–10)
qualification[b]	level of education on a scale of 0 (no diploma) to 7 (PhD)	10.6% (0–1), 35% (2–3), 47.5% (4–5), 6.9% (6–7)
Proenvironmental		
interaction with nature	whether people would like to interact with nature in their virtual garden	34% (yes), 66% (no)
bees	participants' concern for the disappearance of bees in Europe on a scale of 1 (not at all) to 5 (strongly)	12.2% (1), 6.4% (2), 26.7% (3), 26.2% (4), 28.5% (5)
childhood	type of area participants spent their childhood in on a scale of 1 (farm) to 5 (large city)	2.9% (1), 14.8% (2), 15.4% (3), 24.9% (4), 42% (5)
Software		
time	time it took to design the garden in minutes	19.2, 8.1, 5–47 (mean, SD, range)
aptitude	aptitude for use software on a scale of 1 (unable to use the software unaccompanied) to 4 (exceptional user)	26.8% (1), 9% (2), 46.8% (3), 17.4% (4)
Garden		
animal richness	number of different animal species in the garden	5.02, 5.52, 0–31 (mean, SD, range)
native preference[c]	people's preference for native versus nonnative animals	0.09, 0.15, -0.41–0.59 (mean, SD, range)
flower richness	number of different flower species in the garden	7.77, 6.40, 0–23 (mean, SD, range)
woody species richness	number of different woody species in the garden	4.51, 2.76, 0–15 (mean, SD, range)
number of objects	number of different abiotic features in the garden, which could serve as an indicator of garden complexity	8.65, 3.43, 1–19 (mean, SD, range)
Participant type	type of participant: patient, visitor, staff	24% (patient), 29% (visitor), 47% (staff)

[a] *Participants were reluctant to answer this question and reveal their income level when we used numbers (Shwartz 2012); therefore, we asked them to rate their income level in a scale of 0 (low income) to 10 (high income).*
[b] *We used an open-ended question that asked participants what diploma they obtained last (8 categories).*
[c] *Range of responses: −1, only non-native species selected, to 1, only native animals selected.*

mathematical distribution of the number features (biotic and abiotic) placed in each garden. For animals, we explored participants' preferences for particular species by calculating the proportion of gardens where that species was present. We then categorized the animals in the gardens as butterflies, invertebrates, fish, birds, mammals, or herptiles. For each group, we calculated the expected distribution on the basis of random sampling of the animal number and assumed that each animal had a similar probability of being chosen. We used Student's t test to compare observed and expected means. We used the same method to compare native and non-native species groups. We used 3 separate generalized linear models (GLMs) with negative binomial error structure (accounting for overdispersion of the count data; Zuur et al. 2009) to determine whether participant's socioeconomic status and environmental stance, participant type, and garden and software variables explained differences in richness of animals, flowers, and woody species (Table 2). We built an additional linear model to explore participants' preference for native species (native preference). This was calculated by subtracting the share of non-native species (i.e., number of non-native species placed in the garden divided by total non-native species available to choose from) from the share of native species (i.e., number of native species placed in the garden divided by total native species available). Altogether, we entered 12 variables (Table 2) into each GLM, after checking for the absence of collinearity. For model selection, we followed Pellissier et al. (2012) and used the model-averaging approach. We ranked all models on the basis of the AIC_c (corrected Akaike information criterion). For variables from the most parsimonious models (i.e., $\Delta AIC_c < 4$), we averaged their estimates and standard errors weighted

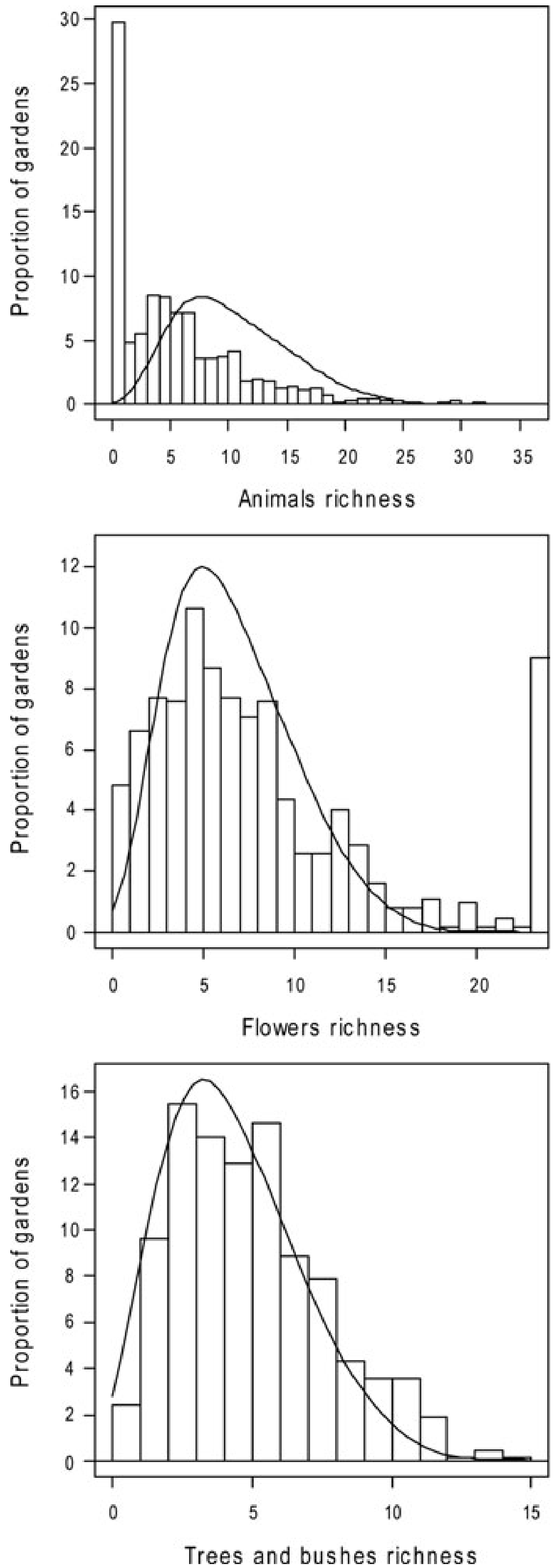

Figure 2. The actual (histogram) and expected (curve) mathematical distributions of (a) animal species richness, (b) flower richness, and (c) woody species richness participants placed in their virtual gardens.

by each model's AIC_c. Model averaging yielded the post-probability (hereafter PP) of an explanatory variable affecting the dependant variable and took into account the number of times the term appeared as significant in the selected models (see Supporting Information for all models and variable coefficients and their PPs). All statistical analyses were performed in R.2.12.2 (R Development Core Team 2007), we used residual and leverage plots to test each model's assumptions.

Results

During the 6 months of the survey, 732 participants created gardens in the Virtual Garden program (Supporting Information), of which 85% ($n = 622$) were useable. It appeared that the 30-minute time limit did not constrain garden design because 93% of participants finished designing a garden to their satisfaction within the allotted time and participants seemed to get impatient toward the end of the allocated time. We granted extra time to 43 participants who could not finish their gardens to their satisfaction due to software bugs, disturbances (e.g., phone calls), or low aptitude for use of the program. The distribution of genders and ages among participants (Table 2) was similar to their distribution in the Paris region (Supporting Information). Participants took 19.2 minutes on average to create a garden, and the average garden contained 24 features altogether, including on average 9 different objects, 5 animals, 8 flowers, and 5 woody species (Table 2).

Preferences for biodiversity elements differed widely among participants. On average participants put fewer biodiversity elements (i.e., animal, flower, and woody species) in their gardens than would have been expected at random. Although the distribution of woody species richness was similar to the expected distribution, flower and animal richness differed substantially from what would have been expected at random (Fig. 2). About 30% of gardens did not contain any animal species, and 27% of gardens contained fewer than 5 animals. The observed distribution of flower richness differed from random; 9% of gardens contained all the possible flower species ($n = 23$). Among animals, ladybug (*Coccinella septempunctata*) were the most frequently selected and preferred animal species. European Peacock (*Inachis io*) and the Great Tit (*Parus major*) were the second- and third-most selected, and the red fox (*Vulpes vulpes*) and chimpanzee (*Pan troglodytes*) were least preferred species (Table 1). Whereas butterflies, other invertebrates, fish, and birds were selected significantly more frequently than expected by random ($t = 8.45, p < 0.001$; $t = 3.74, p < 0.001$; $t = 4.49, p < 0.001$; $t = 1.89, p = 0.058$, respectively), mammals and herptiles were selected less frequently than expected by random ($t = -11.42, p < 0.001$; $t = -2.29, p = 0.022$, respectively). Among the

16 most selected animal species, 81% were common in Parisian gardens, whereas among the least selected species only 37% are common. Most non-native species ($n = 7$) were not among the most selected animals. Participants also tended to prefer native species (e.g., European Robin [*Erithacus rubecula*], small white [*Pieris rapae*], and Mallard [*Anas platyrhynchos*]) to non-native ones ($t = -4.25$, $p < 0.001$).

Software, garden, participant type, and socioeconomic status and proenvironmental stances variables were important in explaining the variance in biodiversity placed in the gardens. While the aptitude of the participant for the software negatively affected only flower richness, the time spent creating the garden had an important positive effect on all the dependent variables (Table 3). Patients designed gardens with more native species than staff and visitors (Table 3). Men designed gardens with significantly fewer animal and flower species than women, and the gardens of older participants contained significantly fewer non-native animal species and more flower and woody species than the gardens of younger participants (Table 3). Participants with advanced degrees placed more woody species in their gardens, and those who perceived their income as low-designed gardens with more animals and woody species (Table 3). Participants who were very concerned about the disappearance of bees placed significantly more species in their gardens across all taxonomic groups and more native animals than participants who were less concerned about the disappearance of bees (Table 3). Participants who wanted to interact with nature in their gardens designed gardens with greater species richness of animals, flowers (PP = 0.49), and woody species than participants who did not want to interact with nature (Table 3). Participants who spent their childhood in relatively rural areas designed gardens that had significantly higher flower and woody species richness than participants who spent their childhood in more urban settings. The number of objects participants placed in gardens was positively correlated to animal, flower, and woody species richness and negatively correlated to placement of native species (Table 3).

Discussion

Most of the extensive research into the psychological benefits of urban nature has considered the natural environment as uniform (Tzoulas et al. 2007; Matsuoka & Kaplan 2008). It is only recently that scholars have begun investigating to what extent ecological complexity of nature is related to these benefits. Their investigations reveal evidence of a mismatch between reality and perception of biodiversity (Fuller et al. 2007; Dallimer et al. 2012; Shwartz 2012). For instance, city dwellers appreciate and desire species diversity in green spaces and relate this diversity to their well being (Lindemann-Matthies et al. 2010; Shwartz 2012). When visiting green spaces, however, people are often unaware of this diversity, and research results do not show a consistent relation between species richness and human well being (e.g., Fuller et al. 2007; Luck et al. 2011; Dallimer et al. 2012). These results emphasize the importance of measuring people's affinity for biodiversity in context (i.e., accounting for their other expectations of a given green space, e.g., recreation or aesthetics). One advantage of Virtual Garden is that it can facilitate this process.

Using Virtual Garden

Virtual Garden is a new tool that offers a novel way to explore the complex relation between people and biodiversity in cities or other contexts. The program was designed to be attractive and simple to use, and indeed only 15% of people who started creating a garden did not finish. Because this software is essentially a garden design game that is based on pictures and not words, it may reduce some of the traditional biases of social-science surveys, such as dependence on formulation (Filion 1981; Luck et al. 2011) and exploring actions versus statements. Another advantage is that the research topic does not need to be specified directly to participants, which can bias results. Furthermore, the program offers a standardized way to explore the people-biodiversity relation across countries and cultures (with minimal modifications).

Our survey in Parisian hospitals provided several insights into the use of the software. When using the software it was important to control for the amount of time taken to create the garden. As expected, the longer participants took the more features were placed in the gardens. Thirty minutes appeared to be a reasonable limit that standardized the work of different participants and the efficiency of the research. Caution should be taken when using the software with people who do not often work with computers. Many of the participants we helped with the program because of their low aptitude for its use, made statements such as, "just put all the flowers." These participants, unlike other participants who had to select each species, exerted little effort into the design of their gardens. Seventy-five percent of participants who placed all the flower species in the gardens had a poor aptitude for use of the program. We also found a strong positive relation between garden complexity (i.e., number of objects) and the diversity of plant and animal species that participants placed in their gardens. Therefore, it is important to account for this variable to ensure that one studies people's preferences for biodiversity and not for complexity.

The program provides opportunities to investigate different questions concerning the relation between biodiversity and people on the basis of several indices. First, the program automatically computes several diversity and garden-characteristic variables that are frequently used

Table 3. Results of models that explored variables that affect the number of animal, flower, and woody species ($n = 622$) people place in their ideal garden and the variables that affect people's preference for native species.

Variable type	*Variable*	*Animal richness (coefficient, SE)[a]*	*Native preference (coefficient, SE)[a,b]*	*Flower richness (coefficient, SE)[a]*	*Woody species richness (coefficient, SE)[a]*
	intercept	0.434, 0.278	−0.044, 0.046	1.400, 0.222	0.437, 0.159
Socioeconomic	gender (male)	−0.200, 0.112*		−0.137, 0.071*	
	age		0.001, 0.000**	0.007, 0.002**	0.004, 0.001**
	income	−0.038, 0.031*			−0.023, 0.014*
	qualifications				0.063, 0.016**
Proenvironmental	interaction with nature (yes)	0.243, 0.108**			0.130, 0.045**
	bees	0.107, 0.041**	0.016, 0.006**	0.038, 0.032*	0.064, 0.015**
	childhood			−0.021, 0.027*	−0.049, 0.018**
Software	time	0.029, 0.006**	0.003, 0.000**	0.013, 0.001**	0.017, 0.002**
	aptitude (unable to use)				
	aptitude (poor)			−0.497, 0.128**	
	aptitude (good)			−0.301, 0.083**	
	aptitude (exceptional)			−0.340, 0.116**	
Participant type	patient				
	staff		−0.024, 0.022*		
	visitor		−0.026, 0.025*		
Garden	number of objects	0.037, 0.015**	−0.006, 0.002**	0.034, 0.010**	0.033, 0.006**

[a]*Significance is *$p < 0.05$ or **$p < 0.01$ on the basis of postprobabilities (PP) >0.95, 0.95–0.5, and <0.5 corresponded roughly to* p *values <0.01, 0.01–0.05, >0.05 (Pellissier et al. 2012).*
[b]*Because this model only analyzed the answers of participants who placed animals in their garden* $n = 435$.

in ecological studies (e.g., richness and abundance of species and objects, lawn, and tree cover). Second, the program records each step during creation of the garden and thus allows researchers to consider participants' priorities, given their socioeconomic status and environmental stances. To illustrate some of these possibilities, we discuss below participants' preferences for animals and the variables that affected the selected richness of different taxonomic groups.

People-Biodiversity Relation

Approximately 30% of participants did not include any animal species in their garden. One possible explanation for this could be that animals are not necessarily considered essential features of a garden (perhaps since in the software animals did not appear alive in the garden itself). Because animals were not embodied in garden design, selecting them indicates a clear interest in biodiversity beyond other gardens functions. Lack of experience with nature (Miller 2005), especially in the heart of a large metropolis, may explain this result. People are increasingly growing up and living separated from nature (Turner et al. 2004); thus, they may lose some capabilities to experience it, which in turn could modify their relation with nature. Several variables that may measure this experience were correlated with the diversity of species participants placed in their gardens.

Important components of how a person experiences nature is knowledge and childhood experiences (Palmer & Suggate 1996). Older participants and participants with a high level of education designed gardens that were more biodiversity rich than younger or less educated participants. Older people are often more knowledgeable and show a higher awareness of and concern and understanding for conservation issues (Kellert 1984; Lindemann-Matthies & Bose 2008). Since older people grew up in a less urbanized, more natural world, they may also be better able to recognize species. Accordingly, older participants placed more native species in their gardens than younger participants and while creating their gardens they were more likely to mention the name of an animal or plant species. Results of studies also show that exposure to the natural environment during childhood increases knowledge and awareness of the environment (e.g., Palmer & Suggate 1996; Lindemann-Matthies 2005). Our results show that participants who grew up in less urbanized environments designed gardens that were richer in flower and woody species. This supports the hypothesis that knowledge and interaction with nature affect people's preferences for biodiversity (Lindemann-Matthies & Bose 2008). Therefore, enhancing people's interactions with nature by providing opportunities for adults and children to explore and learn about it could greatly improve the public's support of conservation (Shwartz et al. 2012).

Participants who placed animals in their gardens selected primarily invertebrates rather than mammals, which is inconsistent with earlier findings (e.g., Kellert 1985, 1993; Driscoll 1995; Lindemann-Matthies 2005). That they did not select "loveable animals," in the words of Kellert (1985), could be context dependent. Although participants were asked to create their ideal public garden, they appeared to limit their choices to species that occur in Parisian public gardens. For instance, chimpanzee, red fox, and beech marten (*Martes foina*) were among the least selected animal species, unlike what was found in other studies (e.g., Driscoll 1995). Thus, in our study, recognition and a cognitive association of the species with public gardens may have affected participants' selections. However, animal selection may also suggest that participants did not consider the functionality of the ecosystem when designing their garden. Instead, they seemed to base their selection of animal species mostly on aesthetic criteria (Lindemann-Matthies 2005), regardless of their viability in the gardens. It is possible that participants perceived their urban gardens as artificial green spaces and this perception may result in selection of ornamental nature that is known (i.e., selection of colorful and known species, as if the garden were a sort of zoo). Altogether our findings could be interpreted as consistent with the extinction-of-experience hypothesis (Miller 2005). The biodiversity people experience in their daily lives could affect their knowledge of nature and shape their preferences and affinity toward nature.

Our results also suggest that a proenvironmental stance and socioeconomic status may help explain participants' relations with biodiversity. Concern for the disappearance of bees was positively correlated to animal, flower, and woody species richness and to the selection of native animals. Participants who wished to interact with nature in the gardens placed more animal, flower, and woody species in their gardens. These results suggest a consistency between the gardens participants created and their stated intentions and knowledge. If we are to understand the effect of socioeconomic variables on the people-biodiversity relation, it is important to control for this confounding variable (i.e., control for proenvironmental stance of participants).

Although age and education were positively correlated with the biodiversity indexes in accordance with previous research (Kellert 1984; Lindemann-Matthies & Bose 2008), income was negatively correlated to the richness of animal and woody species, in contrast to previous research (Kellert 1984). In large cities, wealthy people have the financial means to live closer to biodiversity-rich areas (Turner et al. 2004) and to travel outside the city and experience it. In Phoenix Arizona, income is positively associated with plant diversity (Hope et al. 2003). We found, however, that poorer participants designed more diverse gardens than wealthy participants. These results help dispel the notion that only more affluent people have an affinity with biodiversity (Kellert 1984). Perhaps for less wealthy people, who cannot afford to travel to the countryside often, small public urban gardens are their window on nature, which may explain why they created more diverse gardens. Overall, our results are consistent with the results of field and perception studies that show a relation among socioeconomic variables and species diversity or knowledge and affinity to biodiversity (e.g., Kellert 1984; Hope et al. 2003; Turner et al. 2004; Lindemann-Matthies & Bose 2008). Understanding the variables that affect people's affinity for biodiversity is thus desirable to inform prioritize of conservation efforts in cities.

One of the main motivations for conserving urban biodiversity is to facilitate city dwellers' experiences with nature so as to improve the well being and conservation awareness of city dwellers (Dearborn & Kark 2010). However, mixing those objectives with direct biodiversity conservation objectives is challenging because city dwellers do not necessarily think and experience biodiversity (Dallimer et al. 2012; Shwartz 2012). The Virtual Garden program offers a new user-friendly tool that may serve as a first step in understanding the relations between people and biodiversity in urban areas (among other areas). This software could also be used by conservationists and planners to facilitate participative discussions and interactive decision-making processes. Data generated from different countries, cities, or other locations across the world may provide a better understanding of the role culture and living context (e.g., level of urbanization) play in people's relations with biodiversity. This could help prioritize conservation efforts in cities and allow more evidenced-based decision making when several motivations appear to be conflicting.

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Supporting Information

List of available features in Virtual Garden and the representativeness of participants in the experiment of the human population of Paris (Appendix S1), the Virtual Garden questionnaire (Appendix S2), full coefficients lists for all models and the postprobabilities ratio for each variable (Appendix S3), and several examples of virtual gardens created by participants (Appendix S4) are available online. The authors are responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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