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Characterization of Visitors' Perception of Landscape Heterogeneity in Urban Green Spaces

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Abstract: In the current context of global urbanization, interdisciplinary research is needed to identify planning and management practices in urban green spaces (UGS) that would enhance both biodiversity and visitors' well-being. The perception of landscape heterogeneity, a core ecological concept, has been demonstrated to have a positive impact on visitors' psychological restoration. In order to apply these findings within UGS to planning and management practices, we need to characterize visitors' perception of landscape heterogeneity. We gathered data on 390 visitors' perception of landscape heterogeneity. Our results highlighted that visitors perceive landscape heterogeneity through the mixing of different heights of three vegetation strata and flower areas. Planning and management practices should enhance this landscape aspect within UGS to simultaneously promote biodiversity and visitors' psychological well-being.

Keywords: urban green spaces; urban biodiversity; psychological well-being; landscape configurational heterogeneity; perception

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1. Introduction

Urbanization is now recognized as one of the most important factors in explaining the current decline in global biodiversity [1,2]. In 2005, the Millennium Ecosystem Assessment [3] conceptualized a new framework for analyzing socio-ecological systems and highlighted that the degradation of ecosystems services often causes significant harm to human well-being. In this context, the importance of urban green spaces (UGS) is becoming clearer as they have been shown to partly maintain biodiversity [4,5]. UGS represent the entire network of parks, forests and other open green spaces in an urban area [6]. By their size, UGS help to maintain a diversity of ecosystems and thus species in urban areas [4], and to mitigate the impact of urbanization on the decline of biodiversity [7]. UGS also provide numerous ecological services to urban areas, including air purification or local climate mitigation [8]. Moreover, increasing biodiversity within UGS benefits the functionality of these areas, further strengthening the services provided [9]. Meanwhile, the positive impact of UGS on visitors' physical and psychological well-being has been clearly acknowledged by many studies [10–12]. The psychological well-being provided by UGS is notably supported by the Attention Restoration Theory [13,14]. This theory hypothesizes that nature has the ability to renew attention after exerting mental energy [15,16]. It thus promotes the idea that visitors can recharge and relax in public UGS [15]. Psychological restoration is conceived in terms of the recovery of directed attention from mental fatigue [16], relaxation, and stress reduction [17,18] and has been associated with a sense of contact with nature [19], with UGS being preferred places for a "nature experience" for many visitors [20]. Today, UGS are thus at the crossroads of environmental and social issues [21]. Yet, those issues can sometimes come into conflict, especially with respect to their planning and management [22]. A key challenge is to identify UGS planning and management practices that would enhance both biodiversity and visitors' well-being [23–25]. Interdisciplinary research involving both natural and social sciences is needed to generate an integrated and applied approach that articulates those environmental and social issues [26–28].

From an ecological perspective, biodiversity includes diversity at the genetic, species, and ecosystem (i.e., landscape) levels. It also accounts for the interactions between these levels in space and time (Convention on Biological Diversity, 1992). In this context, landscape heterogeneity is a core ecological concept positively associated with biodiversity [29]. It represents the combination of the complexity and the diversity of spatial arrangement of land-cover types composing a landscape [30]. A land-cover type is an area of relatively homogeneous environmental conditions [19]. In UGS, land-cover types are represented by five major categories (i.e., tree, shrub, grass, water, and minerals [31]). Landscape heterogeneity increases the diversity of available key resources [32], as well as the rates of ecological processes, such as dispersal [33]. Notably, landscape heterogeneity has been identified by landscape ecologists as a key variable enhancing species diversity in a landscape [34].

A recent study has demonstrated that visitors are able to perceive landscape heterogeneity within UGS, and furthermore that this perception has a positive impact on their psychological restoration [35]. Therefore, enhancing landscape heterogeneity within UGS could simultaneously benefit biodiversity and visitors' psychological well-being. Moreover, studies have shown a relationship between the presence of biodiversity within UGS, measured at the species level, and the psychological restoration felt by visitors [10,11,36,37]. In other words, in UGS, psychological restoration felt by visitors would increase with species diversity. This result implies that increasing species diversity in UGS would promote both psychological well-being for visitors and biodiversity [37]. It also implies that there is an opportunity to combine the environmental and social benefits of UGS in their design and management. However, a paradox is that studies have also shown that many "non-ecological" visitors (i.e., with little or no knowledge of animals and plants) have poor naturalist identification skills. As a result, they do not consistently perceive all the different species present in UGS [23,37]. Their assessments of species diversity would tend to underestimate real richness [38,39]. Some studies have found a relationship between the psychological restoration felt by users and the species diversity they perceive (think is present), but not the measured species diversity [37,40]. Thus, while a relationship has been established between psychological restoration felt by visitors in UGS and species diversity, the relationship between social and environmental benefits has not been fully explained. To apply these findings to planning and management practices, further research is needed to accurately characterize and define visitors' perception of landscape heterogeneity (i.e., an environmental parameter related to species diversity while also being perceivable by visitors) within UGS [35].

Thus, the goal of this study is to identify aspects of the landscape within UGS through which visitors perceive landscape heterogeneity. On the basis of a study carried out in 13 UGS in Rennes [35] showing that UGS visitors are able to perceive landscape compositional and configurational heterogeneity, we went further by carrying out a lexical analysis to explore whether these aspects correspond to landscape heterogeneity criteria as defined, and thus measured, within the field of landscape ecology. The originality of this study is related to the lexical analysis of the words used by visitors of UGS to characterize their perception of landscape heterogeneity. We also analyzed if visitors' perception of landscape heterogeneity within UGS is ecologically relevant to bring planners and managers a step closer to increase both environmental and social benefits of UGS.

2. Materials and Methods

2.1. Study Sites

This study was conducted in the city of Rennes (Figure 1a) within 13 UGS (Figure 1b), located in the region of Brittany, western France. The data required for the implementation of the protocol and facilitating the repeatability of the study concern the land-cover map of the city, the localization of the UGS and information concerning the population (available for most urban areas in France [41], and more widely in many countries).

Figure 1. Study area. (**a**) Rennes city (Brittany, France) location map. (**b**) Location of the 13 urban green spaces (UGS) throughout the 12 neighborhoods of Rennes.

For the last 10 years, Rennes has been experiencing a high growth rate, with a population increase of 1.29% per year. This city is currently the most populated city of Brittany. In France, it is also the 11th most populated city. With 216,268 residents inhabiting 5000 ha, its density has reached 4292 residents per square kilometer [41]. Simultaneously, in France, Rennes is one of the greenest French cities, with 880 ha of UGS, representing 18% of its area.

As in [35], UGS were selected based on ecological, landscape and socio-demographic criteria, following a two-step selection protocol: (1) 37 UGS were selected out of the 54 UGS, based on their ability to support biodiversity. Then, those with an area of less than 5000 m^2 and with less than 30% of vegetation were excluded (all species confounded) within a radius of 500 m [2]. The 500 m distance was chosen because it is large enough to have an impact on the dispersal of many species. [42,43]. (2) By using a Principal Component Analysis (see [35] for further details), we placed the 37 UGS on a gradient of land-cover composition. We considered land-cover composition as the relative proportions of 5 main land-cover types (woodland, shrub, herbaceous area, water area, and mineral surface). These proportions were computed for each of the 37 UGS using a land-cover map (urban planning agency of Rennes, AUDIAR) and using ArcMap 10.2 software. The PCA was created using as dependent variables these proportions. We selected UGS to obtain the broadest possible range of land-cover compositions provided by the PCA, therefore distributed over the entire CPA plane. The goal was to select UGS that were different in terms of land-cover composition to capture a wide panel of perceptions. We also take into account the socio-demographic diversity using the 12 neighborhoods of Rennes. A total of 13 UGS were thus sampled by selecting at least 1 from each neighborhood.

2.2. On-Site Questionnaires

To gather data on visitor's perception of landscape heterogeneity, we conducted a total of 390 questionnaires (i.e., 30 in each of the 13 UGS). To interview as many different visitors as possible, we conducted questionnaires from June to September 2017, at different hours (i.e., weekends and weekdays). We randomly chose visitors at different locations within each public UGS. We only selected visitors who had already been in the UGS at few times before, to ensure that they had a relatively good overview of its entire landscape. Indeed, building a cognitive map of a landscape takes time and repeated exposure [15].

We used two complementary quantitative and qualitative questions. We conducted preliminary questionnaires on a small number of visitors (20) to test the vocabulary and the meaning of our questions. As a result, we reworded the term "heterogeneity" to "diversity", which is more comprehensible for non-ecologists. A first question asked the visitors to evaluate and score their perception of landscape heterogeneity in the UGS on a scale from 1 to 5: "Do you consider that the landscape of the green space in which you are today is diverse? Please circle the number that corresponds to your perception on a scale from 1 to 5 (1 = not at all diverse, 2 = not diverse, 3 = not diverse and diverse at once/I can't make up my mind, 4 = diverse, 5 = very diverse)". The second question was "And why? What are the visible aspects of the landscape of this green space that make you say that it is, or that it is not, diverse?". We then asked them to explain their score and describe their perception through an open-ended question.

The 390 answers to the open-ended question were transcribed word for word (i.e., without altering their wording) in 3 different corpuses by distinguishing those given by visitors who scored their perception "1" and "2" (i.e., visitors who perceived the landscape as being not heterogeneous), "4" and "5" (i.e., visitors who perceived the landscape as being heterogeneous), and "3" (i.e., visitors who perceived the landscape as being simultaneously heterogeneous and not heterogeneous). The translation of the words was the object of a very rigorous work where cross-validations were made.

We also analyzed the representativeness of our sample by collecting data on visitors' gender, age (3 classes: 18 to 34, 35 to 54, or 55 and more), and frequency of site visit (frequent = daily to once a week, or not frequent = 2–3 times a month to a few times per year).

2.3. Data Analyses

The open-ended question was designed to be answered briefly in a few sentences. The words used by visitors to answer it had to be chosen carefully, and thus had a strong significance. To identify through which landscape aspects visitors perceived landscape heterogeneity within the UGS, we analyzed the dominant vocabulary used to answer this question. To do so, we identified the words that occurred the most frequently in each of the three corpuses. We represented them in the form of three word-clouds by using textual data analyses. We identified the words that were common across the three word-clouds, and ranked them according to their frequency of occurrence. We carried out Wilcoxon tests to compare the ranking of those common words across the three word-clouds. We also identified the words that were common across only two word-clouds, and those that were present in only one word-cloud. To facilitate interpretations, we considered that the frequency of occurrence of each word represented the number of visitors that used it in their answer because the number of visitors using the same word several times in their answer was low (<10%).

The number of occurrences of a word in a corpus does not provide information on the context in which it is most used (i.e., the words with which it is associated the most to in a sentence) and, thus, its meaning [44]. To gather information on the contexts of use of the words composing each of the three word-clouds, we identified the most frequent associations (i.e., sentences) made by visitors with those words. We used a co-occurrence index to quantify the number of sentences in which the words composing each of the three word-clouds were associated together. We represented these associations in three graphs associated to word-clouds in order to provide a visual map of how the words composing each of the three word-clouds were connected together. We also displayed all the answers in which each of these words occurred.

We conducted the textual data analyses and the calculation of the co-occurrence index using the software IraMuTeQ 0.7 alpha 2. This software considered the words occurring at least three times in each corpus. It automatically excluded the words defined as "tools" (pronouns, additional adverbs, and adjectives), and considered each word by using its root as a reference (i.e., the verbs were brought back to the infinitive, and the nouns to the singular form). It should be noted here that the translation of the words from French to English might have altered their original meaning.

3. Results

3.1. Visitors

Out of the visitors that were interviewed, 62.31% and 37.69% were women and men, respectively. This overrepresentation of women is also found in the average population of Rennes (53.05% women vs. 46.95% men). The most represented age group was 18 to 34 years old (46.6%), the most common age-group in the average population of Rennes (33.7%). Most visitors (52.6%) frequently visited the UGS, which sugessts that they had a relatively good overview of its entire landscape suggesting that our visitors' sample is robust.

3.2. Visitor Perception

Three word-clouds were obtained (Figure 2a–c). They were composed of the words that occurred the most frequently in the corpus of answers given by visitors who scored their perception "1–2", "3", and "4–5", respectively. We identified 23 words that were common across the three word-clouds (Table 1).

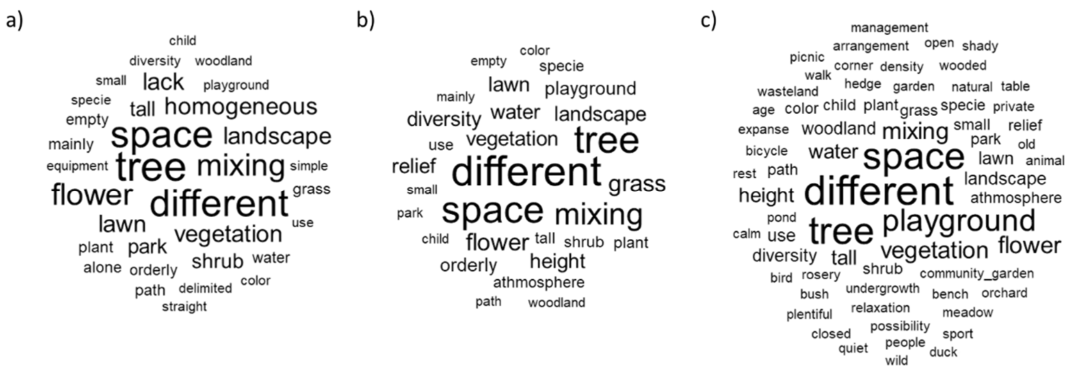

Figure 2. Word-clouds representing the corpus of answers given by visitors who scored their perception "1–2", "3", and "4–5". Word-clouds are named, respectively (**a**–**c**). The size of each word is correlated to its frequency of occurrence and the most frequent words are represented in the center.

The 23 words represent the majority of the words composing the word-clouds (Figure 2a,b), which are composed of 33 and 29 words, respectively. They represent the majority of the words located in the center of the word-cloud C (Figure 2c), which is composed of 66 words. The results of the Wilcoxon tests show that the occurrence of these 23 words is different across the three word-clouds (W = 51.5, p-value < 0.001 between word-cloud B and C, W = 288, p-value = 0.607 between word-cloud B and A, and W = 37, p-value < 0.001 between word-cloud A and C).

We identified 7 and 40 words that are present only in the word-cloud A and C, respectively. These words described aspects of the landscape that are related to its lack of heterogeneity, or presence of heterogeneity. For example, the word "homogenous" for the word-cloud A. The word-cloud B does not present specific words, but has three common words with the word-cloud A and C.

Table 1. List of the 23 words common across the three word-clouds (in alphabetical order) with their rank based on their occurrences. Word-clouds a, b and c refer to Figure 2.

List of the 23 Words	Number of Occurrence			Rank Based on Frequency of Occurrence		
	Word Cloud a	Word Cloud b	Word Cloud c	Word Cloud a	Word Cloud b	Word Cloud c
child	3	3	20	13	11	13
color	3	3	5	13	11	21
different	12	37	169	4	1	1
diversity	3	8	14	13	7	19
flower	12	10	42	4	5	6
grass	10	10	17	6	5	16
landscape	9	3	20	7	11	13
lawn	15	6	73	3	8	5
mixing	11	14	31	5	4	10
park	8	3	25	8	11	12
path	4	3	10	12	11	20
plant	5	4	16	11	10	17
playground	3	9	80	13	6	4
shrub	6	5	15	10	9	18
small	3	3	18	13	11	15
space	16	20	129	2	3	2
species	5	4	19	11	10	14
tall	10	4	38	6	10	7
tree	22	28	125	1	2	3
activity	3	6	20	13	8	13
vegetation	10	9	30	9	7	11
water	5	8	37	11	7	8
woodland	3	3	36	13	11	9

To identify the aspects of landscape through which visitors perceive landscape heterogeneity within UGS, we focused our analysis on the 23 common words across the 3 word-clouds, the common words across 2 word-clouds and those present in only 1 word-cloud to confirm and expand our analysis. The most of the 23 common words (i.e., 13) refer to landscape elements at three different spatial scales; from complex structures (“space”, “landscape”, and “park”), to landscape elements globally apprehended (“vegetation”, “plant”, and “species”), to individual landscape elements (“grass”, “lawn”, “shrub”, “tree”, “woodland”, “flower”, and “water”). When displaying the answers in which the word “park” appears, we identified that it is mainly used to introduce the answer: “This park is diverse/not diverse because . . . ”. We thus excluded this word from our analyses. The remaining 6 words are used in association with one or several of the 13 words referring to landscape elements in order to describe their arrangement or form: “different”, “diversity”, “mixing”, “small”, “tall”, and “color”.

The word “space” is one of the most frequently occurring words in each of the three word-clouds, more than the word “landscape”. The results of the co-occurrence index indicated that the word “space” is frequently associated with the word “different” by all visitors (Figure 3a–c).

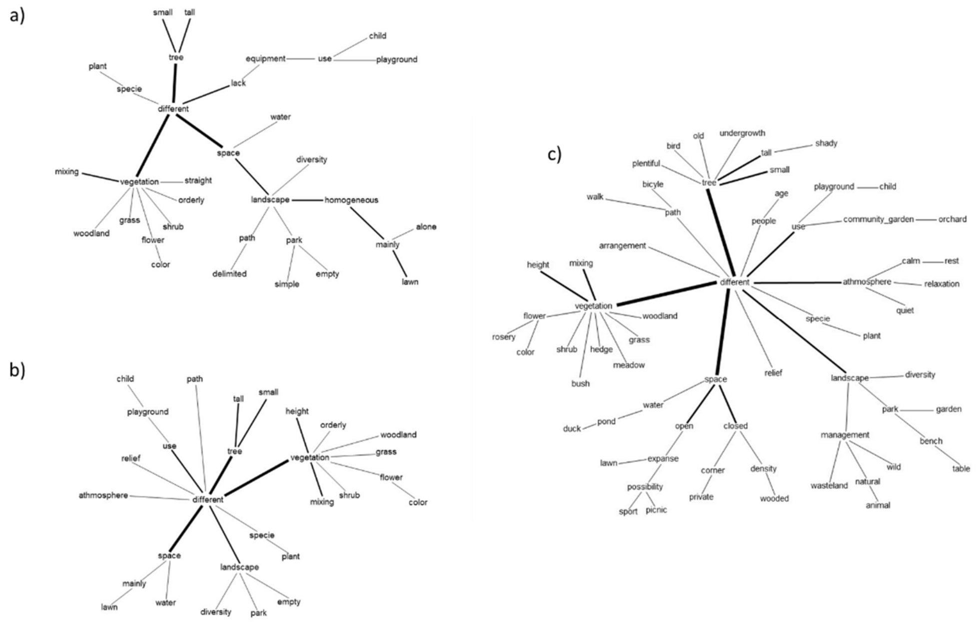

Figure 3. Visual maps of the most frequent associations made by visitors between the words listed in the different word-clouds. Visual maps are named, respectively, (**a**), (**b**) and (**c**) for the word-cloud (**a**–**c**), respectively. The thicker the edges, the more sentences the words were associated in. Word-clouds a, b and c refer to Figure 2.

4. Discussion

4.1. Identifying Landscape Aspects through Which Visitors Perceive Landscape Heterogeneity

The results show that the word "space" is widely used. This might be because "space" could be more common and generic than "landscape" to visitors. Indeed, our results support the statement that the experience of landscape heterogeneity is associated with the heterogeneity of space, and imply that visitors perceive landscape heterogeneity as space heterogeneity [45]. According to the Oxford Dictionary, the word "space" refers to "dimensions of height, depth, and width". Therefore, this suggests that visitors' perception of landscape heterogeneity within UGS is induced by variations in height, depth, and width among landscape elements.

Visitors interviewed all used 23 words to describe their perception, whether they perceived the landscape as being heterogeneous or not. This implies that these 23 words are not used with the same emphasis whether visitors perceived the landscape as being heterogeneous or not. In all three word-clouds, the words "species" and "plant" both occurred less frequently than the word "vegetation". This result corroborates that non-ecologist visitors are not able to systematically perceive the full species diversity within UGS [23,37]. They experience UGS as a green atmosphere apprehended as a whole [46], rather than focusing on specific details [38]. Furthermore, all visitors frequently associated the word "vegetation" with the words "different", and "mixing". These results suggest that the mixing of different types of vegetation is an aspect through which visitors perceive landscape heterogeneity within UGS.

The word "vegetation" was also frequently associated by all visitors with the words: "woodland", "grass", "shrub", and "flower". This implies that when visitors perceive different types of vegetation, they mainly perceive distinctly the three vegetation strata (i.e., woodlands, shrubs, and herbaceous areas), and flower areas. This has also been demonstrated by previous studies [14,47]. The distinctive perception of flower areas can be explained by the fact that flowering influences the aesthetic quality of a landscape [48,49]. Furthermore, all visitors frequently associated the word "flower" with the word "color", which supports a recent study stating that the perception of flowers within public UGS is influenced by color diversity, rather than species diversity [50].

The word "tree" was one of the most frequently occurring words in all three word-clouds (Table 1), which indicates that visitors pay close attention to woodlands. This high use can also be explained by aesthetic preferences for views containing trees [17]. All visitors frequently associated the word "tree" with the words "different", "small", and "tall". This means that visitors distinguished different trees based on their height. Furthermore, the word "vegetation" was frequently associated with the word "height" by visitors who perceived the landscape as being heterogeneous. These results confirm that visitors' perception of landscape heterogeneity is induced by variations in height, depth, and width among landscape elements, and especially by variations in the vegetation height. They also suggest that visitors mainly perceive distinctly the three vegetation strata because they particularly notice variations in the vegetation height. This means that visitors do not necessarily perceive the three vegetation strata per se, rather they perceive the different heights of vegetation that those three strata create.

The large number of words (40) specific to the word-cloud C reveals that there are more aspects to describe in a heterogeneous landscape [51]. Another explanation is that the vocabulary used by visitors who perceived the landscape as heterogeneous is richer. Indeed, visitors used different words to describe the same landscape element (e.g., "bush" vs. "shrub"). Visitors that perceived a presence of landscape heterogeneity also frequently associated the word "atmosphere" with "calm", "quiet", "relaxation", and "rest". Moreover, the word "water" was logically used by all visitors. Previous studies showed that visitors pay specific attention to the presence of water in UGS because it has a positive impact on their psychological well-being [52]. These results confirm that the perception of landscape heterogeneity within UGS by visitors positively affects their psychological well-being, and notably their psychological restoration conceived in terms of relaxation or stress reduction [16,35].

Therefore, taken together, our findings show that the mixing of different heights of the three vegetation strata and flower areas is a landscape aspect within UGS through which visitors perceive landscape heterogeneity.

4.2. Is the Perception of Landscape Heterogeneity of Visitors within UGS Ecologically Relevant?

Landscape heterogeneity is defined by landscape ecology as the combination of compositional heterogeneity and configurational heterogeneity, which interact with one another [30]. Compositional heterogeneity is defined as the diversity of the land-cover types that form a landscape, and their relative proportions. These proportions typically emphasize either dominance or equitability. Configurational heterogeneity is defined as the complexity of spatial arrangement of those land-cover types. It mainly refers to their aggregation, which simultaneously refers to their dispersion and interspersion (i.e., mixing). It also refers to the shape complexity of patches of land-cover types, such as whether they are simple and compact or irregular and convoluted [53].

Based on our findings, we identified that the mixing of different heights of woodlands, shrubs, herbaceous areas, and flower areas is a landscape aspect within UGS through which visitors perceive landscape heterogeneity. The mixing of different heights of the tree vegetation strata within UGS creates a mixing of dense closed areas which favor intimate and quiet activities [54], and open cleared fields which favor active outdoor activities [49]. A vegetation height of more than 54 cm has been identified as having significant obstructive features for recreational use of visitors [55]. These results indicate that visitors' perception of landscape heterogeneity within UGS can be influenced by the diversity of activities that this landscape heterogeneity facilitates [56,57].

This characterization of landscape heterogeneity corresponds to the definition of landscape configurational heterogeneity (i.e., the complexity of spatial arrangement of land-cover types), particularly their mixing. This is supported by the fact that the word "arrangement" was frequently associated with "different" by visitors who perceived the landscape as being heterogeneous. Visitors' perception of landscape heterogeneity within UGS is thus ecologically relevant because it corresponds to landscape configurational heterogeneity as defined, and measured, within the field of landscape ecology. Within UGS, the mixing of land-cover types results in a better connectivity between key resources [58]. As urban species are mostly generalist, it is thus particularly beneficial to species diversity [59].

Surprisingly, our results do not highlight words representing fauna to appreciate the diversity of urban green spaces by visitors. Generally, when the UGS was wildlife rich, more positive emotions were recorded [40,60]. It is possible that the term "species" implicitly refers to this. Further interviews would enable an investigation of this aspect.

5. Conclusions

In this study, through the use of lexical analysis, we demonstrated that the mixing of different heights of the three vegetation strata and flower areas is a landscape aspect within UGS through which visitors perceive landscape heterogeneity. Indeed, our results showed that visitors' perception of landscape heterogeneity within UGS is especially induced by variations in the vegetation height. This focus would simultaneously benefit biodiversity and visitor's psychological restoration. Ways to achieve this could be to plant vegetation by taking into consideration the hierarchy of heights to create visual depth and complexity [16]. Characterizing landscape heterogeneity by mixing different heights of vegetation is consistent with the ecological definition of landscape configurational heterogeneity (i.e., by mixing land cover types). To further investigate the results of this study, the "real" characteristics of the UGS should be measured directly to establish a direct relation to visitor perceptions.

We found that landscape configurational heterogeneity is associated with perception. In a decision-making context in which stakeholders would like to increase landscape heterogeneity for improving perception, particular attention must be paid to the impacts on landscape composition, another important structuring element of UGS [61]. The importance of balancing configuration and compositional elements is a key ecological concern to promote biodiversity [29], particularly in UGS, and thus visitor well-being [62]. Particular attention should be paid to the fact that giving priority to one element (e.g., configuration) would not suppress the other (e.g., composition) and therefore would not harm the biodiversity results of UGS. A solution would be to analyze within each UGS to what extent favoring configuration over composition can induce a significant decrease in biodiversity (e.g., [63,64]) in order to determine thresholds allowing a compromise between increasing configurational heterogeneity, well-being and maintaining biodiversity. Nevertheless, this study highlights the possibility of achieving a win-win situation between ecological and sociological aspects if UGS are managed with parsimony in considering their configurational heterogeneity.

More interdisciplinary research is required to explore and improve our understanding of the underlying processes driving the psychological well-being of visitors within UGS, especially in relation to perceived and measured biodiversity [65]. Firstly, if we have compared the profiles of our visitors to the population of Rennes, it would be useful to deepen the research in order to check whether our sample is large enough to include all diversities within the visitors. Secondly, our study, along with previous ones [66,67], demonstrates the need to identify more aspects of landscape heterogeneity within UGS that are perceived by visitors, and to develop tools to help apply these insights to planning and management practices [24,68].

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