

Article

Key Factors Strengthening Residents' Psychological Well-Being and Critical Human-Nature Connections within the Living Spaces—An Example from Beijing

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Abstract: Background: Residential green spaces and the co-inhabiting bird communities provide critical cultural ecosystem services for urban dwellers, which is critical for citizens' psychological well-being but has largely been overlooked, especially in China. This study attempted to delineate the relationship between human-nature interactions occurring at different scenarios in the health deriving procedure, and identify the key factors influencing urban residents' psychological well-being and the potential critical human-nature connections within their living spaces. Methods: Bird, plant, and social surveys were sequentially conducted. A model selection procedure based on AICc information was used to find the key factors that are responsible for residents' psychological well-being, and logistic regression analysis was conducted to figure out the key drivers for the occurrence of critical within-living-space human-nature connections. Results: Most of the respondents are aware of the neighborhood biodiversity and most of them are fond of it, and respondents who prefer fauna over flora have a considerably lower depression degree. Watching birds is the only critical within-living-space nature-related activity that is responsible for residents' psychological well-being. Both residents' psychological well-being and bird watching activity were simultaneously affected by nature-related activities within and outside the living spaces, while their preference for different aspects of biodiversity and their capability in perceiving them were also important, despite the difference in exact parameters. In addition, personal attributes such as age, financial income, and physical or mental health status also contribute to psychological well-being. Conclusions: This study successfully bridged citizens' minds with health products, and the major contribution was the demonstration of a spatial-scale-oriented circuit for people-nature connections, which contributes to the practical application of nature-based therapy.

Keywords: China; cultural ecosystem services; human-nature connections; neighborhood nature; psychological well-being; residential community



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1. Introduction

Being one of the major urban green space types, residential green spaces account for a significant part of the gross urban green space volume [1]. Although small in size and poor in vegetation structure compared with other well studied urban green spaces such as urban parks, residential green spaces sustain a large number of bird populations and non-negligible avian species clusters [2]. Given the well-known human-nature separation

under the background of global urbanization, residential green spaces and the co-inhabiting avian communities as a whole provide critical ecosystem services for urban residents [3], which is important for improving psychological well-being [4] and life quality, especially in the special period during the COVID-19 shutdown [5], however, their role has largely been overlooked [1].

A deep understanding of key components of the neighborhood nature and the definite benefits they derived could help delineate the underlying mechanism defining the nature-health relationship. According to previous results, different aspects of both nature and citizens could play important roles in mediating the provision of nature-related health benefits [3,6]. Compared with the inconsistent health benefits from the amount of neighborhood nature resources (ranging from insignificant [7] to important [8]), vegetation composition, avian community structure, or even the presence of some bird species, which reflect the green space quality, could be critical in the improvement of psychological well-being [9,10]. Further, a study by Phillips and Lindquist [11] showed that the Pearson correlation coefficient between actual biodiversity and perceived biodiversity was 0.27, while the value was suggested to be 0.33 in another study [12], which, as a whole, highlighted the difference between the two aspects of neighborhood biodiversity. More interestingly, the author reported a highly significant quadratic relationship between actual biodiversity and participants' preferences, indicating a threshold in people's preferences for biodiversity [11]. Given the abundant information on the psychological benefits from biodiversity [13,14], there are still knowledge gaps that exist in the green-health relationship, for example, how do residents residing in Chinese-style residential communities enjoy neighborhood biodiversity, and which is the most dominant way? In this case, which aspect of neighborhood biodiversity is most important for residents' psychological well-being [3]?

Citizen's personal characteristics and social-economic status could also be critical in the formation of nature-derived health benefits. For example, residents' subjective well-being varied with home ownership [15], while the benefits that are gained from access to green space could be either significantly mediated by personal characteristics such as age, gender, and ethnic background [16], or unrelated to them [9]. A person's lifestyle could also be important for their psychological well-being, since a healthy lifestyle, such as those with regular physical activity, could be beneficial for both the physical [17] and psychological health [18]. Furthermore, the frequency of human-nature interactions could be highly significant for the derivation of health benefits. Recently, many studies have focused on the influence of access frequency and key factors that are responsible for it, which is important for the improvement of life satisfaction [19].

More systematically, it was suggested that cultural ecosystem services that are provided by different types of urban green space could be different while complementary [20], and there were clear distinctions in the urban nature-health relationships derived from different spatial scales. For example, at large spatial scales, the effect of biodiversity level on psychological health is significant [21], while the given relationship was not significant at the neighborhood scale [3,22]. The paradox could be implicitly evidenced by a multi-city study, which suggested the critical effects of living spaces' location in the green-health relationship, highlighting the role of landscape configuration at different spatial scales [23].

Nowadays, the positive effects of urban nature on citizens' psychological well-being has been widely accepted, while the definite pathway through which urban green space and the co-inhabiting avian community benefit urban residents is still unclear, especially the exterior ones, that is, the actions connecting people with nature. It was suggested that successful identification of the linkages between biodiversity and human health is critical for the demonstration of the specific causal pathways through which biodiversity affects human health [22], while the amount of natural benefits has been demonstrated to be dependent on people's connectedness with nature [24], which varied among different populations and has been successfully modeled to evaluate the potential personalized benefits in specific status [25]. However, which factors promote the formation of human-nature connectedness is still ill-defined. In this study, based on a comprehensive research

on cultural ecosystem services that are provided by private/semi-private residential green and public green spaces, we try to differentiate the cultural services that are derived from natural resources belonging to different green space types or spatial scales, which would be helpful in delineating the definite mechanisms underlying the formation of human-nature connections, or, more practically, provide detailed references for nature-based therapy to treat ubiquitous mental illness.

Based on previous studies, here, we assume that psychological well-being is affected by nature-related activities occurred within the residential community, such as watching the green space through a window, taking photos of flowers or trees, which varies across populations; while the occurrence of those human-nature connection-promoting activities also depends on the nature-related activities inside and outside the living spaces, but also varies across different populations. Based on the above assumptions, we aimed at filling the following knowledge gaps: 1. Which aspects of neighborhood biodiversity are most efficient for the derivation of health benefits? 2. Which type of human-nature interactions most efficiently promote the positive effects of residential green spaces and birds upon urban residents' psychological well-being? 3. What are the key factors deciding the occurrence of those key interactions? Our results could help delineate the specific mechanisms underlying the relationship between natural elements within the urban region and human psychological well-being.

2. Materials and Methods

2.1. Study Area and Sites

Beijing, the capital of China, is an international metropolis with about 21.89 million residents at the end of 2020 [26]. In this study, we focused on the urbanized area (area located within the 5th ring-road), which covered about 660 km² while being inhabited by nearly half of the gross population [26]. There is a significant social-economical gradient from the city center to the outer ring roads, which is characterized by the population density and urbanization degree [27]. There are about 4000 residential communities within our study area, however, only about 3.48% (1080.05 ha) of urban green cover was located within them [27]. Although small in size, residents are still able to directly (intentionally appreciate natural processes or phenomenon) or indirectly (unintentionally encounter with neighborhood biodiversity) utilize the collectively owned residential green spaces. In this study, a total of 27 residential communities were selected as our sample sites, which were evenly distributed and varied in size, shape, height, and constructed years. The geographic distribution of our sample sites can be found in Figure 1. More detailed information for our sample sites can be found in [2].

2.2. Avian and Vegetation Survey

We conducted the avian surveys in the breeding (May 2018 to June 2018) and wintering (December 2017 to February 2018) season, each of the 136 sample points designed for the 27 sample sites was surveyed sequentially once per month.

The avian surveys were conducted within the three hours after sunrise, on days without rain/snow and strong wind. We accurately counted bird species and individuals that appeared in each census circle (25-m radius) within five minutes.

Vegetation surveys were conducted in the period when regional vegetation is at its most exuberant (July 2019). Within each avian survey point, we recorded the vegetation structure within a 10 m × 10 m standard quadrat. In each single count, we sequentially recorded the coverage of woody plants; plant species (including tree, shrub, and herb species); and their phenology. The size and width of each single green patch were measured in Google Earth. A more detailed description for the avian and vegetation surveys can be found in [2].

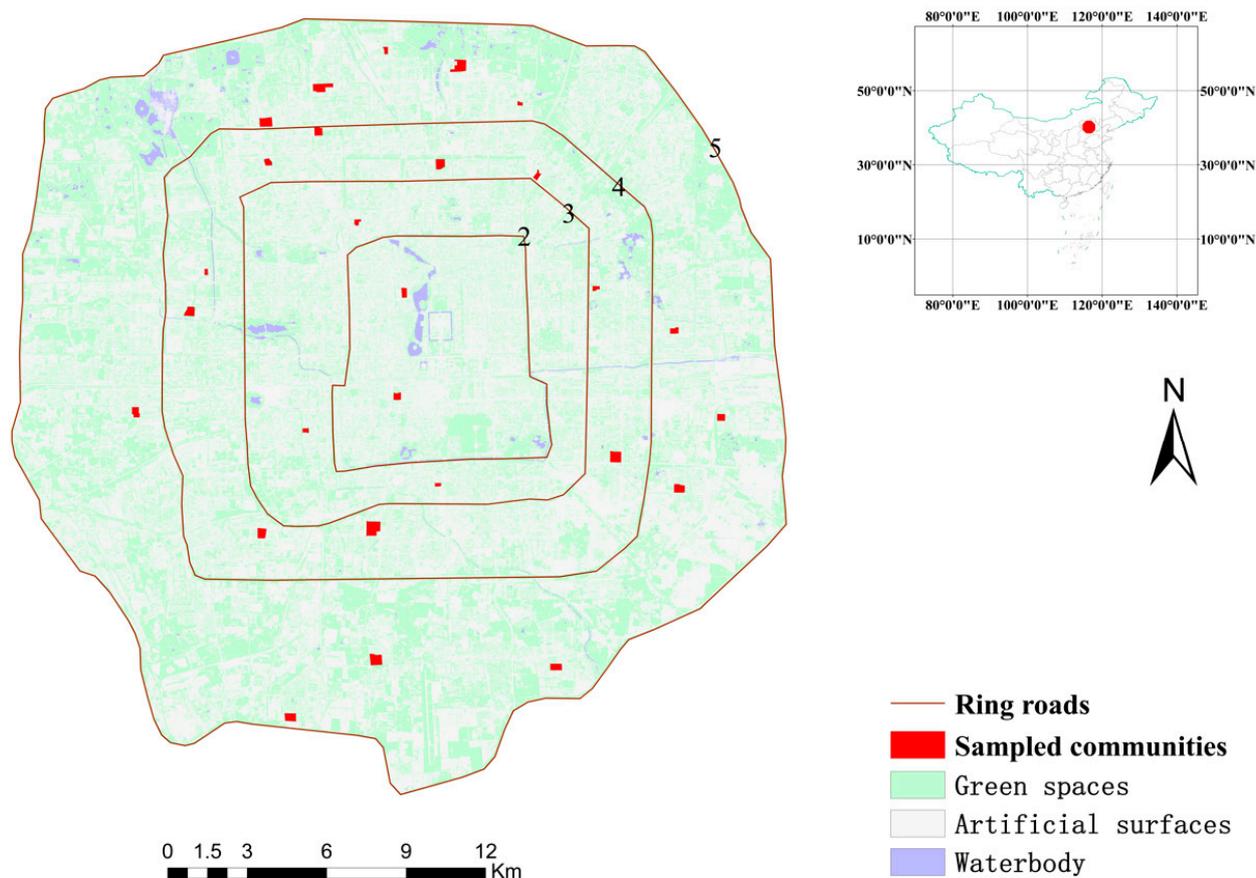


Figure 1. Spatial distribution of our sample sites within urban Beijing. The brown concentric lines indicate urban Beijing’s major beltways (2nd–5th). All the samples are spaced more than a kilometer apart.

2.3. Questionnaire Survey

After the avian and vegetation survey, a systematic social survey was conducted in each of our sample sites. To fill the mentioned knowledge gaps, we designed a questionnaire which includes four major parts, namely: (1) the frequency of different kinds of nature-related activities; (2) knowledge and attitudes toward biodiversity in residential communities; (3) mental health status and psychological well-being; and (4) necessary basic personal information.

In the first part, we asked each interviewee about the frequency for nature-related activities both within and outside the living space, the answers were settled as five levels, ranging from never to nearly every day, which were then transformed to numeric values (1–5) for the convenience of statistical analysis.

In the second part, we asked each interviewee about their knowledge for the neighborhood biodiversity, including the perceived number of bird and plant species, which were settled as a series of numerical intervals based on the actual bird/plant species richness that were derived from the above-mentioned field surveys, and their preference for different biomes (fauna and flora). In addition, according to an existing study that was conducted in the same area, the Eurasian Tree Sparrow (*Passer montanus*) is the most abundant (accounted for 91.0% of total individuals in the breeding season) and well known bird species in urban Beijing’s residential communities [2]. Thus, we designed a question to evaluate whether residents prefer more bird individuals by asking their preference for more Eurasian Tree Sparrow.

In the third part, to get the response variable, we directly tested the psychological well-being for each respondent, using seven scale answers within five well-designed

questions [28]. Since the psychological well-being could be affected by both the physical and mental health status, we additionally asked respondents about their self-reported physical health status and, with the permission of each respondent, we tested the depression level using the simplified depression-test of Hong Kong Mood Disorders Centre [29].

In the last part, after promising that the data would only be used for statistical analysis, we asked each interviewee about their basic personal information, including gender, age, education, occupation, income, household tenure, length of residence, and some information on lifestyle, which would help differentiate different populations in our later analysis.

Before the formal questionnaire survey, all five investigators (including the first author) gathered in an unrelated community to conduct a pre-survey, aimed to communicate and standardize the social etiquette. To ensure responses from representative population samples were effectively collected, we simultaneously adopted the face-to-face paper questionnaires and online platform to collect answers. Detailed process in this part could be found in [30].

2.4. Data Analysis

We excluded responses from residents who had lived in their current residential communities for less than three months, assuming that their psychological well-being is largely affected by their previous living spaces. We adopted the Mann–Whitney U test to compare the differences between the number of respondents holding different preferences or attitudes toward different aspects of neighborhood nature.

The relationship between psychological well-being and environmental variables (all indices displayed in Table 1) were determined with a linear mixed model (LMM), with the residential communities being the random effect. Predictive variables identifying different population clusters were defined as categorical variables, while the others were treated as numeric variables. We adopted the `gvlma` function in R package “`gvlma`” [31] to ensure that the initial model fit the basic assumptions of linear regression (including skewness, kurtosis, link function, and heteroscedasticity). We calculated the variance inflation factors (VIF) for each predictive variable to solve the multicollinearity problems, and we checked outliers based on the Bonferroni test ($p < 0.05$). When the $\sqrt{\text{vif}}$ of all the independent variables in initial models were < 2.0 , we used stepwise regression to obtain the best model subsets based on the rule of $\Delta\text{AICc} < 2.0$ (sensu [32]). In addition, if any categorical variables were included in the final models, we further conducted the Tukey post hoc test with Bonferroni correction for the p -values to clearly delineate their effects on respondents’ psychological well-being.

Table 1. Predictive variables used in our data analyses. The categorical variables are displayed in italics.

Types	Abbreviation	Range	Descriptions
<i>Basic1</i>	<i>Gender</i>	1,2	<i>Man-1; Woman-2</i>
<i>Basic2</i>	<i>Age</i>	1–5	<i>Each integer stands for an age interval</i>
<i>Basic3</i>	<i>Occupation</i>	1–10	<i>Each integer stands for an occupation type</i>
<i>Basic4</i>	<i>Resi_type</i>	1,2	<i>Residential type: Owner-1; Tenant-2</i>
<i>Basic5</i>	<i>Exer_habit</i>	1,0	<i>Regular Exercise habit: Yes-1; No-0</i>
<i>Basic6</i>	<i>Birding</i>	1,0	<i>Experience in intentionally watching birds appeared in the living spaces: Yes-1; No-0</i>
Basic7	Education	1–7	From Primary education to PhD
Basic8	Income	1–7	From none to >20,000 CHY/month
Basic9	Dur_liv	1–6	Living duration: From less than three month to more than 10 years

Table 1. Cont.

Types	Abbreviation	Range	Descriptions
Health1	Phys_cond	1–5	Physical condition: From very bad to very good
Health2	Depre_level	1–7	Depression degree: From none to pathologically
NatAct1	Appre_nat_liv	1–5	Frequency of appreciating natural phenomenon in living spaces: From never to nearly every day
NatAct2	Park_vis_freq	1–5	Frequency of visiting urban parks: From more than once per week to rarely
NatAct3	Nat_vis_Freq	1–5	Frequency of visiting natural scenery: From more than once per week to rarely
DivKnow1	Prefer_bio_liv	1,2	Preference for different biomes in the living spaces: Animal-1; Plant-2
DivKnow2	Aware_bird_var	1,0	Awareness of seasonal bird species change: Yes-1; No-0
DivKnow3	Altit_bird_liv	1,0	Altitudes toward birds appeared in the living spaces: like-1; dislike-0
DivKnow4	Perc_tree/shrub/herb_spe	2–16; 3–31; 2–41	Perceived number of tree/shrub/herb species in the residential community
DivKnow5	Perc_bird_spr/wint	1–9	Perceived number of bird species in spring/winter
Green1	Max_green	0.16–1.22	Maximum size of a single residential green patch (ha)
Green2	Green_wid	15.25–70	Average width of all major green patches in each site(m)
Green3	Green_rat	0.15–0.46	Green ratio of each residential community
Green4	Tree/Shrub/Herb_Spe	1–25; 5–31; 3–46	Recorded number of tree/shrub/herb species in each residential community
Birds1	Birds_breed/wint	2–7/1–8	Recorded number of bird species in the breeding/wintering season
Birds2	Den_ETS_breed/wint	27.52–229.30; 10.19–173.25	Recorded density of ETS in the breeding/wintering season
Social1	Location	2–5	Beijing's major ring roads: From the city centre toward suburb area
Social2	Housing_price	4.3–15	Average housing price in the past three years (10,000 CNY)

To figure out the reason for evaluating which specific nature-related activities within the living spaces have critical effects on psychological well-being, we further conducted mixed logistic regression analysis, assuming a binomial distribution for the responsible variables. The sampled communities were adopted as the random effects. The environmental variables that were used for the logistic regression analysis were the same as the LMM analysis, except for the additional add of the self-reported depression degree (Depres_degree), and the perceived number of tree/shrub/herb species was redefined as numeric variables to improve the convergence of the initial model. The model selection and logistic regression analyses were based on the R package lme4 [33], and the multiple comparisons were conducted with package multcomp [34].

3. Results

3.1. Urban Residents' Attitudes toward Neighborhood Biodiversity

In our questionnaire survey, we successfully collected 659 answers from 23 residential communities, after careful screening and exclusion, 568 of them were deemed to be valid.

Among the valid questionnaire dataset, there were 272 males and 296 females, 29 juveniles (under the age of 18), and the majority of the valid respondents were aged between 18 and 60 (425, 74.8%).

Residents in urban Beijing showed differentiated responses toward major aspects of neighborhood nature. Most of the respondents noticed the birds appeared in their living spaces ($p < 0.001$, Figure 2A), and a major portion of them showed an obvious positive attitude towards them ($p < 0.001$, Figure 2B). In addition, residents successfully perceived that most of the bird species that appeared in their living spaces, and the most dominant way to enjoy them was by looking with the naked eye (about 53% of the gross number of respondents, Figure 2C). It is interesting that respondents showed a preference for animals over plants with a significantly lower level of depression possibility ($p = 0.03$, Figure 2D).

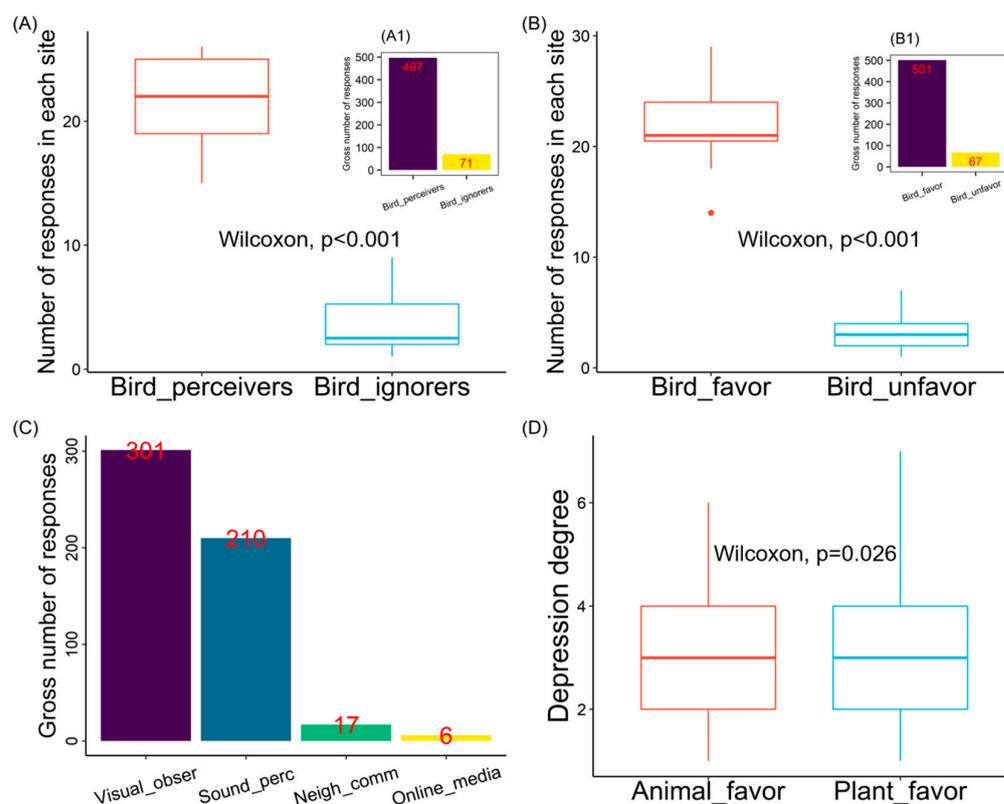


Figure 2. Characteristics of cultural ecosystem services provided by biodiversity within urban Beijing's residential communities. Panels: comparisons between (A) the number of respondents who perceived or ignored birds in their living spaces, and subfigure (A1) showed the gross number of respondents of the two population guilds, (B) the number of respondents who like or dislike birds in the neighborhood, and subfigure (B1) showed the gross number of respondents holding each attitude, (C) the major way to enjoy neighborhood birds in all the sampled residential communities, and (D) the depression degree of respondents who favor animals or plants that appeared in their living spaces.

3.2. Key Factors Influencing Citizens' Psychological Well-Being

Based on our model selection results, the psychological well-being of our respondents was simultaneously affected by nature-related activities within (Birding) and beyond (Nature visit frequency) the residential communities (Table 2). Respondents that usually (intentionally) watched birds that appeared in the living spaces showed a significantly higher level of psychological well-being (Figure 3B).

Table 2. Results of model selection analysis for residents' psychological health based on AICc criterion. All the models are very significant ($p < 0.01$) with a marginal R^2 ranging from 0.2712 to 0.2755. The '+' stand for the significant effects of categorical variables. For descriptions for predictive variables, please see Table 1.

	Mod1	Mod2	Mod3
(Intrc)	4.787	4.571	4.871
Nature visit frequency	0.06564		0.06535
Birding	+	+	+
Age	+	+	+
Income	−0.1177	−0.108	−0.1182
Duration of living			−0.02064
Physical state	0.2198	0.2296	0.2209
Preferred biome	+	+	+
Perceived herb species	+	+	+
AICc	1678.4	1680	1680.1
weight	0.53	0.244	0.226
R^2_m	27.55%	27.12%	27.51%

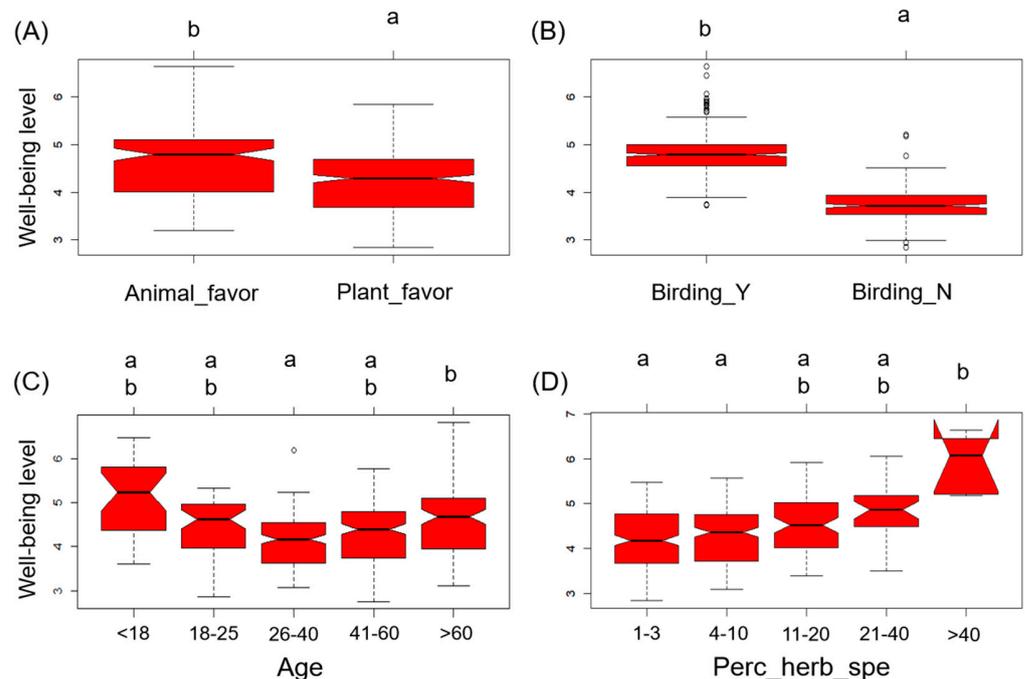


Figure 3. Predicted psychological well-being under different levels of the four key categorical variables. Different lowercase letters represent for different effect levels, and significant difference only occurred between the single letters 'a' and 'b'. Panels: comparisons between (A) people who prefer animals and plants within their neighborhood, (B) residents with (Birding_Y) and without (Birding_N) bird watching experience, (C) residents in different age intervals (here presented as the original intervals in our questionnaire), and (D) residents who perceived different number of grass species (here presented as the original intervals in our questionnaire) within their living spaces.

In addition, residents' preference for different biomes appeared in their living spaces and their perceived number of herb species also showed significant effects. Compared with flora, respondents that preferred fauna within the living spaces showed a significantly higher level of psychological well-being and a lower depression degree (Figure 2A); the number of perceived herb species steadily contributed to residents' psychological well-being, but the contribution seems to be especially significant when the residents have an excellent ability in capturing the neighborhood herb species (Table 2 and Figure 3D).

Personal characteristics could also mediate nature-derived health benefits, including age, financial income, living duration, and self-reported physical health status (Table 2). It is worth noting that the psychological well-being did not change linearly with growing age (Figure 3C).

3.3. Key Nature-Related Activities within the Living Space and Factors That Promote or Hinder Their Occurrence

With regards to the factors that promote or hinder the occurrence of the only key nature-related activity within living spaces (watching birds), both the appreciation of nature within (Appre_nat_liv, CI: 0.25~0.63, $p < 0.001$) and beyond (Nat_vis_freq, CI: 0.31~0.64, $p < 0.001$) the residential community had a significant contribution, while residents' capability in perceiving the neighborhood biodiversity (Perc_shrub_spe, CI: 0.01~0.62, $p = 0.04$, Perc_bird_wint, CI: 0.09~0.37, $p < 0.001$) also showed significant positive effects. In addition, respondents' attitude towards birds that appeared in the living spaces significantly affects the bird watching activity within the living spaces, although the effect size fluctuates widely (CI: 0.08~1.42, $p = 0.03$). The self-reported mental health status (Depres_degree, CI: -0.36~-0.07, $p < 0.001$) also significantly hinders the occurrence of the focused nature-related activity, while the effect of physical condition (Phys_cond, CI: -0.38~0.15, $p = 0.39$) is not significant (Figure 4).

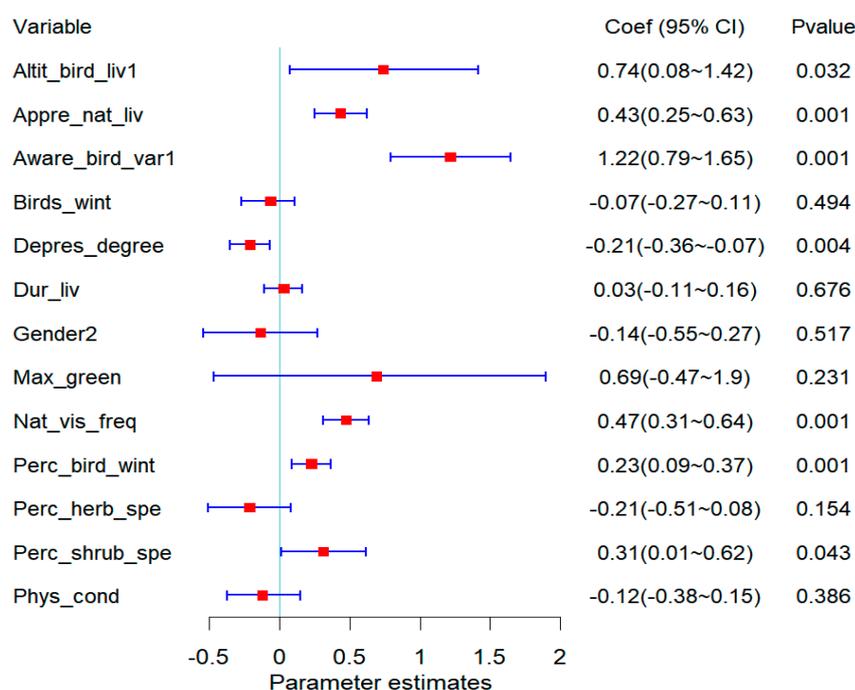


Figure 4. Logistic regression results for key factors promoting bird watching activity within the living spaces. The definition of the level for categorical variables can be found in Table 1.

4. Discussion

The population structure is reasonable compared to the gross regional population [26]. In this study, we successfully demonstrated that the establishment of effective connection with nature is a key step toward increasing residents' psychological well-being, which provides a reasonable description for a previous study, which suggests that respondents who are more connected to nature will enjoy greater psychological benefits after exposure to green space [12]. More definitely, we suggest that the intentional enjoyment of natural elements either within or outside the living spaces is exactly the most efficient bridge between urban residents and neighborhood nature.

Our results showed that the appreciation of the natural world could influence not only psychological well-being, but also the occurrence of nature-related activities inside

the living spaces. It is consistent with previous research which delineated the indirect effects of restoration-mediating influence of biodiversity on emotional well-being [24]. On the other hand, according to the spirit of personalized ecology [35], different aspects of the neighborhood nature (such as the shrub and herb species) showed different effects on residents' psychological well-being, specifically in different pathways, which highlights the importance of the definite classification of people, nature, and ecosystem services.

It is worth mentioning that people's attitudes toward neighborhood biodiversity, such as the attitudes towards birds in the living spaces, may not show significant effects on psychological well-being because of the deficiency of reasonable connections, but they largely decided whether a citizen would intentionally appreciate the nearby birds. In this case, the nature-related activity within the living spaces successfully bridged neighborhood biodiversity and urban dwellers to derive health benefits. Indeed, we do not feel surprised about the key role of watching birds within the living spaces because its effects in connecting people and nature has been consistently reported [36,37]. Instead, the major contribution of this study was the demonstration of a spatial-scale-dependent circuit for people-nature connections. However, we have to confess that there are only a limited number of birdwatchers who could be evaluated as high or medium specialization in China, according to the current classification standard [38], thus, we suggest that future studies in developed countries include new questions that could help classify the respondents' specialization in bird watching activity, which could further validate the importance of bird watching around the home in generating health benefits.

According to the existing results, perceived biodiversity is important for improving psychological well-being [36], while the actual species richness of birds or plants could be either important [8] or negligible [39]. Our results highlighted the effects of perceived species richness, while the influence of actual neighborhood biodiversity is insignificant both for the psychological well-being or the nature-related activity within the living spaces. Thus, we suggest that the future development or application of assessment tools for urban green spaces, such as the RECITAL [40], should pay more attention to the perceived green space quality, which has been suggested to be critical in deriving health benefits [41].

Nowadays, more and more city dwellers are migrating into residential districts with limited fauna and flora species diversity, which intensified the human-nature separation in urban areas [42]. Consistent with previous results [36,43], our study showed that most residents successfully captured neighborhood birds in their mind, and visual perception as being the major way to enjoy their beauty [36].

However, it is interesting that respondents who preferred fauna over flora had considerably better mental health. Given the limited knowledge on biodiversity concepts in developing countries [44], we believe that after a more effective and wide promotion of the beauty of urban fauna species (especially birds) by the authorities, citizen's attention and preference for those mobile and habitually hidden species could be improved, which has the potential to derive health benefits, although the causal relationship still needs further demonstration.

Also, it was suggested that residents on the urbanization gradient showed differentiated understanding on the green space benefits, such as the heat island effect mitigation and biodiversity enhancement [45]. More directly, a study in Tokyo suggested that bird or plant species with more obvious traits were perceived by more visitors, and a strengthened familiarity with local species which is less noticeable could enhance their perception of neighborhood biodiversity [6]. As a whole, this reflects the plasticity of citizen's attitude towards or knowledge on neighborhood nature. This is meaningful since our study demonstrated that residents' capability in perceiving neighborhood biodiversity could derive both direct and indirect benefits to residents' psychological well-being, while their preference for natural elements largely decided whether they would take action to achieve a deeper understanding of them.

5. Conclusions

This study successfully revealed the direct and indirect pathways through which urban residents' psychological well-being could be efficiently improved. Among the demonstrated key factors, bird watching activity within the living spaces seems to be a key connection which bridged urban residents and neighborhood nature to derive mental health outcomes. Citizens' capability in perceiving neighborhood nature and their attitude towards them largely decided the occurrence of the critical nature-related activities (watching bird) within the living spaces, while the plasticity of them has significant application value.

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Data Availability Statement: The authors have no right to share the data.

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

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