

## **Do small green roofs have the possibility to offer recreational and experiential benefits in a dense urban area? A case study in Helsinki, Finland**

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# 1. Introduction

Urban areas cover less than 3% of the earth's surface (SEDAC, 2011), but house more than half (54%) of the world's population (United Nations, 2014). Furthermore, it has been projected that 66% of the population is urban by 2050 (United Nations, 2014), which means an increase in residential and other built areas. This sets pressures for preserving and enhancing good quality natural and semi-natural urban green (and blue) environment, including, e.g. forests, parks and seashores – the so-called green infrastructure (European Commission, 2013). Innovative solutions, such as integrating vegetation with buildings (on roofs and walls) are needed as part of the green infrastructure, where adequate and diverse green space in dense urban areas is the planning target (e.g. Jim, 2013; Haaland and van den Bosch, 2015).

Numerous studies show that natural-like environments, such as forests and water areas, are rich in recreational and experiential qualities (e.g. Hartig et al., 2003; Tomalak et al., 2011; Hauru et al., 2012; Takayama et al., 2014). Moreover, some studies suggest that also small public green spaces, such as pocket parks less than 5000 m<sup>2</sup>, or even a few green elements, such as street trees or flowerbeds within dense urban areas, may offer recreational and experiential benefits (e.g. Nordh et al., 2009; Peschardt et al., 2012; Peschardt and Stigsdotter, 2013; Lindall and Hartig, 2015). The role of such small-scale green in contributing to human well-being may increase in the future as cities get more populated (e.g. Thwaites et al., 2005). Furthermore, urban green spaces located near homes and workplaces are important from social and sustainable perspective, as they are easy to access (Neuvonen et al., 2007; Coombes et al., 2010), and have the potential to offer everyday recreational experiences, e.g. aesthetic pleasure and restoration from attentional fatigue (e.g. Swanwick, 2009; Peschardt et al., 2012; Lottrup et al., 2013; Hauru, 2015). Even short exposure to nature is beneficial for human well-being (Tyrväinen et al., 2014), reaffirming the importance of easy access to green areas.

Green (i.e. vegetated) roofs are one way to offer green spaces where people live and work. In this paper, we consider green roofs as those purposefully constructed for having vegetation on them. Depending on the constructional solution, as well as the amount (number, size and scale) of green roofs, they can provide various ecological and technical benefits, such as managing stormwater (e.g. Nawaz et al., 2015;

28 Versini et al., 2015; Kuoppamäki et al., 2016), and abating noise (Van Renterghem et al., 2013). Green roofs  
29 contribute to preserving and enhancing urban biodiversity (Madre et al., 2014; Gabrych et al., 2016; Kyrö et  
30 al., 2017) that is also argued to have positive effects on the health and well-being of people (e.g. Hanski et  
31 al., 2012; Carrus et al., 2015;). Furthermore, green roofs comprise a potential for making urban landscapes  
32 more relaxing, interesting and aesthetically appealing, and may add to the collection of green spaces for  
33 diverse user groups (Mesimäki et al., 2017).

34 To fully realize the potential of green roofs, knowledge is required on their affordance for various  
35 recreational and experiential benefits. In line with White and Gatersleben (2011), we suggest that people's  
36 experiences and preferences should be studied on roofs, instead of just leaning on results gained in ground  
37 level green spaces. A few previous studies (e.g. White and Gatersleben, 2011; Fernandez-Cañero et al., 2013;  
38 Lee et al., 2014) suggest positive responses towards vegetated over non-vegetated roofs, especially towards  
39 roofs with lush flowering vegetation. There is also some evidence that flowering, taller and diverse  
40 vegetation is more restorative and aesthetically appealing than a monotonous one with low vegetation (White  
41 and Gatersleben, 2011; Jungels et al., 2013; Loder, 2014; Lee et al., 2015). However, a lush green roof is not  
42 always possible, due to technical (e.g. load capacity), ecological (e.g. extreme heat or wind), economic,  
43 architectural or other limitations. Small and sparsely vegetated roofs may sometimes be the only option to  
44 offer at least a pinch of green in a dense urban environment.

45 Many studies examining experiences and preferences of green roofs (White and Gatersleben, 2011;  
46 Fernandez-Cañero et al., 2013; Lee et al., 2014, 2015), as well as the majority of studies regarding other  
47 green spaces (e.g. Ulrich, 1979; Kaplan and Kaplan, 1989; Tyrväinen et al., 2003; Tveit et al., 2006;  
48 Blumentrath and Tveit, 2014), were based on visual evaluation of images. However, on-site studies allow for  
49 an exposure to the real-life environment (Scott and Canter, 1997; Özgüner and Kendle, 2006). Jungels et al.  
50 (2013) and Loder (2014) examined people's experiences of real roofs, arguing that access, scale and the  
51 distance from which one observes, influence the perception of a green roof. Moreover, Loder (2014)  
52 suggested that besides visual, other experiential aspects, such as multisensority, should be taken into account  
53 in green roof designs.

## 55 1.1 Study objectives

56

57 Our main research question was whether a small and sparsely vegetated green roof in a dense urban area has  
58 potential for offering experiential benefits. More specifically, we explored the experiential quality of the  
59 green roof, including restorative, aesthetic, and other types of multisensory experiences that are  
60 multidimensional themselves, i.e. reflect different perceived qualities of the environment, as described below.

61 *Perceived restorativeness* is a well-known approach for studying experiential qualities of  
62 environments. It refers to a feeling of psychological restoration that indicates recovery of the ability to direct  
63 attention, which is important in the everyday urban life often loaded with demanding tasks and stress-  
64 inducing stimuli (cf. e.g. Kaplan, 1995; Hartig et al., 1997). Restorativeness has been suggested to reflect  
65 four perceived qualities of an environment: 1) fascination, including the wish to explore and the environment  
66 being interesting; 2) compatibility with one's own needs and desires; 3) coherence, i.e. parts fitting together  
67 and to a larger whole; and 4) being away, i.e. a feeling of getting away from the everyday worries and hassles  
68 (e.g. Kaplan and Kaplan, 1989; Korpela and Hartig, 1996; Hartig et al., 1997).

69 Besides restorative, the experiences of natural environments and green spaces reflect many other  
70 types of perceived qualities, such as unity, congruence and complexity (Kaplan and Kaplan, 1989; Tveit et  
71 al., 2006; van Berkel and Verburg, 2014), cultural aspects (Hands and Brown, 2002), scale and mystery  
72 (Kaplan, 1989; Tveit, 2006; Kirillova et al., 2014), diversity and species richness (Ode and Fry, 2002; Grahn  
73 and Stigsdotter, 2010; Hauru et al., 2014; Kirillova et al., 2014), visual interestedness (cf. e.g. Hauru et al.,  
74 2014; Pazhouhanfar and Kamal, 2014), nature and naturalness (Coeterier, 1996; Grahn and Stigsdotter,  
75 2010), multisensority (e.g. colour and smell, Coeterier, 1996; sound, Kirillova et al., 2014), and beauty (cf.  
76 Gobster et al., 2007; Hauru et al., 2014; Kirillova and Lehto, 2015).

77 Finally, a person may like and accept an environment independent of the above qualities (e.g. Ribe,  
78 2013; Hauru et al., 2014). Therefore, we also studied the overall preference and acceptability of the observed  
79 environment.

80

81

## 2. Material and Methods

### 2.1 Study site: small and sparsely vegetated green roof in a city centre

Our study green roof is located in Helsinki, Finland, a city with approximately 600 000 inhabitants and a population density of 2 785 inhabitants per km<sup>2</sup>, at the time of the data gathering (2012) (OSF 2016). The roof (Fig. 1) is on top of the University of Helsinki Language Centre and surrounded by other buildings so that the vista from the roof contains only a skyline with roofs and walls of buildings. The roof is non-smoking, occasionally used by the personnel for short breaks. The total roof area is 130 m<sup>2</sup>, with approximately 70 m<sup>2</sup> covered by vegetation. Most of the vegetated area of the roof consisted of mosses and a few Sedum species with a thin (3 cm) substrate. In addition, there were eight experimental plantings 2 - 3 m<sup>2</sup> each, with 6 - 8 cm substrate depth. Two of them were barren, with just a sparse scatter of seedlings, and the rest covered with meadow-grass vegetation. There was a paved path, and a patio with three flower pots, two chairs and a table (Fig. 1; Electronic Appendix A). A construction site nearby caused some noise.

Fig. 1

### 2.2 Data generation and the respondents

During the World Design Capital Helsinki year in 2012, visits to innovative university facilities were organized by the Public Relations Unit of the University of Helsinki, advertised via their customary channels. These events were open to all, but a registration was required to control the number of participants. Thus, the visitors were voluntary citizens, selected in order of registration. We conducted an on-roof survey during four similar events that included a visit to the study roof and a tour at the new University Library.

The visits to the roof and the surveys were conducted during four days: 5.9.2012 (two visits: 11 a.m. and 17.00 p.m.), 11.9.2012 (11.30 a.m.), 13.9.2012 (17.30 p.m.) and 15.10.2012 (16.30 p.m.). Weather was sunny or cloudy with mild/moderate wind (the mean hourly wind during the visits ranging between 2,1–5,9

109 m/s, with an average of 4,4 m/s; Finnish Meteorological Institute). The temperatures varied between 8 and  
110 18°C (mean t/h during the visits; Finnish Meteorological Institute). The researchers gave a 15–20 min  
111 general introduction to green roofs in a seminar room with no view to the study roof prior to the visits. After  
112 this, visitors were taken to the green roof in groups of 30–46 people and given a questionnaire, with an  
113 explanation that it is for academic research and that they have a free choice to participate or not. The  
114 respondents were instructed to fill in the questionnaire individually, without discussing with anyone, and to  
115 return it after completion. Filling in the questionnaire took 10–15 minutes.

116 Altogether 178 people participated in the survey. However, as some of the respondents did not answer  
117 all questions, the number of respondents varied across the questions (from 150 to 176). 70% of the  
118 respondents who told their gender (n = 164) were female. The respondents represented a variety of fields of  
119 expertise, and age groups between 20 to over 70 years. Most (99%) of the respondents lived in an urban area.  
120 Age, living environment, and expertise of the respondents are presented in detail in the Electronic Appendix  
121 B.

### 123 2.3 Questionnaire

124  
125 The questionnaire consisted of a section including the Perceived Restorativeness Scale, PRS (Hartig et al.,  
126 1996, 1997), and it was complemented with statements, adjectives and open questions targeted at revealing  
127 other perceived qualities on the roof (see Electronic Appendix C).

128 The PRS included 16 statements that were originally constructed to measure four restorative qualities  
129 of an environment (Hartig et al., 1996; Electronic Appendix C). The respondents rated their (dis)agreement  
130 with each statement on a scale from 1 (*not at all*) to 7 (*completely*) in agreement with the statement.

131 We supplemented the PRS with statements we had used earlier (2012) in a study that examined  
132 aesthetic qualities of urban forests (n=287, Hauru et al. 2014). These statements, some of them modified to  
133 be applicable on the roof, measured multisensority and perception of beauty (statements 17 - 19), mystery  
134 (statement 20), understanding of the environment (statement 21), visual interestedness (statement 22), as well  
135 as diversity and nature (23 - 25). To explore the acceptability of the green roof in the urban context, we asked

136 the respondents how modern they thought the place is (statement 26), and how well the roof fits into the city  
137 (statement 29). Moreover, we inquired the general acceptability (preference) of the roof (statements 27 - 28).

138 We complemented the statements by 17 adjectives. This method was inspired by previous studies that  
139 used adjectives as contrasting pairs (e.g. beautiful vs. ugly) or as ranking lists, to characterize and evaluate  
140 different kinds of environments (cf. e.g. Stewart, 2007; Akalin et al., 2009; Jeon et al., 2012; see also  
141 Lindemann-Matthies and Marty, 2013). We used a list of single adjectives that were evaluated on the same  
142 scale as the statements above (i.e. from 1 to 7). This list of adjectives was piloted in 2012 in urban forests  
143 (n=287, unpublished data).

144 At the end of the questionnaire, we included six open questions which allowed respondents to provide  
145 free-form answers that could offer in-depth understanding and to reveal perceived qualities not gained  
146 through the closed questions. The questions concerned aesthetically appealing and disturbing things on the  
147 roof, as well as feelings evoked by the place. As we assumed that first observations in the environment may  
148 affect the overall experience on the roof (see e.g. Hietanen and Korpela, 2004 and refs. therein for affective  
149 priming; O'Connor et al., 2016 for first impressions), we asked what things first caught the attention of the  
150 respondents. Similarly, as the acoustic environment is suggested to influence the overall comfort in urban  
151 open spaces (e.g. Yang and Kang, 2005), and as smell is argued to have a role in urban environmental  
152 experience, perception, and place identity (cf. Henshaw, 2014), we also asked about the sounds and scents.  
153 Finally, by asking about feelings we targeted the emotional dimension of experiences (cf. e.g. Carroll, 1993;  
154 Brady, 2003).

155 The questionnaire with altogether 45 items (statements or adjectives), and six open questions in  
156 Finnish, was translated into English for publication.

157

#### 158 *2.4 Analyses*

159

160 To be able to compare the restorative capacity of the roof to literature, we first ran a factor analysis with the  
161 16 PRS statements only. Studies have shown that the 16 statements tend to load on two instead of four  
162 factors in factor analyses, reflecting general restorativeness (combining statements measuring fascination,

163 being away and compatibility) and coherence (e.g. Hartig et al., 1996, 1997; Korpela and Hartig, 1996;  
164 Hauru et al., 2012).-Therefore, we conducted a confirmatory factor analysis (Principal Axis Factoring) to test  
165 whether the 16 PRS statements form the two factors (i.e. the factor number was fixed to two). We used  
166 promax-rotation that allows correlation between factors and tested the internal consistency of the factors with  
167 Cronbach's alpha coefficients. Finally, we calculated the mean scores for the factors. Similar to previous  
168 studies (e.g. Hartig et al., 1996; Korpela and Hartig, 1996; Hauru et al., 2012), we reversed the scales of the  
169 negatively tuned statements (3, 11, 12 and 13, see Electronic Appendix C) to make them parallel to the rest  
170 of the statements.

171 While we had a list of the tentative perceived qualities, as presented above in section 1.1, we also  
172 hypothesized that there could be experiential qualities yet unidentified. Therefore, we ran an exploratory  
173 factor analysis with the whole dataset, without a priori fixing the factor number. We used similar methods as  
174 described in the previous paragraph, also reversing the scales of the negatively associated adjectives (ugly,  
175 restless, everyday, boring, confined, scary). The 16 statements of the PRS, the 13 other statements and the 17  
176 adjectives gave an 11-factor solution (retaining factors with eigenvalue  $\geq 1$ ). Three more solutions with 8, 9  
177 and 10 factors were explored (cf. Preacher et al., 2013), but they included nonsensical factors with no  
178 distinctively high factor loadings. The factor composition was interpreted by the three researchers of this  
179 study independently and then discussed to reach a mutual understanding of the meanings of the emerging  
180 factors.

181 We conducted a two-phase analysis of the free-form answers. First, we categorized the answers to  
182 each question by using a double-blind method where two researchers classified the answers independent of  
183 each other, and the final composition of categories was determined in mutual discussions. We identified and  
184 counted mentions, i.e. meaningful words and phrases in the answers. As the closed questions preceding open  
185 ones may direct the respondent to use the same kinds of expressions in the open responses, we closely  
186 scrutinized all expressions in the free-form answers, and evaluated whether they further explained the  
187 findings, or opened new avenues.



### 3. Results

The respondents scored high for perceived restorativeness on the roof. The results also revealed multiple perceived qualities that reflected visual as well as other sensory experiences, beauty, suitability of the place for oneself and the urban context, nature, desire to explore and interestedness, positive excitement, break from everyday, and safety. The free-form answers supported the results of the closed questions, but also revealed other experiential dimensions, such as feeling of spaciousness and freedom, strong positive feelings, and issues concerning design.

#### *3.1 Perceived restorativeness was high*

The two-factor solution for the 16 PRS statements reflected General Perceived Restorativeness (GenPR) and Coherence (Table 1). Cronbach's alpha values were similar to previous studies: for GenPR it was 0.93, indicating a good internal consistency, and for coherence 0.68 indicating a moderate or questionable internal consistency (e.g. Korpela and Hartig, 1996). Correlation between these two factors was not too high (0.41), thus we dealt with them as individual components. The mean rating of statements loading on GenPR was 5.07 (min = 2.75, max = 7, s.d. = 0.81) and on Coherence 5.59 (min = 2.75, max = 7.00, s.d. = 0.86).

Table 1

#### *3.2 Exploratory factor analysis resulted in 11 perceived qualities*

The factor analysis of all the 29 statements and 17 adjectives resulted in 11 factors (factors A - K, Table 2), with the cumulative percentage of variance explained being 58. Below, we describe the content of each factor based on the highest loadings of statements on each factor (Table 2).

Table 2

217 Factor A reflects Visual Interestedness towards the place and the many aspects of aesthetic experience (e.g.  
218 diversity, excitement, beauty and harmony). Factor B gathers together statements that reflect Compatibility  
219 between the Place and Oneself, including feeling of oneness, belonging, and understanding the place as well  
220 as escape from the everyday. Factor C reflects Serene Beauty, with high loadings of the reversed statements  
221 for, e.g. chaos and distraction. Also, the reverse of the adjective *Ugly* gets its highest, and *Harmonious* gets  
222 its second highest loading on factor C.

223 Statements concerning General Likeability, as well as modernity and acceptability of the place as part  
224 of the city load strongly on factor D, and also the reverse of *Boring* gets its highest loading here. Factor E  
225 gathers high loadings of statements reflecting Freshness and Pleasant Soundscape, combined with perceiving  
226 the place as mysterious. Factor F reflects Tempting Nature, as all the adjectives and statements describing  
227 living verdant nature get their highest loadings here, together with the adjective *Tempting*. Also, statements  
228 and adjectives mirroring fascination, likeability and multisensority (visual interest, soundscape, freshness)  
229 get relatively high loadings on this factor.

230 Exploration manifests itself on factor G, through statements reflecting desire for exploring the place  
231 and fascination. Factor H represents the place being Safe and Comfortable (and not scary, restless or  
232 confusing), as well as green and alive. Statements reflecting suitability to one's personality get their highest  
233 loadings on factor I that also reflects the place being Interesting in Many Ways: there are many ways to enjoy  
234 the place, and many interesting things to observe. The place being Exciting and Attracting distinguish in  
235 factor J and finally, factor K stands for Break from Everyday Routines, with the place being mysterious  
236 getting its second highest loading.

237 Pairwise correlations between the 11 factors varied from very low (0.07 between H Safe and  
238 Comfortable. and K Break from Everyday Routines) to moderate (0.61 between K and J Exciting and  
239 Attracting see Table 2). Communalities of the statements and adjectives in the 11-factor solution were  
240 sufficiently high in general: only statements *It is a confusing place*, *This looks like a place where many*  
241 *insects and invertebrates live*, and *This place is modern*, had communalities lower than 0.30.

242 An evaluation of the overall scores of individual statements and adjectives revealed a positive  
243 environmental experience. The overall mean across all score values for the positive statements or adjectives  
244 was 5.1 (*fairly much*). The ultimately highest scores reflected the acceptability of the place: *It is good places*  
245 *like this exist, I like this place, Places like this fit into the city*, and the adjective *Safe*, were all represented by  
246 value 7 as the upper quartile and with a mean of 5.7 - 6.6. *Places like this fit in into the city* also received the  
247 lowest standard deviation of the scores (0.6) among all statements and adjectives, i.e. there was a high  
248 consensus that places like the roof are suitable for cities.

249 All the lowest scores (with the scores 1 or 2 representing the first quartile) were received by the  
250 negative expressions, with the mean per statement/adjective ranging from 1.6 to 3.2. Furthermore, the  
251 statements *The soundscape is pleasant here* and *This looks like a place where many insects and invertebrates*  
252 *live* got average score values less than 4 (3.9 and 3.7. respectively).

### 253 254 *3.3 Open questions revealed a rich set of perceptions and experiences*

255  
256 In this section, we present themes identified in the free-form answers (for the detailed classification of  
257 answers, see Electronic Appendix D).

258 The first thing that most of the respondents (53% out of 178) paid attention to when entering the roof,  
259 was some form of living nature. Only a few (4%) reported negatively tuned impressions, e.g. the small size  
260 of the roof. Mosses were the most frequently mentioned single nature element (15% of the 336 mentions to  
261 this question, Fig. S10, Electronic Appendix D). Many other elements were also paid attention to when  
262 entering the roof, such as concrete slabs and furniture on the roof (17% of the mentions). Features related to  
263 the roof design were quite frequent (13% of the mentions, e.g. forms, shapes and unity of elements on the  
264 roof), as were colours and verdancy (13% of the mentions): ‘Green moss – red sand – grey stones –  
265 beautiful’. The environment on and around the roof also received various characterisations, such as ‘A  
266 peaceful place high up’, ‘It feels as if I stepped in the middle of a forest’, ‘Roofs, sky, spaciousness, just as if  
267 I was in Middle-Europe!’.

268 As aesthetically pleasing features on the roof, 60% of the 178 respondents mentioned, again, some  
269 form of living nature. Also here, mosses were the most frequently mentioned single nature element (12% of  
270 the 338 mentions to this question, Fig. S11, Electronic Appendix D). Many respondents mentioned colours  
271 and their combinations, as well as verdancy (18% of the mentions): ‘Colourfulness of different moss  
272 species.’ Design aspects, including rhythm, symmetry, scale, horizontal and vertical dimensions, and  
273 different textures were mentioned relatively often (14% of the mentions): ‘Small scale on the roof of a big  
274 building.’ Furthermore, single (non-living) elements on the roof and features of the built environment around  
275 the roof were considered as aesthetically pleasing (‘surprising spaces around the roof’, ‘layers of time in  
276 architecture’). Some reported closeness of sky and horizon, and characterized the roof space as aesthetically  
277 pleasing, e.g. ‘beautiful courtyard’.

278 The most frequent disturbing thing on the roof was noise, mentioned by one third of the 178  
279 respondents (34% of the 175 mentions to this question, Fig. S12, Electronic Appendix D), mainly due to an  
280 air conditioner on the roof (e.g. hum, creak): ‘Soundscape is somewhat industrial.’ Sounds of traffic were  
281 reported as disturbing only by two respondents. Features related to the built environment and landscape  
282 outside the roof were also mentioned as disturbing (14% of the mentions, e.g. walls, a construction site  
283 nearby). Some respondents mentioned non-natural elements on the roof (e.g. concrete slabs) as well as lack  
284 of vegetation, and used characterizations such as small, cramped or restless, messy, and too formal.

285 66% of the 178 respondents mentioned hearing the air conditioning nearby (40% of the 292 mentions  
286 to this question, Fig. S13, Electronic Appendix D). Other sounds mentioned were traffic (17% of the  
287 mentions), construction (16%), human (such as talking, walking or coughing, 16%). Sounds from the street  
288 or cityscape, e.g. ‘hum of the city’, and nature (e.g. birds, wind) were also noticed.

289 To the question of what the respondents smelled, 12% of the respondents left the space empty, i.e. did  
290 not answer anything. Some respondents marked ‘ – ‘ (N=26, not counted into the mentions) that may indicate  
291 smelling nothing, or ‘no answer’. The number of mentions to this question was 153, i.e. lower than to the  
292 other open questions. Most mentions here included fresh and clean air or wind (27% of the mentions, Fig.  
293 S14 Electronic Appendix D). 21% reported to smell nothing or almost nothing. Scents such as food (20% of

294 the mentions) and nature (16%, e.g. forest, tuft, moist, autumn), as well as scents from the cityscape (10%)  
295 were mentioned. ‘Pleasant scent of sunshine, wind and city centre.’

296 The biggest category of feelings reflected positive emotions such as pleasure, joy, sympathy,  
297 admiration and love, mentioned by 37% of the 178 respondents (26% of the total of 249 mentions to this  
298 question, Fig. S15, Electronic Appendix D) – ‘warm and joyful feelings’, while 11% of the respondents (8%  
299 of the mentions) reported negatively tuned feelings (e.g. boring, disappointment) or related to confusion:  
300 ‘Perhaps I waited for something more, where is the real nature?’. Peaceful and relaxed feelings, e.g. ‘a  
301 calming city corner’, ‘calming greenness!’, composed 22% of the mentions. One set of feelings (19% of the  
302 mentions) reflected excitement, inspiration and expectancy for the idea of having green roofs: ‘Hope for this  
303 country and the world.’ Moreover, some respondents expressed a desire to stay longer, come back, or do  
304 something on the roof (e.g. lie in a hammock, look at the sky, follow plants over time, ‘desire to stay and  
305 enjoy the space and the moment’). The feelings related also to freedom and familiarity (‘atmosphere of the  
306 childhood yard’) as well as character of the place, e.g. ‘as in the old towns of Central-Europe’. A couple of  
307 respondents expressed envy for those who have the possibility to use these kinds of places.

308 Finally, analysing all the free-form answers together revealed themes that were not apparent from  
309 analysing the answers to each question separately. Expressions of spaciousness and openness, height and  
310 light with feelings of liberty, as well as freedom and being close to sky, were recognized in the answers to  
311 questions 1, 2, 4, 5 and 6. These, together with sensing freshness and clean air (responses to question 5),  
312 encapsulated in the mention ‘freedom to breathe’, and longing for vistas over the city (responses to question  
313 3) reflect a liberating multisensory experience (see Electronic Appendix D).

314 The ground materials, the gravel, and the crushed brick were mentioned several times in questions 1  
315 and 2, while these were not at all mentioned as disturbing things: ‘different substrates side by side’, ‘beautiful  
316 substrate’. Furthermore, other answers may refer to substrates indirectly, e.g. ‘flowers, the division of space  
317 into sections’, or ‘the whole, colours’ that were first paid attention to, or ‘moss, colours and composition’ that  
318 were mentioned as aesthetically pleasing. Moreover, the surface of the roof received attention through  
319 comments concerning the paths and the stepping stones on the roofs (positive) and the concrete slabs (also

negative, considered artificial). Wind was mentioned by 34 respondents across the dataset (altogether 40 times), and seven respondents considered it disturbing.

#### 4. Discussion and design implications

This study showed that a small and sparsely vegetated green roof, located between buildings in an urban milieu, may provide various types of recreational and experiential benefits. Our findings are in line with previous studies conducted in small urban parks at the ground level, showing that even a small piece of green in the city can offer experiential and recreational benefits (e.g. Nordh et al., 2009; Nordh and Østby, 2013; Peschardt and Stigsdotter, 2013). Our results also support the ideas by Lee et al. (2014) that in urban spaces surrounded by high buildings, even low-growth grassy vegetation can be highly valued. Furthermore, as Thwaites et al. (2005) proposed, small, human-scale spaces may offer comfortable and restorative surroundings in urban environment.

Furthermore, our results showed that some features (e.g. the roof design and the surrounding sceneries) can be seen both as aesthetically pleasing and disturbing, depending on the respondent, thus reflecting the subjectivity of experiencing places and spaces (cf. Relph, 1976). Nevertheless, asking people's experiences is important, as experiential qualities of urban spaces cannot be assessed only by measuring physical features of environments (cf. e.g. Lothian, 1999).

In the following sections we sum up the factorial solutions as well as the qualitative results to generate an overview of the multiple experiential dimensions that a small green roof could provide.

##### *4.1 Preliminary conditions: safety and greenness*

This study showed that a small and relatively barren green roof in a city centre provides a diverse set of perceived qualities that manifest at different experiential levels (cf. e.g. Leder et al., 2004; Tveit et al., 2006). Some qualities clearly reflect the so-called preliminary conditions, such as safety and comfort, as well as the

347 roof being verdant (factor H in the exploratory factor analysis). Also van Herzele and Wiedemann (2003)  
348 suggested that properties such as safety may operate as preconditions for the use of an environment, and,  
349 once these conditions are fulfilled, qualities such as unity and naturalness start affecting the people's  
350 willingness to stay there. Our recommendation is that the starting point for green roof design should include  
351 guaranteeing the feelings of safety and comfort and offering a living green roof ecosystem.

#### 353 *4.2 Restorative potential of a small urban green roof*

354

355 The level of perceived restorativeness on the study roof was quite high (mean GenPR 5.07 on a scale 1 - 7),  
356 even when compared to urban forests in Helsinki where the mean PR per forest site varied between 3.9 and  
357 5.1, on a scale 1 - 7 (Hauru et al., 2012). To our knowledge, only a few studies have surveyed perceived  
358 restorativeness of green roofs. White and Gatersleben (2011) showed that perceived restorativeness was  
359 significantly higher for photos of buildings with integrated vegetation compared to those without. According  
360 to Lee et al. (2015), the restorative effect of a green roof occurred already after a 40-second viewing of a  
361 flowering roof. These two photo-based studies, even though they used a different version of PRS than we, are  
362 in line with our results that green roofs can provide restorative experiences.

363 Together with the relatively high perceived restorativeness, the many mentions concerning peaceful  
364 and relaxed feelings in the free-form answers, and the low scores of the adjective 'restless' indicate that the  
365 roof could provide a respite that the visitors enjoyed – a place to rest for a moment. Furthermore, the various  
366 mentions in the free-form answers concerning activities on the roof, e.g. to lie in a hammock, relax with a  
367 book, look at the sky, meditate, or observe plants over time, indicate the unhurried ways these kinds of  
368 spaces could be enjoyed: 'I could come here to calm down, I would like to stroke the moss.' This is in line  
369 with mental images (hopes, needs, wishes) of urbanites (studied by Mesimäki et al., 2017) that suggested that  
370 green roofs can offer relaxing spaces for 'everyday renewal', especially at work.

371 Although earlier research indicates that lush and flowering green roof vegetation would be more  
372 beneficial for restorative purposes than low-growth one (White and Gatersleben, 2011; Lee et al., 2014;  
373 Loder, 2014), ascetic greening remains a good option when load capacity or other circumstances limit the

374 choices. The relatively short period of flowering nature in the northern climate underlines the need for  
375 ‘background green planting’ that still may offer restorative experiences (Hoyle et al., 2017). Based on the  
376 richness of mentions in our data concerning the ground materials and composition, a hypothesis could be put  
377 forth that one could also design with substrate colour and materials as well as topography to offer richer  
378 experiential qualities than can be achieved with uniform flat designs. Nordh et al. (2009) argued that the  
379 possibility for restoration is in relation to the design and the components of small (< 3000 m<sup>2</sup>) pocket parks.  
380 Thus, there is an urgent need for research on the particular design aspects in order to achieve this (Velarde et  
381 al., 2010).

382 The multiple reactions revealed by the free-form answers to the built environment including modern  
383 and historical styles (see Electronic Appendix A), indicate the importance of the whole scenery in how the  
384 respondents experienced the place. For example, perceived restoration is not only specific to natural places  
385 but can be achieved in urban places too (Korpela et al., 2010), and may depend on the variability of the scene  
386 (Tenngart Ivarsson and Hagerhall, 2008), as well as types of buildings and architectural styles (cf. Korpela,  
387 2013, Stigsdotter et al., 2017).

#### 388 389 *4.3 Two dimensions of escaping everyday*

390  
391 Experiencing compatibility of oneself with the place and escaping the everyday actualized in the same factor  
392 (B), and also through the free-form answers, such as ‘own place in the middle of urban scenery’, thus  
393 reflecting a possibility to withdraw from everyday hassles to a place suitable for oneself. This comes close to  
394 perceived restorativeness, and indeed, the statements getting the highest loadings on this factor were  
395 originally statements of the PRS (cf. Hartig et al., 1996). At the same time, the statement reflecting a break  
396 from the everyday routines was the strongest determinant of factor K that had quite a low correlation with  
397 factor B. This suggests that these two factors might reflect separate dimensions of escaping the everyday.

398 While factor K associated the break from day-to-day routines with beauty, temptation, fascination,  
399 and mystery, factor B associated the escape experience with the suitability of the place to oneself. This is in



400 line with the classical Attention Restoration Theory presented by S. Kaplan (1995) that mention fascination  
401 and compatibility among the four components that characterize an environment's restorative potential.

402 Interestingly, factor B comes close to the concept of place identity as presented by Bryce et al.  
403 (2016), who used statements such as 'I feel a sense of belonging in these sites'. The nostalgic feelings and  
404 memories described by some respondents (free-form answers), further indicate a strong connection between  
405 the observer and the place.

#### 407 *4.4 Exploration and mystery*

408  
409 In our factor solution, exploration was reflected through practical statements of wanting to explore and look  
410 around, together with fascination. In previous studies, exploration has been linked to complexity and  
411 mystery, for example Kaplan and Kaplan's (1989) preference matrix model and studies based on it (see  
412 Stamps, 2004 for a meta-analysis). However, in our study this practical wish to explore did not clearly relate  
413 to complexity-diversity nor mystery. Our hypothesis is that on this particular roof, small in size, exploration  
414 was not connected to prospect, i.e. spaces one wants to go to, but rather to investigating and observing the  
415 space that is already within one's experiential sphere. The open questions gave support to this, with answers  
416 that stated a wish to explore the environment closer: 'I would like to look at the mosses at the eye level.', 'It  
417 would be interesting to visit here, for example, in the rain. As a friend of bugs, it would be fun to see them as  
418 well.' However, despite this quite practical exploration-dimension, paths were mentioned several times as  
419 aesthetically pleasing elements in the free-form answers, e.g. 'A permitted passageway has been created to  
420 the railings.', suggesting that also the prospect kind of exploration can be achieved to some degree even in a  
421 small space if design is given some thought about that dimension.

422 As for mystery, Stamps (2004), in his meta-analysis of the Kaplans' mystery-complexity-legibility-  
423 coherence model (1989), discussed the varying results concerning mystery, defined as 'How much does a  
424 scene promise more if you could walk deeper into it?'. Based on our findings that the statement concerning  
425 the place being mysterious had its three highest and equal loadings on factors reflecting freshness/pleasant  
426 soundscape, nature, and break from daily routines, we suggest that the conceptualization of mystery might be

427 too weak (cf. e.g. Hofmann, 2012). It would be important to reconceptualise and operationalize mystery and  
428 empirically reassess its role among the perceived environmental qualities. Mystery might best be explored as  
429 multisensory perceptions experienced on-site and not, e.g. when looking at a picture of a landscape (cf.  
430 Kaplan and Kaplan, 1989).

#### 432 *4.5 Positive feelings and hope for the future*

433  
434 The free-form answers revealed experiences not traditionally recognized in the literature concerning urban  
435 green spaces, such as perceived on-site happiness, joy, love, sympathy, admiration, and pleasure. The  
436 manifold of positive feelings may indicate a favourable a priori attitude as well as the on-site experiential  
437 quality. These expressions were abundant, and much more so than expressions of disappointment (some of  
438 which also occurred). Also, Mesimäki et al. (2017) found positive expressions (e.g. happy, smile, joy) in the  
439 stories for imaginary green roofs as a distinct theme. Thus, it would be fruitful to further investigate the role  
440 of various positive feelings as part of the effects of urban green spaces for well-being: though scales exist for  
441 measuring perceived happiness, it is mostly related to people's personalities and lives in general, and not to  
442 experiential qualities provided by urban greenspace.

443         Moreover, the free-form answers reflected expectancy, enthusiasm, curiosity, surprise and admiration.  
444 For example, hope for the future was expressed as a feeling evoked by the roof. It may be that for some  
445 respondents, the place represented progress and modern urban design, a theme found also in the mental  
446 images of urbanites for green roofs (Mesimäki et al., 2017), and described by Loder (2014) as 'surprise and  
447 fascination' of vegetation existing in a very constructed urban space, and nature on a roof as a sign of hope  
448 and progress. An inspiring hypothesis would be whether 'futuricity' (i.e. place evoking positive expectations  
449 for future city, combining built environment and nature) could be an important experiential dimension in  
450 contradiction with historicity as part of the place attachment. Our study green roof may have represented  
451 values not only directly attached to the place itself, but to the *idea* of an innovative future city integrating  
452 vegetation with built environment.

454 *4.6 Multisensory aesthetic experience and the urban context*

455

456 Statements reflecting visual aesthetic quality – interest, variety, beauty, and harmony – manifested in the  
457 same factor. This result is in line with previous studies that suggested diversity and complexity to be essential  
458 elements of visual or aesthetic environmental quality (Tveit et al., 2006; Ode et al., 2008; Hauru et al., 2014;  
459 Kirillova et al., 2014).

460 Besides the visual, also audio- and olfactory aspects were frequently mentioned in our data. The  
461 sounds, and the scents included neutral or positive perceptions of the cityscape, not necessarily related to any  
462 particular source. This means that the city provides a background for the experiences: it is there but it does  
463 not ‘bother’. Indeed, e.g. soundscape perception consists of various determinants, such as the composition of  
464 sound sources, and it is context-specific (Hong and Jeon, 2015). Thus, we argue that it is not necessary to try  
465 to completely hide the presence of the city to achieve positive experiences.

466 However, smells and sounds were also evaluated as disturbing, implying immediate planning aspects.  
467 Axelsson et al. (2010) reported that technical sounds are more unpleasant than natural sounds, which was  
468 also reflected in our study where the respondents mentioned the ventilator as the most disturbing. The strong  
469 practical implication for green roof design is that noisy technology on the roofs should be avoided: one  
470 misplaced outlet may spoil the experience.

471 Jeon et al. (2011) argued that, visual image, odour, and impressions of openness and density affect  
472 soundscape perception. At moderate noise levels (55dBA), high visual quality can improve the pleasantness  
473 of the soundscape (Hong and Jeon, 2013, 2015). Furthermore, a review by Dzhambov and Dimitrova (2014)  
474 suggests that vegetation may reduce the negative perception of noise, and Hauru et al. (2012) showed that a  
475 limited view to the urban matrix may improve the restorative experience. These findings put forth an  
476 interesting hypothesis that limiting views from roofs with plantings might have positive impacts on the roof  
477 experience where the view to the surroundings does not include natural features, is not picturesque, inspiring,  
478 nor loaded with positive meanings.

479 Smell may be the most subjective of the human senses, challenging to measure and define, and thus  
480 often characterized simply as good or bad (Agapakis and Tolaas, 2012). Our results are in line with this

481 finding as the question regarding smells received the least amount of contents from the respondents.  
482 Obviously, methodological development is needed to fully assess scents as part of a multisensory experience.  
483 Considering the significance of a multisensory experience for the human well-being, it would be interesting  
484 to test a green roof deliberately designed for various sensory experiences (cf. e.g. Gonzalez and Kirkevold,  
485 2014 for the benefits of sensory gardens).

486 We emphasize the wholeness of the perception, interaction of different sensory dimensions, feelings  
487 and the specific context of experience on a roof as reflected for example by the liberating multisensory  
488 experience, revealed by the free-form answers. A corresponding theme was reported in Mesimäki et al.  
489 (2017), where the mental images of urbanites for green roofs described enjoying the height and being close to  
490 sky, as well as the feeling of spaciousness and freedom. Also, Ode et al. (2008) regarded visual scale as an  
491 important dimension of environmental experience. In the present study cramping and small size were  
492 reported by many respondents as disturbing, which poses an interesting challenge for the designer: how to  
493 facilitate a positive feeling of space and height, and avoid the feeling of tightness on small roofs, or other  
494 small green spaces in a dense city.

495

#### 496 *4.7 Tempting nature*

497

498 Visual Interestedness and General Likeability correlated with Tempting Nature, suggesting that these  
499 qualities may be connected. This association is further supported by the free-form answers where some form  
500 of nature was frequently mentioned as an aesthetically pleasing element on the roof, such as ‘flowers, stones,  
501 moss’, and ‘nature, sky’. Furthermore, other responses, e.g. to the question about what things first caught  
502 one's attention, combined aesthetic experience explicitly with nature: ‘green moss - red sand - grey stones –  
503 beautiful’, and ‘verdancy, silence, composition’. Moreover, many respondents smelled, e.g. soil, forest, rain,  
504 nature, moss and autumn, heard the hum of the wind, and sensed the fresh wind, indicating multisensory in  
505 experiencing nature (cf. Hoyle et al. 2017).

506 Perhaps the most surprising practical design implication of our study was that that mosses were so  
507 readily accepted as part of the roof design, while traditionally, mosses on roofs and lawns have been  
508 considered a nuisance.

#### 510 *4.8 Acceptability*

511  
512 In this study the high mean scores of the statements *It is good places like this exist, I like this place*, and  
513 *Places like this are compatible with the city* suggest that the studied green roof was accepted as part of the  
514 city, and the participants also shared a high positive consensus regarding the place being compatible with the  
515 city. Furthermore, General Likability of the roof arose from the results as a factor, indicating that  
516 acceptability is essentially different from the other experiential qualities. As e.g. Hauru et al. (2014) suggest,  
517 acceptability may be affected by the aesthetic or other experiential qualities perceived on site, but it can also  
518 be based on the facts about the place only. Therefore, acceptability, also reflecting the normative attitude  
519 towards the place, should not be confused with aesthetic or other experiential qualities provided by the place  
520 (cf. Hauru et al., 2014; Hauru, 2015, p. 20, 29, 33).

#### 522 *4.9 Methodological considerations and limitations*

523  
524 There are some considerations regarding surveys including closed and open questions. First, closed questions  
525 preceding open ones may lead the respondent to repeat similar ideas. The most interesting findings based on  
526 the open questions brought up themes or nuances not revealed by the closed ones, such as the variety of  
527 positive feelings and feeling of spaciousness, which might be worth incorporating into the closed questions in  
528 future studies.

529 Second, the low communalities of some of the statements, such as *It is a confusing place* and *This*  
530 *place is modern*, suggest that these statements were difficult to assess (i.e. unclear or unsuited for the site), or  
531 represent experiential qualities not implied by other statements or adjectives. The latter suggests a hypothesis  
532 that statements and adjectives operationalizing experiences of novelty or innovativeness were not sufficiently

533 well included in our study, and that new statements reflecting such experiential dimension should be created.  
534 This hypothesis is supported by the free-form answers showing that for some respondents the green roof  
535 represented a new kind of thinking and hope for the future.

536 Third, there are methodological issues that imply a need to rethink the design of instruments that use  
537 statements or questions to measure human-environment relationships. For example, the current version of  
538 PRS measures Coherence only by negative statements that all are formed from the perspective of the 'site'  
539 (e.g. *There is too much going on* rather than *I feel there is too much going on*). At the same time GenPR  
540 gathered all the positive statements and 11 out of the 12 statements on GenPR were phrased so that they  
541 contained a personal perception, i.e. 'one-self' (e.g. *Here I feel I can escape the everyday*). These findings  
542 are in agreement with the analysis of the full dataset with 45 items: 7 out of 10 negatively phrased statements  
543 gathered on one factor (C). Items that reflect the opposites (e.g. *Harmonious, It is beautiful here* vs. *It is*  
544 *chaotic here, Ugly*) loaded on different factors, suggesting an effect of negative vs. positive items. Had the  
545 actual meaning of the items been decisive, the opposites could have loaded on the same factor but with  
546 positive vs. negative loadings. Furthermore, the statements that were phrased from the perspective of one-self  
547 gathered on different factors from those that referred to the site only: of the nine factors with the highest  
548 loading of more than one item, three (B, G, I) contained almost only statements including 'one-self', and six  
549 (A, C, D, E, F, H) almost only statements that were phrased to concern the site. We recommend testing for  
550 the effect of negative vs. positive phrasing of the statements, and statements that are phrased from the  
551 perspective of the observed environment vs. those that emphasize the personal experiences of the respondent,  
552 with explicit contrasts specifically designed to test this methodological hypothesis.

553 The short lecture about green roofs given before the visit, or simply the concept of *green* roof may  
554 have produced expectations for a more verdant place than the roof was. The free-form answers revealed  
555 negative experiences and observations related to, e.g. unfulfilled expectations concerning the type and lack of  
556 vegetation, as well as size and design of the place.

557 Lastly, as the visitors to the study roof were selected through a registration based on first come first  
558 serve rule, the results cannot be straightforwardly generalized to a wider population. Even though the green  
559 roof was not the only destination during the event, the participants may have been biased in terms of positive

attitude towards innovative spaces. However, the respondent group represented a variety of professions and educational backgrounds, thus offering relevant data to explore the dimensions of experiencing small green roofs in a dense urban area. Further studies should e.g. test whether similar experiences manifest on different green roofs, in various urban areas, and among different user groups.

## **Conclusions**

Although literature concerning the technical performance of green roofs has dramatically increased during the last 10 years, the experiential quality of green roofs has remained almost terra incognita. While our results offer practical guidelines, they also suggest that investment in research focusing on experiential aspects would be effective in terms of improving the liveability of cities. As people can experience the same space variably, the needs of specific user-groups should be considered. Participatory methods and co-design could be useful for finding and negotiating common ground for high experiential quality. On-site studies in realistic environments are a powerful tool to inform planning and design.

Furthermore, we argue that it is necessary to consciously plan the sensoryscape on a green roof, taking into account the sources of sounds, scents, and the visual stimuli in the immediate surroundings, and further away. We agree with Henshaw (2014) that a ‘new sensory approach to urbanism’ should be developed, and smell and its interactions with other forms of sensory information should be considered in urban design and management.

Finally, following the idea of Campbell et al. (2016) we suggest ecosystem services are constantly re- and co-created via the human interaction with spaces. Therefore, adaptive planning and management require regular data generation to keep researchers and practitioners updated about the experiential ecosystem services that urban green space offers. This is especially important with such emerging nature-based solutions that are not culturally established, and in places with demographic turbulence where meanings and uses may abruptly change.

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## Appendices A–D. Supplementary Data

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Fig. 1 The study roof. Photo: Ismo Kirves 2012. The colour version of the photo is displayed in Electronic Appendix A, figure S1.





Table 1 Loadings of PRS statements on two factors representing General Perceived Restorativeness (GenPR) and Coherence. The higher of the two loadings of each statement is in bold. Note that scales of statements 3, 11, 12 and 13 are reversed (=R; see section 2.4 above).

	GenPR	Coherence
1) <i>My attention is drawn to many interesting things.</i>	<b>0.50</b>	0.31
2) <i>Being here suits my personality.</i>	<b>0.68</b>	0.29
3) <i>There is too much going on.</i> (R)	0.29	<b>0.68</b>
4) <i>I could find many ways to enjoy myself in a place like this.</i>	<b>0.65</b>	0.35
5) <i>Here I feel able to escape the everyday.</i>	<b>0.65</b>	0.33
6) <i>I have a sense that I belong here.</i>	<b>0.78</b>	0.18
7) <i>I have a sense of oneness with this setting.</i>	<b>0.72</b>	0.22
8) <i>The setting has fascinating qualities.</i>	<b>0.75</b>	0.35
9) <i>I want to explore the area.</i>	<b>0.58</b>	0.18
10) <i>I would like to get to know this place better.</i>	<b>0.63</b>	0.21
11) <i>It is a confusing place.</i> (R)	0.04	0.21
12) <i>There is a great deal of distraction.</i> (R)	0.37	<b>0.87</b>
13) <i>It is chaotic here.</i> (R)	0.31	<b>0.74</b>
14) <i>I'd like to spend more time looking at the surroundings.</i>	<b>0.63</b>	0.39
15) <i>Spending time here gives me a good break from my day-to-day routine.</i>	<b>0.55</b>	0.28
16) <i>I can do things I like here.</i>	<b>0.54</b>	0.18

Table 2 The 11-factor solution of the 29 statements and 17 adjectives, and correlations between the factors A - K. The highest loading of each statement is in bold (note that a statement may have high loadings on several factors). Reversed statements (=R).

	A	B	C	D	E	F	G	H	I	J	K
22) <i>It is a visually interesting place.</i>	<b>0.82</b>	0.49	0.40	0.63	0.27	0.59	0.48	0.30	0.46	0.37	0.43
23) <i>There is a lot to observe here.</i>	<b>0.67</b>	0.37	0.19	0.38	0.24	0.43	0.57	0.42	0.37	0.40	0.22
17) <i>It is beautiful here.</i>	<b>0.66</b>	0.48	0.49	0.60	0.29	0.56	0.42	0.37	0.35	0.50	0.54
<i>Diverse</i>	<b>0.66</b>	0.33	0.22	0.32	0.31	0.46	0.35	0.17	0.26	0.34	0.30
<i>Picturesque</i>	<b>0.65</b>	0.29	0.40	0.38	0.34	0.45	0.31	0.18	0.33	0.27	0.33
<i>Harmonious</i>	<b>0.61</b>	0.36	0.52	0.37	0.41	0.51	0.34	0.31	0.26	0.11	0.26
<i>Well-being</i>	<b>0.61</b>	0.34	0.24	0.43	0.36	0.54	0.40	0.46	0.19	0.50	0.37
6) <i>I have a sense that I belong here.</i>	0.45	<b>0.89</b>	0.20	0.59	0.27	0.51	0.38	0.26	0.44	0.36	0.23
7) <i>I have a sense of oneness with this setting.</i>	0.44	<b>0.77</b>	0.26	0.40	0.27	0.48	0.37	0.17	0.40	0.24	0.33
5) <i>Here I feel I can escape the everyday.</i>	0.27	<b>0.64</b>	0.35	0.40	0.14	0.44	0.31	0.09	0.46	0.39	0.48
16) <i>I can do things I like here.</i>	0.37	<b>0.60</b>	0.16	0.40	0.15	0.32	0.24	0.35	0.20	0.37	0.33
21) <i>I feel I understand this place.</i>	0.55	<b>0.59</b>	0.23	0.39	0.21	0.39	0.38	0.29	0.29	0.27	0.29
12) <i>There is a great deal of distraction. (R)</i>	0.38	0.21	<b>0.85</b>	0.32	0.22	0.35	0.23	0.29	0.41	0.21	0.20
13) <i>It is chaotic here. (R)</i>	0.37	0.23	<b>0.76</b>	0.36	0.06	0.24	0.17	0.39	0.13	0.19	0.22
3) <i>There is too much going on. (R)</i>	0.16	0.23	<b>0.69</b>	0.17	0.25	0.25	0.06	0.10	0.26	0.12	0.30
<i>Restless (R)</i>	0.38	0.19	<b>0.69</b>	0.25	0.36	0.30	0.11	0.51	0.14	0.13	0.08
<i>Ugly (R)</i>	0.42	0.25	<b>0.52</b>	0.44	0.13	0.46	0.22	0.28	0.28	0.35	0.42
<i>Confined (R)</i>	0.30	0.24	<b>0.42</b>	0.32	0.39	0.22	0.10	0.35	0.23	0.12	0.09
<i>Everyday (R)</i>	-	0.09	<b>-0.50</b>	-0.18	-0.03	-0.28	-0.29	-0.17	-0.31	-0.22	-0.17
27) <i>It is good that places like this exist.</i>	0.40	0.50	0.32	<b>0.92</b>	0.27	0.45	0.26	0.36	0.47	0.47	0.34
29) <i>Places like this fit in into the city.</i>	0.34	0.36	0.23	<b>0.74</b>	0.20	0.41	0.27	0.37	0.41	0.37	0.30
28) <i>I like this place.</i>	0.41	0.50	0.39	<b>0.68</b>	0.34	0.56	0.33	0.38	0.41	0.43	0.33
<i>Boring (R)</i>	0.58	0.37	0.53	<b>0.66</b>	0.24	0.56	0.40	0.43	0.47	0.58	0.42
<i>Nice</i>	0.47	0.41	0.30	<b>0.58</b>	0.20	0.57	0.30	0.44	0.46	0.56	0.30
26) <i>This place is modern.</i>	0.33	0.28	0.11	<b>0.48</b>	0.12	0.24	0.27	0.16	0.18	0.18	0.14
19) <i>The air is fresh here.</i>	0.32	0.17	0.22	0.27	<b>0.83</b>	0.29	0.17	0.21	0.16	0.23	0.23
<i>Fresh</i>	0.44	0.26	0.22	0.48	<b>0.65</b>	0.56	0.33	0.42	0.29	0.39	0.20
18) <i>The soundscape is pleasant here.</i>	0.28	0.25	0.31	0.17	<b>0.61</b>	0.41	0.20	0.13	0.28	0.18	0.24
20) <i>This is a mysterious place.</i>	0.32	0.26	0.12	0.28	<b>0.44</b>	<b>0.44</b>	0.23	-0.07	0.25	0.40	<b>0.44</b>
<i>Lively</i>	0.53	0.38	0.28	0.48	0.32	<b>0.77</b>	0.36	0.55	0.38	0.40	0.25
24) <i>I can sense nature in this place.</i>	0.52	0.51	0.35	0.44	0.34	<b>0.75</b>	0.32	0.17	0.44	0.29	0.40
<i>Verdant</i>	0.46	0.30	0.22	0.40	0.37	<b>0.69</b>	0.29	0.55	0.25	0.34	0.18
<i>Tempting</i>	0.57	0.49	0.36	0.58	0.47	<b>0.60</b>	0.42	0.45	0.52	0.59	0.52
25) <i>This looks like a place where many insects and invertebrates live.</i>	0.30	0.32	0.24	0.27	0.19	<b>0.49</b>	0.24	0.12	0.15	0.25	0.23
9) <i>I want to explore the area.</i>	0.55	0.38	0.18	0.36	0.20	0.36	<b>0.86</b>	0.27	0.38	0.19	0.12
10) <i>I would like to get to know this place better.</i>	0.43	0.38	0.24	0.42	0.24	0.47	<b>0.86</b>	0.33	0.32	0.54	0.44
8) <i>The setting has fascinating qualities.</i>	0.55	0.52	0.36	0.52	0.36	0.59	<b>0.62</b>	0.37	0.52	0.55	0.46

14) <i>I'd like to spend more time looking at the surroundings.</i>	0.53	0.41	0.36	0.36	0.24	0.44	<b>0.56</b>	0.31	0.47	0.42	0.45
<i>Safe</i>	0.31	0.25	0.25	0.39	0.22	0.35	0.21	<b>0.63</b>	0.21	0.22	0.26
<i>Scary (R)</i>	0.16	0.07	0.29	0.18	0.10	0.18	0.15	<b>0.60</b>	0.11	0.13	-0.05
11) <i>It is a confusing place. (R)</i>	0.05	0.12	0.18	0.07	-0.18	-0.02	-0.07	<b>0.28</b>	0.10	-0.05	-0.20
4) <i>I could find many ways to enjoy myself in a place like this.</i>	0.24	0.56	0.28	0.54	0.15	0.44	0.26	0.25	<b>0.76</b>	0.50	0.41
1) <i>My attention is drawn to many interesting things.</i>	0.48	0.26	0.32	0.37	0.24	0.34	0.39	0.16	<b>0.64</b>	0.24	0.28
2) <i>Being here suits my personality.</i>	0.43	0.62	0.28	0.59	0.39	0.54	0.34	0.42	<b>0.63</b>	0.33	0.19
<i>Exciting</i>	0.51	0.32	0.23	0.41	0.32	0.45	0.43	0.22	0.34	<b>0.68</b>	0.33
15) <i>Spending time here gives me a good break from my day-to-day routine.</i>	0.37	0.49	0.29	0.36	0.25	0.36	0.25	0.15	0.37	0.25	<b>0.62</b>

	A	B	C	D	E	F	G	H	I	J	K
B	0.47										
C	0.42	0.26									
D	0.53	0.54	0.38								
E	0.40	0.28	0.23	0.30							
F	0.58	0.48	0.41	0.57	0.44						
G	0.53	0.34	0.22	0.36	0.23	0.44					
H	0.43	0.30	0.32	0.47	0.25	0.37	0.27				
I	0.35	0.45	0.36	0.49	0.25	0.51	0.39	0.22			
J	0.31	0.31	0.24	0.53	0.21	0.54	0.39	0.34	0.38		
K	0.32	0.30	0.34	0.39	0.19	0.48	0.32	0.07	0.30	<b>0.61</b>	

Appendix A. The study roof



Fig. S1 The study roof. Photo: Ismo Kirves 2012.



Fig. S2 Vegetated areas and paved paths on the study roof. Moss-sedum vegetation in the front, and newly constructed experimental plots (separated with gravel) in the middle. Photo: Malgorzata Gabrych 2012.

Figs. S3–S4 Surrounding roof scenery (opposite to Figs S1 and S5–S6), and patio with two chairs, a table and flower pots. In Fig S4, the crane of the construction site nearby is visible.



Fig. S3 Photo: Taina Suonio 2012.



Fig. S4 Photo: Malgorzata Gabrych 2012.

Figs. S5–S6 Surrounding wall scenery (opposite to Figs. S3–S4): the library building with a balcony (S5), and colorful curtains (S6).



Fig. S5 Photo: Malgorzata Gabrych 2012.



Fig. S6 Photo: Taina Suonio 2012.

## Appendix B. Age, living environment, and expertise of the respondents

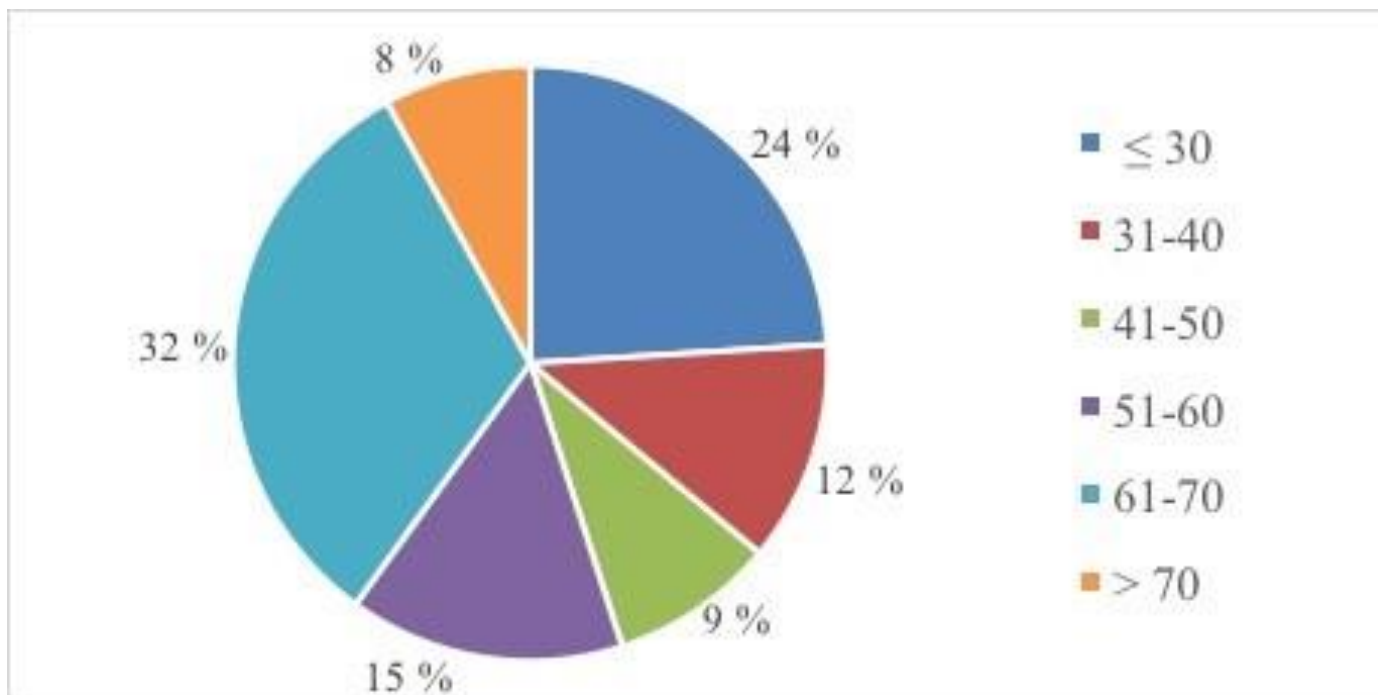


Fig. S7 Age of the respondents. Age groups as percentages of the 165 respondents who answered this question.

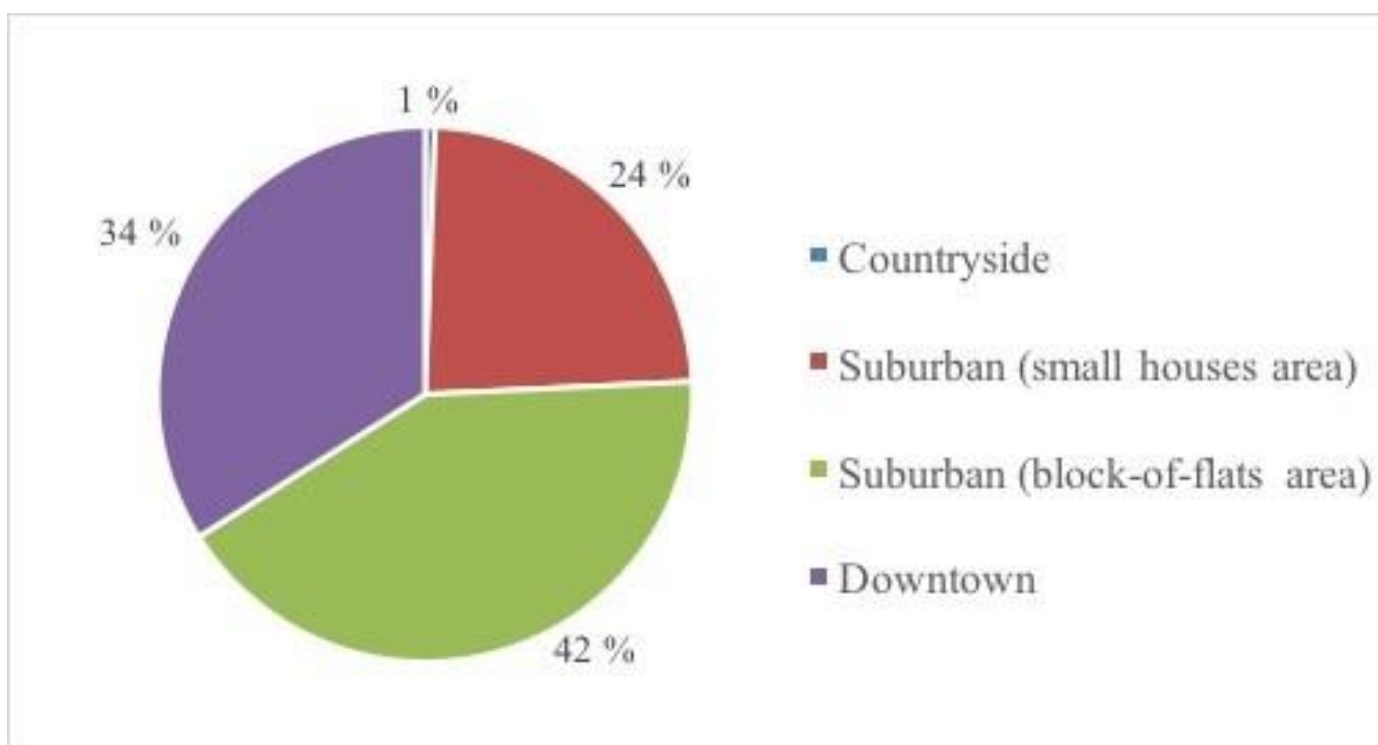


Fig. S8 Living environment of the respondents. Living environment groups as percentages of the 165 respondents who answered this question.



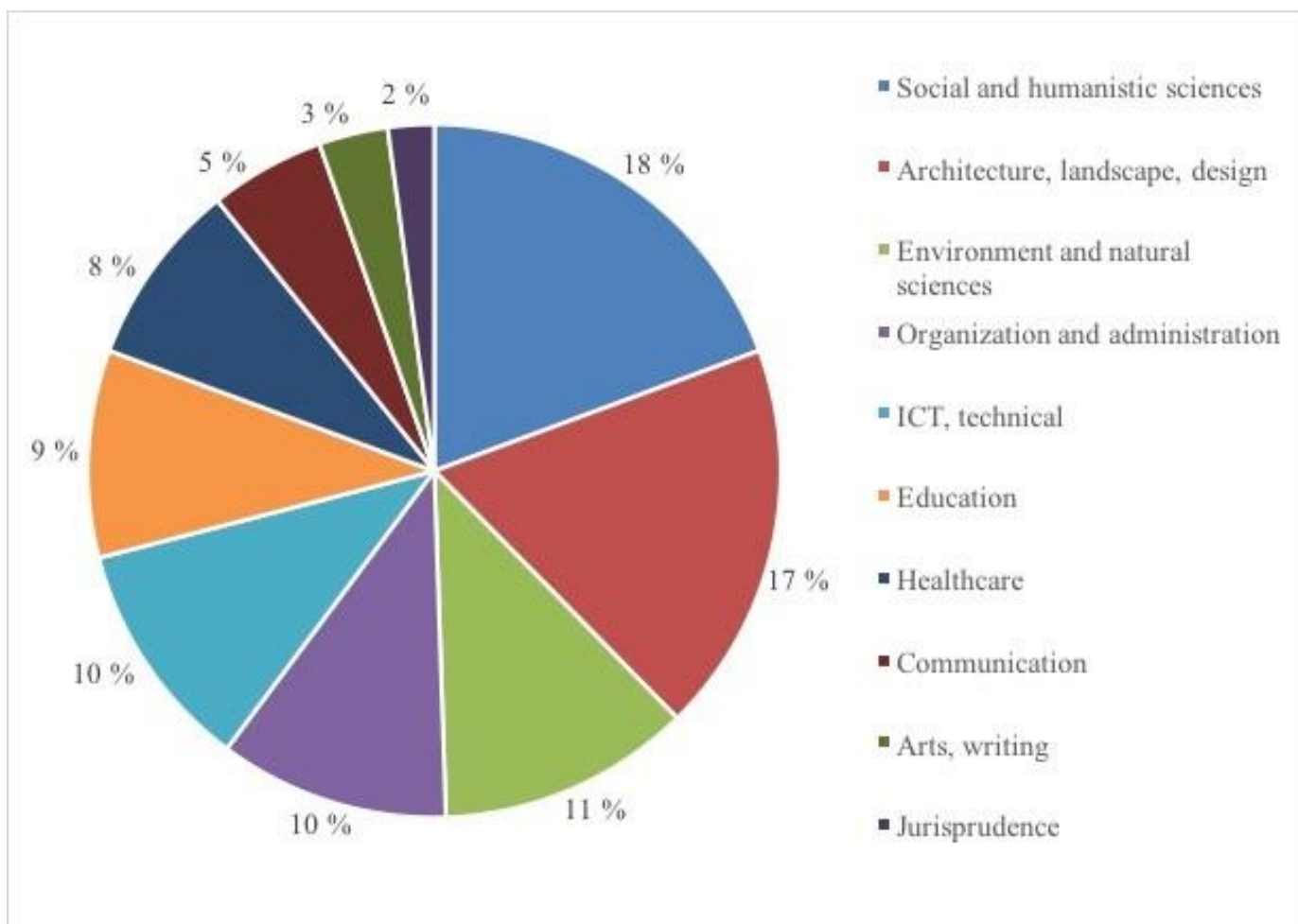


Fig. S9 Expertise of the respondents. We categorized the expertise mentioned by 140 respondents (originally 160 responses to this question, out of which 20 were so unclear that they could not be categorized). However, some respondents reported to be experts in many fields, thus the total number of mentioned expertise was 174.

## Appendix C. The Questionnaire

Respondents were given the following introduction:

There is a green roof landscape around you. We are interested in your experience right at the place where you are standing. To help us understand your experience, we have provided the following statements for you to respond to. First, look around you, and then, carefully read each statement. Ask yourself “*How much does this statement apply to my experience right here?*”

After having answered to the close-ended questions, and, standing at the same place, please answer with a couple of words to the open-ended questions at the end of the questionnaire.

Note that there are no right or wrong answers to the questions.  
We are interested in your personal experience here and now.

Please circle for each statement the alternative that applies best to your own experience here and now.

1= not at all, 2 = Very little, 3 = Fairly little, 4 = Neither little nor much, 5= Fairly much, 6 = Very much, 7 = Completely.

1) My attention is drawn to many interesting things.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
2) Being here suits my personality.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
3) There is too much going on.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
4) I could find many ways to enjoy myself in a place like this.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
5) Here I feel I can escape the everyday.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
6) I have a sense that I belong here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
7) I have a sense of oneness with this setting.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
8) The setting has fascinating qualities.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
9) I want to explore the area.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
10) I would like to get to know this place better.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
11) It is a confusing place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
12) There is a great deal of distraction	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
13) It is chaotic here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
14) I'd like to spend more time looking at the surroundings.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
15) Spending time here gives me a good break from my day-to-day routine.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
16) I can do things I like here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
17) It is beautiful here	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
18) The soundscape is pleasant here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
19) The air is fresh here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
20) This is a mysterious place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
21) I feel I understand this place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
22) It is a visually interesting place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
23) There is a lot to observe here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
24) I can sense nature in this place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
25) This looks like a place where many insects and invertebrates live.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7



26) <i>This place is modern.</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
27) <i>It is good that places like this exist.</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
28) <i>I like this place.</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
29) <i>Places like this fit in into the city.</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7

Please evaluate, how well the following adjectives describe this environment. Please circle for each adjective the alternative that applies best to your own experience.

1= not at all, 2 = Very little, 3 = Fairly little, 4 = Neither little nor much, 5= Fairly much, 6 = Very much, 7 = Completely.

I think that the landscape is:

<i>Ugly</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Nice</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Harmonious</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Restless</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Diverse</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Everyday</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Picturesque</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Well-being</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Exciting</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Boring</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Lively</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Verdant</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Fresh</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Confined</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Tempting</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Scary</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
<i>Safe</i>	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7

Observe this environment with all your senses and answer following questions considering what you are experiencing right now in this place.

- 1) What things first caught your attention?
- 2) If there are some aesthetically pleasing things in the place, what are they?
- 3) If there are some disturbing things in the place, what are they?
- 4) What sounds do you hear?
- 5) What do you smell?
- 6) What kinds of feelings does the place evoke in you?

**Appendix D. Classified contents of free-form answers.**

**1. What things first caught your attention?**

Main category	Examples of mentioned things, <i>word to word quotations</i> (translated from Finnish) from the original answers are shown in italics
Elements within the roof	Objects on the roof, e.g. concrete slabs, red substrate, terrace chairs, different surfaces
Mosses	Mosses, moss cover, <i>lovely green moss</i>
Design of the roof	Composition of different features, space, forms, shapes, <i>harmonic layout of surfaces, great use of small space</i>
Colors, verdancy	Different colors, green, greenness, verdant, <i>intensive color of green moss, great colors and contrasts</i>
Characterizations of the place and space	Beautiful, small, cozy, high, spaciousness, <i>just as stepping in the middle of a forest, green area in the middle of stony city, new constructional idea</i>
Built environment around the roof	Roof landscape, roofs, walls and buildings in the surroundings, <i>fine roofs around</i>
Plants and mushrooms	Plant species, plant communities, plant surfaces
Environmental attributes	(Respiratory) air, light/sunshine, wind, smells, sounds, scents, <i>fresh wind, sounds of the city</i>
Flowers	Flowers, flower pots, <i>yellow daisies</i>
Negative things	Less plants/not as fancy as expected, (unexpectedly) small, unfinished, <i>too many concrete and ugly slabs, buzzing sound of the air conditioning</i>
Sky, horizon	

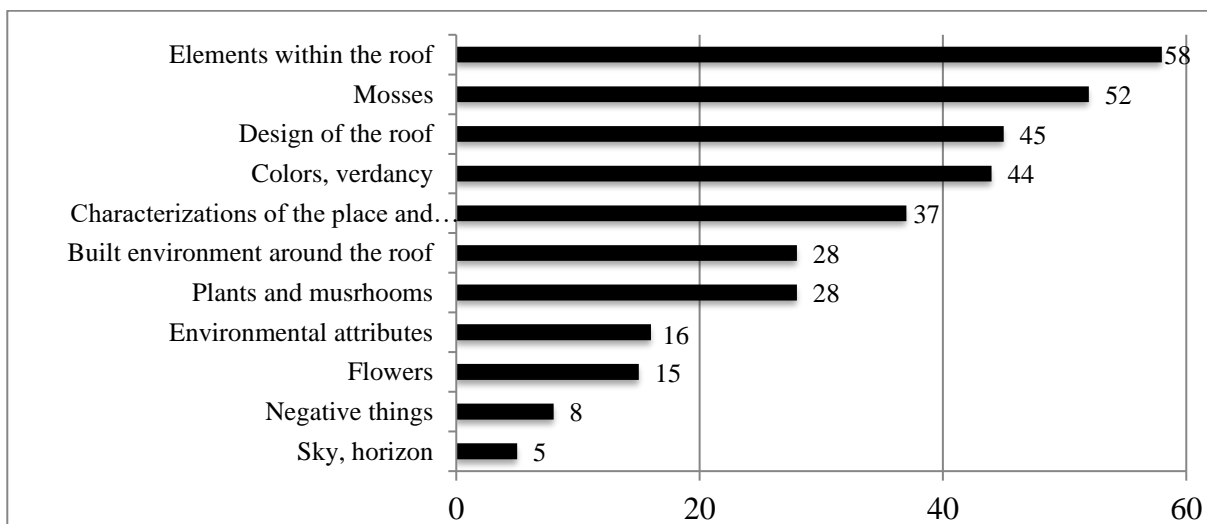


Fig. S10 Classified answers to the question: ‘What things first caught your attention?’ Altogether 165 respondents (93% of all respondents, N=178) answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

## 2. If there are some aesthetically pleasing things in the place, what are they?

Main category	Examples of mentioned things, <i>quotations</i>
Colors, verdancy	Green, different shades of green, colors of the buildings, greenness, richness of colors, <i>beautiful colors, intensive green color</i>
Elements within the roof	Furniture, (natural) rocks, macadam paths, substrate, slabs, tiles
Design of the roof	Composition of different sectors, elements and materials on the roof and their interaction, shapes, forms, scale, diversity/versatility (of e.g. elements, shapes), balance, <i>harmonic unity, beautiful shapes, modernly symmetric, nicely arranged plants and paths, combination of mosses, plants and stones.</i>
Mosses	Mosses, moss cover, <i>velvety moss, moss is rather natural</i>
Built environment around the roof	(Roof) landscape, different types of roofs, forms and shapes of the roofs, old buildings, facades, windows, <i>urban milieu, beautiful views, I liked the walls of the buildings – do they store warmth for the plants?</i>
Flowers	Wild flowers, flowerpots, flower arrangements
Characterizations of the space	Spaciousness, openness, beautiful/beauty, small, intimacy, simplicity, cleanliness, closeness to nature, surprising, connection to urban environment, <i>small and neat garden, barrenness is attractive, a lot of space above</i>
Vegetation, nature	Plants, high/short plants, stonecrops (Sedum), mushrooms, funnel chantarelles, <i>varying vegetation of the roof</i>
Sky, horizon	Blue sky and clouds, sky is close, open sky, <i>great bright sky</i>
Environmental attributes	Good weather, air, sun, light, <i>slant evening light</i>

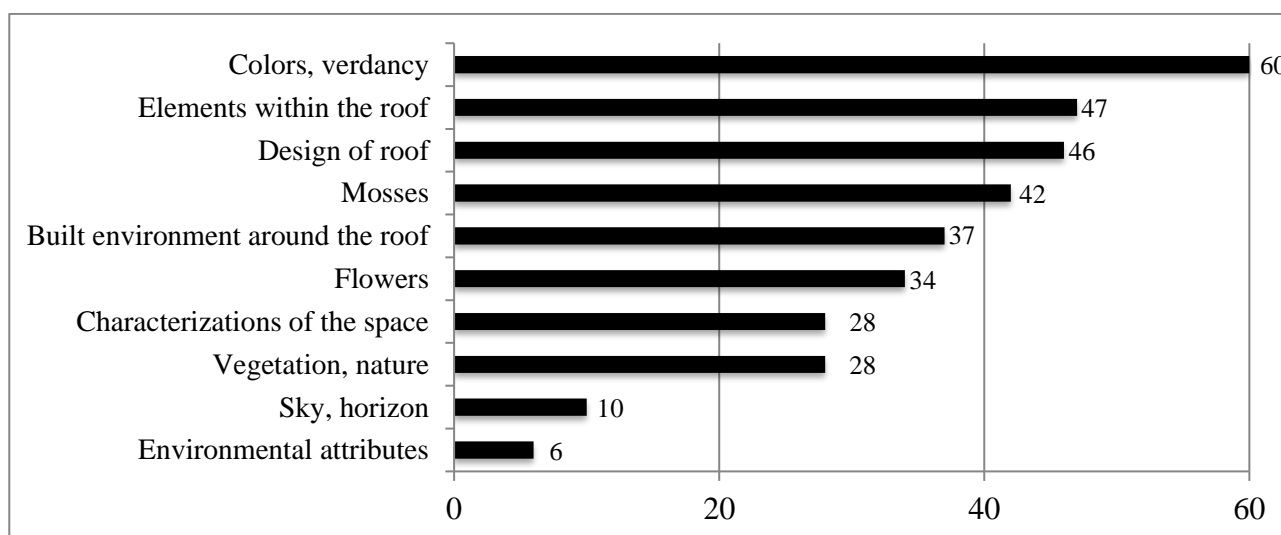


Fig. S11 Classified answers to the question: ‘If there are some aesthetically pleasing things in the place, what are they?’ Altogether 162 (91%) respondents answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

### 3. If there are some disturbing things in the place, what are they?

Main category	Examples of mentioned things, <i>quotations</i>
Noise	Air conditioner/ventilator, drone, hum, whirr, creak, wheezy sound, construction noise, traffic noise from the street
Built environment around the roof	Walls, (garish, bright) colors, balcony (and people on it), construction site, crane, restricted view
Built elements on the roof	Concrete slabs, fences, <i>flowerpots do not fit here</i>
Characterizations of the space	Small, tightness, restless, too close to buildings, too stony, dull, lack of action
Design of the roof	too many/composition of slabs, flat/planar vegetation, messy, formality, too ordered, <i>perhaps a little bit too much of everything, not quite harmonious</i>
Lack or unsuitable choices of vegetation	Lack of green, stunted vegetation, lack of high vegetation and climbing plants, <i>I miss a sheltered corner for spending time, mosses remind me of harms related to humidity and moisture</i>
Environmental attributes	Wind, windy
Nothing	
Smells	Smells from the canteen, construction site

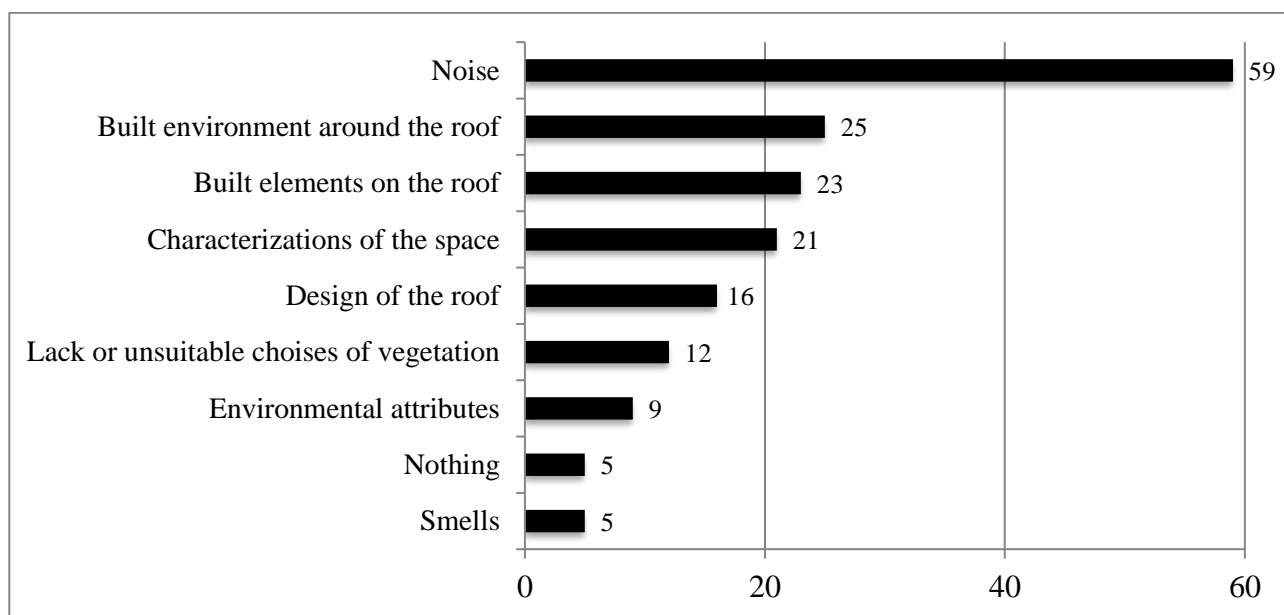


Fig. S12 Classified answers to the question: ‘If there are some disturbing things in the place, what are they?’ Altogether 129 (72%) respondents answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

#### 4. What sounds do you hear?

Main category	Examples of mentioned things, <i>quotations</i>
Air conditioning	All kinds of buzz, whirr, drone, burr, squeak, whine etc. characterizations were interpreted as sounds of air conditioning
Traffic	Cars, trams, honking, aeroplane, <i>traffic noise is surprisingly mild, faint traffic noise</i>
Construction site	Including sounds from ‘machines’ (cranes etc.)
Human sounds	Speech, walking, coughing, rustling of questionnaire papers
Sounds of the city	City sounds in general/background sound of the city, <i>hum of the city, occasional sounds from the street</i>
Sounds of nature	Wind, sound of gravel, birds, seagulls
Nothing	

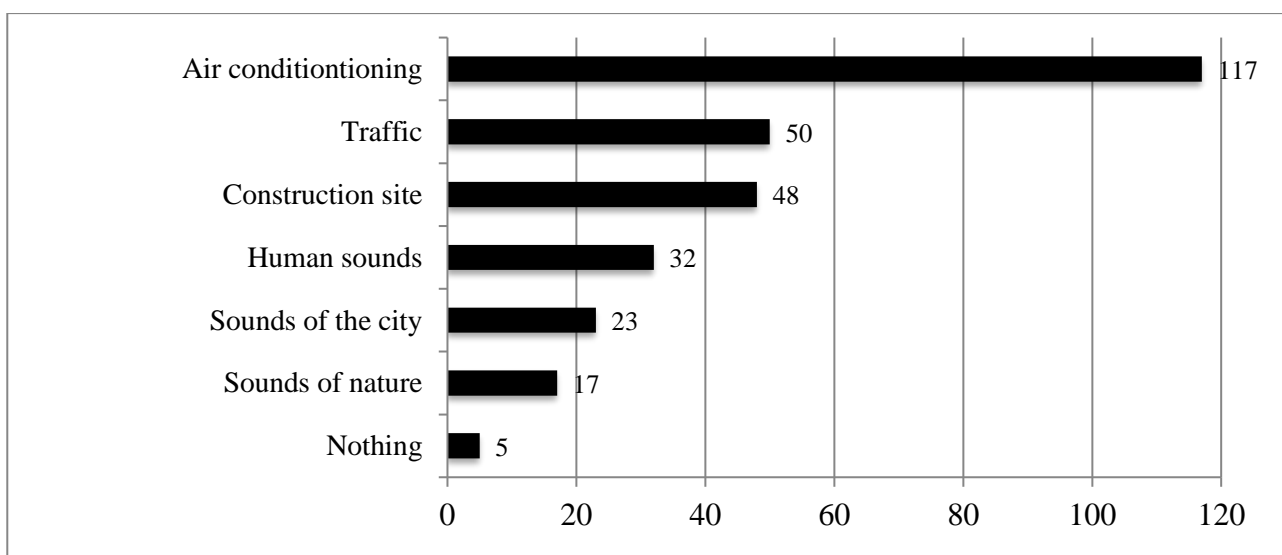


Fig S13 Classified answers to the question: ‘What sounds do you hear?’ Altogether 167 (94%) respondents answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

## 5. What do you smell?

Main category	Examples of mentioned things, <i>quotations</i>
Fresh air	Fresh air, wind, sea air
Nothing	Nothing, almost nothing
Food	Smell from the canteen (likely emanating from somewhere in the building through the air conditioning)
Nature, seasons	Forest, vegetation, tussock, moss, soil, rain, moist, autumn, cold, <i>moist wind, crisp autumn</i>
City	Smells of the city (in general), exhaust gas, dust of the city, asphalt, construction site
Other	sharp, nice, soft, sweet, sun, smoke, stuffy

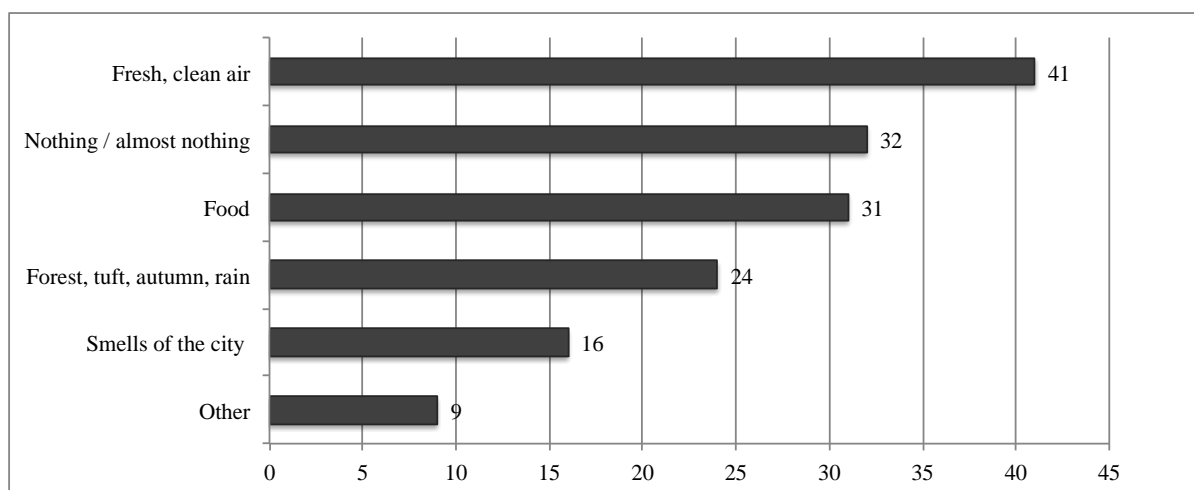


Fig S14 Classified answers to the question: ‘What do you smell?’ Altogether 157 (88%) respondents answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

## 6. What kinds of feelings does the place evoke in you?

Main category	Examples of mentioned things, <i>quotations</i>
Pleasant	Pleasant, joy, love, cozy, sympathy, nice, good feeling/mood, smile, admiration, wonderful, fascinating, <i>oasis of the city center, it is a great feeling to be here, sunny feelings, nice place to visit</i>
Peaceful, relaxed	Peaceful, calm, calming atmosphere, relaxed, unhurried, leisurely, serene, escape (from everyday life), <i>calming greenness, positive peace, a place to rest for a while, inspiring tranquility</i>
Interested, inspiring	Curiosity, excitement, surprising, hope (for the future), inspiring, <i>this is future, something new!, great idea, more places like this</i>
Desire to stay, to come back	Stay longer, lie in a hammock, relax with a book, have lunch, sit down, look at the sky, meditate, grow useful plants, follow plants over time, see bugs, play, hide, <i>I could come here to calm down, I would like to stroke the moss</i>
Negative	Boring, disappointment, tight, <i>could be higher up, I waited for more</i>
Freedom	Liberating, freedom to breath, spacious, <i>own space in the middle of urban landscape</i>
Familiar, nostalgic	Coziness, memories from childhood or past, <i>sedums and mosses remind of the cottage island of the family, climbing in nature in childhood, old memories from the 60's</i>
Confused, vague	Ambivalent, questions
Feelings related to the environmental attributes	Fresh (ref. to air), autumnal
Feelings related to identity	<i>European mixed to Finnish identity, this is a true Helsinkian place, A cheap trip to Amsterdam!</i>
Nothing	<i>Nothing at this kind of group visit</i>
Other	Aesthetic pleasure, refreshing, harmonious/harmony, connection

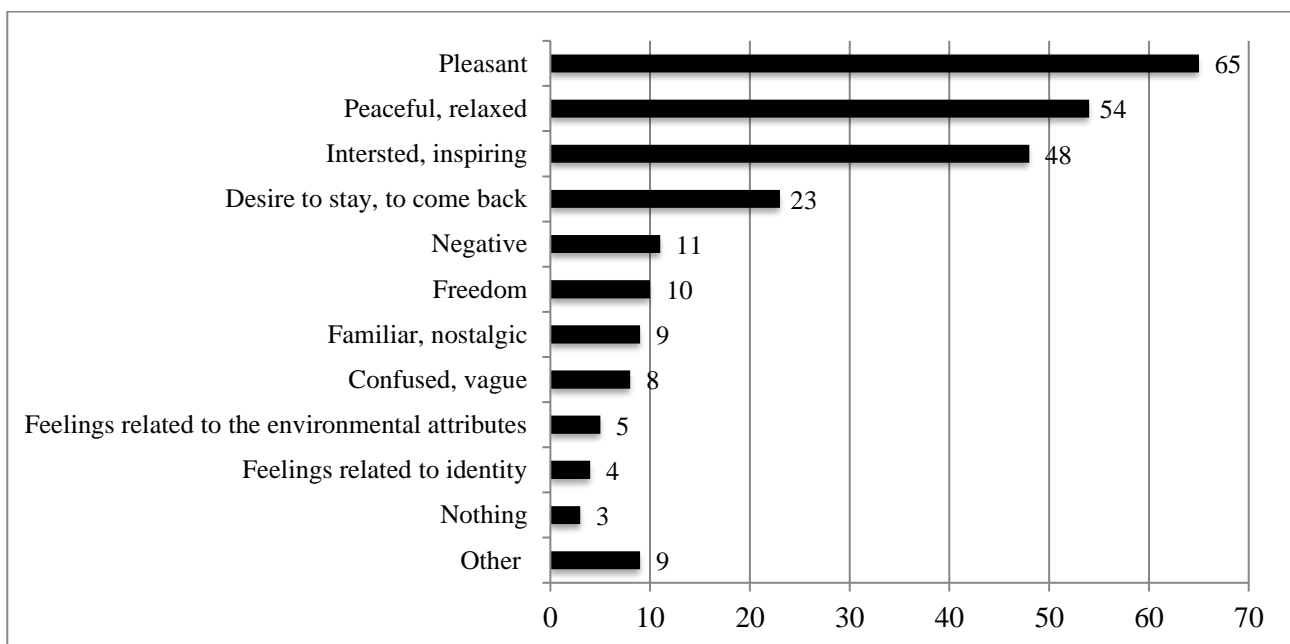


Fig. S15 Classified answers to the question: ‘What kinds of feelings does the place evoke in you?’ Altogether 162 respondents (91%) answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.