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Research Paper

Living roof preference is influenced by plant characteristics and diversity

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HIGHLIGHTS

- Living roofs with tall, green, grassy vegetation were highly preferred.
- Flowers increased living roof preference.
- Plant diversity increased preference overall, but decreased preference for most preferred vegetation.
- Psychological restoration was associated with the most preferred living roof.

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ABSTRACT

Living, or green roofs, are increasingly built in cities for their environmental benefits, however there is little evidence about how to maximise their aesthetic appeal. Because preferences for landscapes can be determined by vegetation characteristics we surveyed the preferences of 274 Australian office workers using 40 living roof images which systematically manipulated plant life-form, foliage colour, flowering, diversity and height. These preferences were compared to those for a bare concrete roof. The potential restorativeness of the most preferred living roof and the concrete roof were also assessed. Results showed that all living roofs were preferred over the concrete roof; however preferences differed according to vegetation characteristics. The most preferred and restorative living roof had taller, green, grassy and flowering vegetation, while lower-growing red succulent vegetation was least preferred. Participants preferred a productive landscape, with green foliage and flowering consistently preferred. Participants with a stronger connection to nature consistently assigned higher preferences to taller, compared to lower-growing, vegetation. Increasing diversity was associated with higher preferences overall, but decreasing preferences for highly preferred vegetation. This research makes an important contribution to understanding employee preferences in the unique context of urban living roof landscapes.

1. Introduction

As a growing number of people live and work in cities, urban green space is likely to play an increasingly important role in promoting well-being (van den Berg, Maas, Verheij, & Groenewegen, 2010). However, increasing building density means that space for ground-level urban vegetation is becoming rarer (Wong, Tan, Tan, Sia, & Wong, 2010). In response, cities are incorporating innovative forms of green space (Thwaites, 2007), such as green or living roofs, that can be integrated into existing infrastructure. Although generally constructed for environmental benefits such as stormwater mitigation (Berndtsson, 2010) and increased building energy efficiency (Sailor, 2008), living roofs may also provide social benefits such as the psychological restoration associated with vegetation in other urban landscapes like parks (Nordh, Hartig, Hagerhall, & Fry, 2009).

Psychological restoration is important as it is associated with improved mood, cognitive functioning, stress levels, and health and well-being (cf. Kaplan & Kaplan, 1989; Tennessen & Cimprich, 1995; Ulrich et al., 1991). Psychological restoration can occur when viewing preferred vegetation for short periods of time and in very limited amounts (Kaplan, 1993, 2001; Nordh et al., 2009). As such, preference may be used as an implicit measure of a landscapes' restorative potential (Hartig & Staats, 2006; van den Berg, Koole, &

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van der Wulp, 2003). In cities, where contact with plants is often limited to nearby nature (Kaplan, 1993; Nordh et al., 2009) small pockets of urban green space in parks, on roofs or in streets are likely to become increasingly important for everyday restoration (Thwaites, Helleur, & Simkins, 2005).

Previous research has highlighted links between landscape preference and vegetation characteristics (Kaplan & Herbert, 1987; Misgav, 2000; Yuen & Hien, 2005). Preferences for landscapes are partly due to the physical characteristics of the vegetation such as foliage colour, vegetation height and density (e.g. Kendal, Williams, & Armstrong, 2008; Misgav, 2000; White & Gatersleben, 2011). Consequently, determining preference for vegetation characteristics will identify the features of highly preferred living roofs capable of providing restoration. Research identifying preferred vegetation on living roofs will support the design of living roofs that are more acceptable to the public, and provide greater psychological benefits.

Existing knowledge of preferred vegetation characteristics may not be applicable to predicting preferences for vegetation on living roofs because of horticultural constraints of living roofs. For example, evolutionary accounts of preference suggest our responses to landscapes reflect the extent to which their features would be able to support survival (Orians & Heerwagen, 1992; Ulrich, 1993). Green vegetation indicates sustenance, flowers indicate future resource potential, trees provide shelter and protection from predators and a short smooth grassy understory is easier to traverse and enables a view of potential threats (Kaplan & Kaplan, 1989; Orians & Heerwagen, 1992). Many preferred landscape characteristics such as moderate to high levels of visual openness, large trees and short, smooth ground cover are commonly used in ground level park design (Kaplan & Kaplan, 1989; Ulrich, 1986). However, tall trees and the high levels of irrigation required to maintain plant palettes traditionally used in ground-level landscapes are not feasible on many living roofs (Nagase & Dunnett, 2010). To date only a single study has been published on visual preferences for living roofs (White & Gatersleben, 2011). It showed that meadow roofs were more preferred than flowering red succulent roofs, green turf roofs and ecological brown roofs. A small set of follow-up interviews suggested that peoples' preferences were affected by features like perceptions of care and vegetation characteristics; however these were not systematically examined so it remains uncertain how these vegetation characteristics influence preference.

Existing knowledge of landscape preferences also has limited applicability to predicting preferences for living roofs because of the unique perspectives from which people view living roofs. Landscape preference is context dependent (Gobster, Nassauer, Daniel, & Fry, 2007; Purcell, Lamb, Mainardi Peron, & Falchero, 1994) and we cannot assume that patterns of preference for ground-level landscapes such as parks will apply equally to living roofs. Unlike ground-level landscapes, living roofs are integrated into the building fabric, are not necessarily accessible to people and may be viewed from different angles and distances (Dagenais, Gagnon, & Pelletier, 2009; Sang, Miller, & Ode, 2008). As a result, preferences based on traditional views of nature (Loder, 2007), may not apply.

Further research is required to identify preferences for vegetation characteristics which are common to plants able to be used on living roofs, and which may enhance the restorative potential of urban environments. Therefore, we conducted a preference study focusing on images that manipulated important plant characteristics such as life-form, foliage colour, flowering, vegetation height and diversity in an urban living roof context.

1.1. Preferences for visual characteristics of vegetation

Preferences for plant life-forms, or growth-forms, in living roof contexts have received little empirical attention. While trees, grasses and shrubs all influence preference in ground-level landscapes (Nordh et al., 2009), translating these preferences to living roofs is problematic as limited water availability due to shallow substrates and weight constraints restrict planting to lower-growing drought-tolerant succulents, woody herbs and grasses (Bousselot, Klett, & Koski, 2011; Nagase & Dunnett, 2010; Oberndorfer et al., 2007). A study on English residential living roofs revealed that grassy living roofs were more preferred than succulent living roofs (White & Gatersleben, 2011). However, these living roofs also differed non-systematically in foliage colour (green grass vs. red succulents) and vegetation height (taller grass vs. lower growing succulents), so it is difficult to ascertain the extent to which plant life-form influenced preference. Therefore, while we predict that grassy life-forms should be preferred over shrubby succulent life-forms overall, there is limited evidence to suggest how plant life-form will interact with other plant characteristics to influence preference.

Foliage colour also plays an important part in determining landscape preference (e.g. Kendal et al., 2008; Orians & Heerwagen, 1992; White & Gatersleben, 2011). However particular colour preferences vary based on the setting and vegetation type (cf. Hands & Brown, 2002; Kaufman & Lohr, 2004; Kendal et al., 2008). Research suggests that green vegetation is highly preferred, and perceived as beautiful (van den Berg et al., 2003), particularly in savannah and forest-like landscapes (Balling & Falk, 1982; Heerwagen & Orians, 1993). Green foliage is associated with preferred landscapes in different countries, landscapes and contexts (Balling & Falk, 1982) as it indicates landscape health (Orians & Heerwagen, 1992). We would expect that green-coloured foliage should also be highly preferred in a living roof context.

Flowering is also perceived as an indication of healthy, productive landscapes (Heerwagen & Orians, 1993). In addition to influencing preference (e.g. Jorgensen, Hitchmough, & Calvert, 2002; Kaplan, 2007; Kendal et al., 2008), cognition and well-being (Haviland-Jones, Rosario, Wilson, & McGuire, 2005; Todorova, Asakawa, & Aikoh, 2004), flowers may be perceived as cues of human care (Nassauer, 1995). Research indicates that flowers improve preferences across a variety of contexts (e.g. Akbar, Hale, & Headley, 2003; Kaplan, 2007; Lindemann-Matthies & Bose, 2007; Todorova et al., 2004) and so preferences for living roof plantings should be higher whenever flowers are present.

Like flowers and green foliage, height may act as an indicator of care and maintenance with shorter, smoother groundcovers looking neater than taller plantings (Kaplan & Kaplan, 1989; Nassauer, 1995; Todorova et al., 2004; White & Gatersleben, 2011). While very tall vegetation such as trees elicit consistently high preferences (Ulrich, 1986), they are not able to survive on extensive living roofs. This means that preferences for much shorter understory vegetation such as grasses and shrubs need to be considered. While neat vegetation like turf may be preferred by some, it has little ecological value (Gobster et al., 2007; Steinberg, 2005) and may even be perceived as a sign of a degraded landscape (Gobster, 1994; Nassauer, 1995). Conversely, messier plantings are generally perceived as more sustainable, and higher in ecological function (Gobster, 1994). This highlights a possible role for individual differences in determining preferences for lower-growing or taller vegetation based on the extent to which a connection to the landscape and its ecological function are valued.

In addition to vegetation characteristics, the structural composition of the landscape – including landscape diversity – is important in determining preference. Research indicates that moderately diverse landscapes are most preferred (Orians & Heerwagen, 1992; Ulrich, 1986); low diversity may be perceived as boring, whereas very high diversity may be confusing (Kaplan & Kaplan, 1989; van den Berg & van Winsum-Westra, 2010). Diversity can be assessed using vegetation characteristics as proxy indicators of diversity (Jorgensen & Gobster, 2010). For example, structural heterogeneity

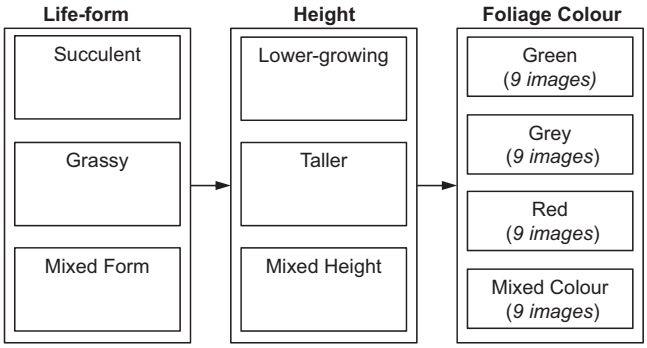

Fig. 1. Diagrammatic representation depicting how images were created by systematically varying vegetation characteristics across life-form (succulent, grassy or mixed form), vegetation height (lower-growing, taller or mixed height) and foliage colour (green, grey, red or mixed colour). Flowers were added to four of these images which were representative of different living roof types. An image of a standard bare concrete roof was also included. There were a total of 41 unique images.

(cf. Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007; Lamb & Purcell, 1990) and increasing amounts of foliage colour (cf. Hands & Brown, 2002) can improve preferences for landscapes. Therefore, we predict that moderate levels of diversity, meaning mixtures of several plant characteristics, should be preferred over living roofs with which lack diversity or are too highly diverse.

Based on existing research, we hypothesise that participants will prefer green, grassy vegetation, which is flowering and is moderately diverse. We also expect that participants' preferences for lower-growing or taller vegetation may vary according to their feelings about the maintenance or ecological functioning of the living roof vegetation. This may depend upon their attitudes towards, and feelings about, the natural environment.

2. Method

2.1. Photographic images

Participants were presented with a series of 41 different images of the same city scene with a living roof in the foreground. These were created using photo editing software to allow the manipulation of vegetation characteristics on the roof and to assess preference independent of extraneous factors such as weather conditions and background features. The angle and distance of viewing represented a view from a window.

The following vegetation characteristics were manipulated: plant life-form (succulent; grassy; mixed life-form), foliage colour (green; grey; red; mixed colour), vegetation height (lower, taller, mixed height) and diversity (none; low; moderate; high) (Fig. 1). Flowers were also added to a subset of four images with a mixed range of heights, life-forms, colours and diversity. In the images depicting diverse vegetation, the pattern and proportion of each colour, height and plant species were matched as closely as possible (via a masking and layering procedure), while still keeping the images realistic. Vegetation density, colour hue and saturation were replicated as closely as possible across all images. In addition to the living roof images, an image of a bare concrete roof was created.

2.2. Preference survey

2.2.1. Participants

274 employees of several large organisations in Melbourne, Australia (73% female; mean age = 40 years; 77% full time employed; 82.3% ≥ Bachelor degree) participated in this study. All participants were office workers based in Central Business District (CBD) locations. Participants were recruited via advertisements placed in the organisations' electronic newsletters and via e-mail contact lists.

2.2.2. Procedure

Participants accessed the survey by clicking on a web link provided in an e-mail advertisement. Participants could complete the survey at any time of the day and in any location. The link remained active for three-weeks.

Participants were presented with the project aims, scope and requirements of the survey. Instructions were provided along with a selection of thumbnail images selected to represent different levels of the vegetation characteristics (Fig. 2). These were provided so that participants were able to consider the range of different images included in the survey prior to providing preference scores. Following this, the survey images, appearing at full screen size to represent a window view, were presented consecutively in a randomised order and participants were asked 'How much would you like to have this view from your office?' Participants responded by indicating the appropriate number on the scale (1 = *not at all*; 10 = *very much*). If participants missed rating any of the images they were reminded that the question remained unanswered, but were still able to proceed to the next page if they chose not to rate the image. Pilot testing revealed that the taller green grassy image was highly preferred, while the concrete image received low preference ratings. Therefore for these two images participants were also asked to indicate the restorative potential of the living roof by responding to the question, "To what extent do you feel that you would be able to rest and recover your attention while looking at this view?" Participants responded by clicking the appropriate number on the scale (1 = *not at all*; 10 = *very much*).

After viewing all images participants completed the Connectedness to Nature Scale (CNS; Mayer & Frantz, 2004), provided some general information about their knowledge of living roofs and demographic information (i.e. age, gender, highest education level, and employment status). The CNS measures emotional connections and attitudes to nature with 14 statements such as 'I often feel a sense of oneness with the natural world around me'. It was included as a control variable as differences in environmental attitudes have been shown to influence landscape preferences (e.g. Kaltenborn & Bjerke, 2002; Rauwald & Moore, 2002) and may differentiate between participants who prefer manicured or more natural landscapes. Participants responded by clicking on the appropriate number on a 5-point Likert scale (1 = *strongly disagree*; 5 = *strongly agree*) according to how they generally felt. Items 4, 12 and 14 were reverse-scored. The scale demonstrated good reliability with Cronbach's alpha at .81. The online survey took approximately 20 min to complete.

2.3. Data analyses

Graphical inspection of histograms and *p–p* plots and transformation of skewness values to *Z*-scores revealed that preferences for several images were negatively skewed. However, square-root transformation of variables did not alter the substantive interpretation of the results, so the original variables were retained. Two unusual cases where subjects seemed to be responding indiscriminately with no variation in scores were identified. These cases were removed from further analyses. Although 21 missing cases were identified on the CNS scale, missing value analysis revealed no patterns of missing data which was spread across all items on the scale. Therefore, all participants with ≤2 missing values on the CNS scale were included in the final analyses. This meant that 272 surveys were used in the final analyses. For each test, the assumption of homogeneity of variances was assessed. Where this assumption

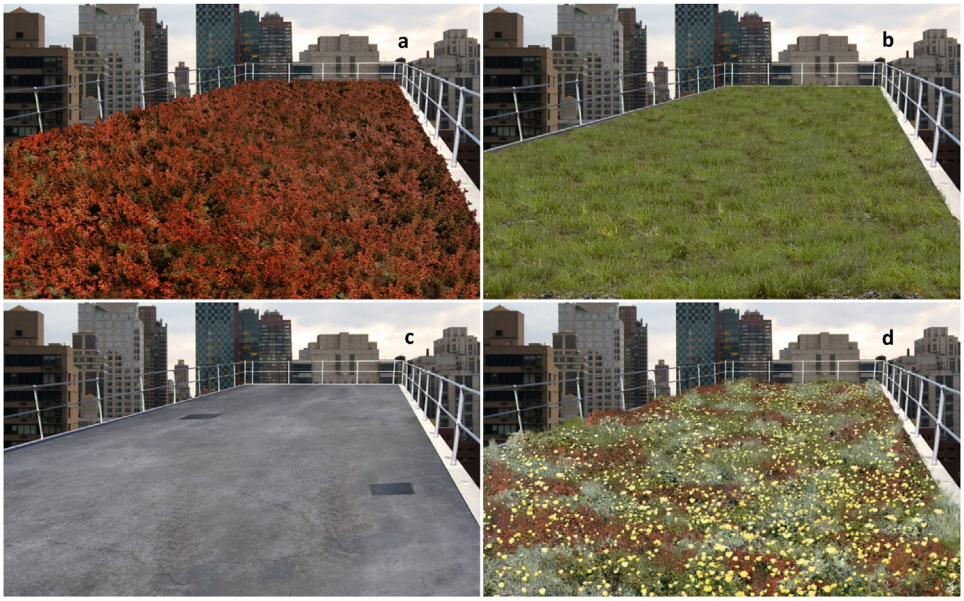

Fig. 2. A representative selection of the 41 different living roof images used in the survey, showing (a) taller, red, succulent vegetation, (b) lower-growing, green, grassy vegetation, (c) a bare concrete roof, and (d) mixed height, colour and form, flowering vegetation. A selection of thumbnail images were provided at the start of the survey so that participants were aware of the range of vegetation characteristics included in the survey before providing preference scores.

was violated, the Greenhouse–Geisser correction was applied and reported.

Preference scores for the concrete image and flowering images, as well as the restoration question were not normally distributed. Square-root and logarithmic transformations were not able to correct the spread of these variables. Therefore, separate non-parametric Wilcoxon Signed Ranks Tests were conducted to assess differences in overall preferences for vegetated compared to non-vegetated images, to compare results for images with and without flowers and to compare perceived restorativeness between the taller green grassy living roof image and the concrete image.

To assess preferences for overall diversity, separate variables were created by combining preference scores for images with similar levels of diversity. Images with no diversity – that is, all one colour, one height and one life-form made up the no-diversity level ($N = 12$). Images with one mixed characteristic formed the low diversity variable and could occur either as mixed colour, mixed height or mixed life form ($N = 16$). The third diversity variable – moderate diversity – was made up of images with two mixed height, life-form or foliage colour characteristics ($N = 7$). In the high diversity variable, all plant characteristics were varied; that is, the image comprised mixed foliage colours and mixed heights of mixed life forms ($N = 1$).

Preferences for diversity of each of the plant characteristics were created by combining preferences for images depicting diversity in life-form ($N = 12$), diversity in foliage colour ($N = 9$) and diversity in height ($N = 12$). While the mixed colour variable was negatively skewed, square-root transformations did not alter the substantive interpretation of results. Therefore, analyses were conducted on the untransformed data.

To explore the influence of diversity on preferences for the taller green grassy living roof, we compared it against preferences for images of this living roof with increasing levels of diversity. Images with one mixed characteristic formed the low diversity variable ($N = 3$), images with two mixed characteristics formed the moderate diversity variable ($N = 3$) and the image with three mixed characteristics formed the high diversity variable ($N = 1$). *Z*-score transformations revealed that several diversity variables were negatively skewed. Therefore the negatively skewed variables were reflected and a square-root transformation was applied to all diversity variables. Descriptive statistics are presented using the original variables, while all significance values are reported using the transformed variables. Initially CNS was included in all diversity models. However, as it did not contribute significantly to the models or change their substantive interpretation, it was removed from the analyses.

2.3.1. Statistics

The results were analysed using a $2 \times 3 \times 2$ within-subjects analysis of covariance. The within-subjects factors were plant life-form (succulent, grassy), foliage colour (green, grey, red) and vegetation height (lower-growing, taller); the covariate was each respondent's mean centred average CNS score. As CNS did not interact with diversity, overall diversity and diversity for the taller green grassy living roof were analysed using one-way within-subjects analyses of variance with four levels of diversity. Preferences for diversity of plant characteristics were analysed using a one-way analysis of variance with three levels of diversity. Analyses were conducted through the General Linear Model in SPSS.

3. Results

As expected, a Wilcoxon Signed Ranks Test revealed that all living roof images ($Mdn = 6.44$) were preferred over the image of the concrete roof ($Mdn = 1.00$) ($Z = -14.00$, $p < 001$). Further analyses were then conducted to examine how preferences varied according to vegetation characteristics across different types of living roofs.

3.1. Preferences according to life-form, vegetation height and foliage colour

Living roof preferences differed significantly across the levels of life-form, foliage colour and vegetation height when mean centred connectedness to nature (CNS) was controlled for in the model. While there was an overall main effect of CNS, $F(1, 269) = 9.37$, $p = .002$, Partial $\eta^2 = .034$, such that increasing CNS scores were associated with higher preference ratings, CNS did not significantly interact with plant life-form, $F(1, 269) = .67$, $p = .41$, or foliage colour, $F(1.73, 466.55) = .89$, $p = .40$, but did interact with preferences for vegetation height, $F(1, 269) = 7.26$, $p = .008$, Partial $\eta^2 = .26$.

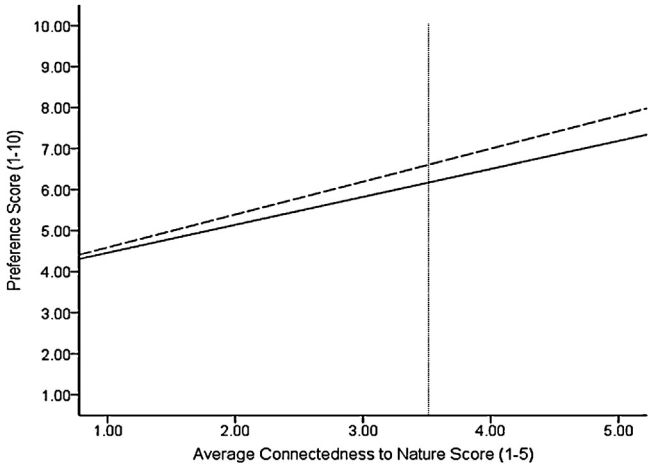

Fig. 3. Interaction between preferences for vegetation height and participants' scores on the Connectedness to Nature Scale (CNS) (dashed line = taller vegetation; solid line = lower vegetation). Preferences were recorded on a Likert scale (1 = *not at all*; 10 = *very much*) and indicate how much respondents would like to have that view from their window. Responses on the CNS were also recorded on a Likert scale (1 = *strongly disagree*; 5 = *strongly agree*). Although preference scores for the taller vegetation were higher on average than those for lower vegetation, the Johnson–Neyman procedure revealed that for those scoring ≥3.46 out of 5 on the CNS, this difference was consistent, whereas for those scoring < 3.46, increasingly lower scores are associated with less difference between preference scores across vegetation height ($p < .05$).

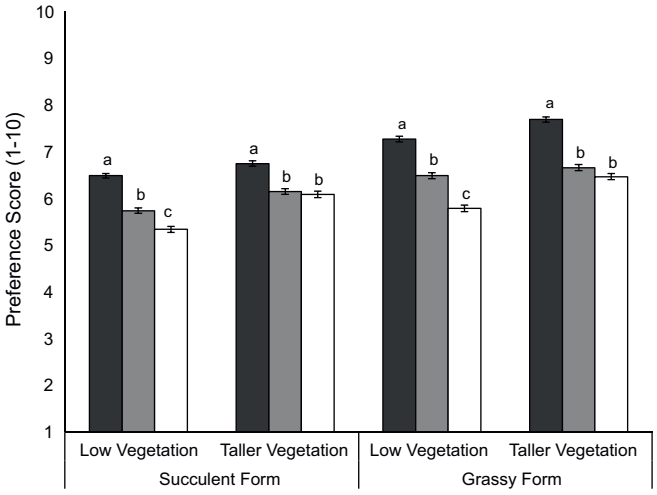

Fig. 4. Preference scores (mean ± *S.E.*) for living roofs which differed according to their vegetative forms (succulent or grassy), height (lower-growing or taller) and foliage colour (green, grey or red). Preferences were recorded on a Likert scale (1 = *not at all*; 10 = *very much*) and indicate how much respondents would like to have that view from their window. Black bars indicate green foliage, grey bars indicate grey foliage and white bars indicate red foliage. Different lowercase letters indicate significant pairwise differences with a Bonferroni correction within foliage colour and life-form.

An exploration of this interaction using the Johnson–Neyman procedure in SPSS using MODPROBE (Hayes, n.d.), with the data restructured in long form revealed that those with a stronger connection to nature provided consistently higher preferences for taller vegetation compared to lower-growing vegetation (Fig. 3). However, for those with CNS scores ≤3.46, increasingly lower scores on the CNS were associated with less distinction in preferences between lower-growing and taller vegetation.

Living roof preferences significantly differed between plant life-form, $F(1, 269) = 106.95$, $p < .001$, Partial $\eta^2 = .28$, with grassy life-forms ($M = 6.76$, *S.E.* = .10) preferred over shrubby succulent forms ($M = 6.12$, *S.E.* = .11). Living roof preferences also significantly differed between foliage colours, $F(1.73, 466.54) = 81.64$, $p < .001$, Partial $\eta^2 = .23$, with green foliage ($M = 7.07$, *S.E.* = .10) preferred over grey ($M = 6.30$, *S.E.* = .11; $F(1, 269) = 110.53$, $p < .001$, Partial $\eta^2 = .29$) and red foliage ($M = 5.95$, *S.E.* = .13; $F(1, 269) = 115.69$, $p < .001$, Partial $\eta^2 = .30$). Finally, living roof preferences significantly differed according to vegetation height, $F(1, 269) = 106.75$, $p < .001$, Partial $\eta^2 = .28$, with taller vegetation ($M = 6.66$, *S.E.* = .10) preferred over lower-growing vegetation ($M = 6.22$, *S.E.* = .10) particularly for participants scoring >3.46 on the CNS. However, these main effects were qualified by a significant 3-way interaction, $F(2, 538) = 3.74$, $p = .024$, Partial $\eta^2 = .014$ between plant life-form, foliage colour and vegetation height which was consistent across all CNS scores.

3.1.1. Planned comparisons assessing preferences between living roof images

Looking at the mean preference scores across each living roof image, we found that these scores followed patterns predicted by conditional main effects (Fig. 4). This meant that the living roof with a grassy life-form, taller height and green vegetation received the highest preference score. Conversely, the least preferred living roof consisted of lower-growing red succulent vegetation.

For living roofs with green foliage, preference scores across both succulent and grassy life-forms were higher for the taller vegetation compared to the lower-growing vegetation as revealed by planned contrasts with a Bonferroni correction. For lower-growing succulent and grassy vegetation, green foliage was significantly preferred over grey foliage which was more preferred than red foliage. For taller succulent and grassy vegetation, green was still the most preferred foliage colour; however there was no significant difference in preference for grey and red foliage. In addition, preferences for grey foliage did not significantly differ across vegetation height.

3.2. Preferences for flowering living roofs

All flowering living roof images were significantly more preferred than the original non-flowering living roof vegetation (Table 1), as indicated by a Wilcoxon Signed Ranks Test correcting for four comparisons ($\alpha = .013$). All flowering living roofs received median preference scores one-point higher than the original non-flowering image. The most preferred flowering living roof consisted of vegetation with taller green foliage and a grassy life-form, which replicates findings for the non-flowering living roof images.

3.3. Preferences for diversity on living roofs

Level of diversity on the living roof significantly influenced preference scores, $F(1.36, 366) = 25.62$, $p < .001$, Partial $\eta^2 = .09$. Overall, moderate levels of diversity ($M = 6.70$, *S.E.* = .11) were preferred over no diversity ($M = 6.44$, *S.E.* = .10), $F(1, 270) = 26.83$, $p < .001$, Partial $\eta^2 = .09$, and low diversity ($M = 6.50$, *S.E.* = .10), $F(1, 270) = 39.17$, $p < .001$, Partial $\eta^2 = .13$, living roofs. However, the highly diverse living roof ($M = 6.81$, *S.E.* = .14) was, in turn, significantly more preferred than moderately diverse living roofs, $F(1, 270) = 12.81$, $p < .001$, Partial $\eta^2 = .05$.

Further comparison of preferences for diversity revealed significant differences across plant characteristics, $F(1.15, 311.06) = 24.53$, $p < .001$, Partial $\eta^2 = .08$. Within-subjects contrasts revealed that mixed foliage colour ($M = 6.85$, *S.E.* = .13) was significantly more preferred than mixed form ($M = 6.47$, *S.E.* = .11), $F(1, 271) = 31.39$, $p < .001$, Partial $\eta^2 = .10$, and mixed height ($M = 6.58$, *S.E.* = .11), $F(1, 271) = 16.75$, $p < .001$, Partial $\eta^2 = .06$.

Conversely, preferences for the taller, green grassy living roof image ($M = 7.69$, *S.E.* = .11) significantly decreased with low levels

Table 1
Mean (±*S.E.*) and median preference scores for flowering living roof images. Preferences were recorded on a Likert scale (1 = *not at all*; 10 = *very much*) and indicate how much respondents would like to have that view from their window. A priori comparisons using Wilcoxon's signed ranks test (*Z*) indicate significant differences in preferences. Negative *Z* values indicate higher preference scores for flowering living roof images.

Vegetation characteristics	No flowers		Flowers		*Z*	*p*
	Mean (±*S.E.*)	Median	Mean (±*S.E.*)	Median		
Taller green grassy	7.68 (.11)	8.00	8.54 (.10)	9.00	−7.69	<.001
Mixed height green succulent	6.97 (.13)	7.00	7.99 (.11)	8.00	−8.95	<.001
Low-growing mixed-coloured grassy	6.82 (.13)	7.00	7.65 (.14)	8.00	−8.14	<.001
Mixed height, mixed coloured, mixed form	6.81 (.14)	7.00	7.74 (.13)	8.00	−8.75	<.001

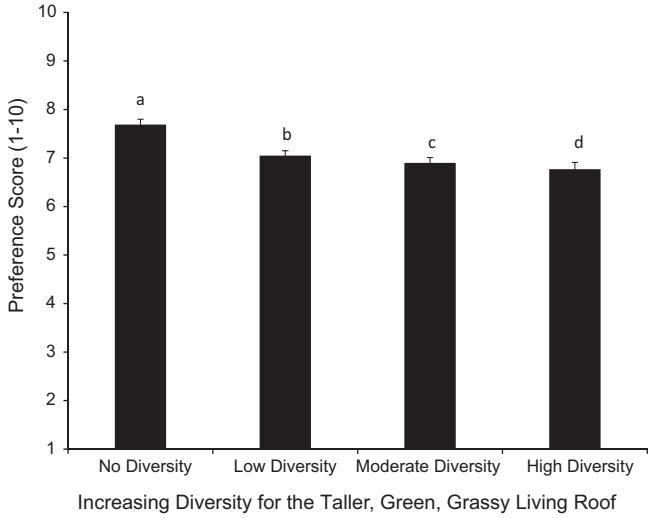

Fig. 5. Preference scores (1 = *not at all*; 10 = *very much so*) for images depicting increasing levels of diversity for the taller green grassy living roof indicate how much respondents would like to have that view from their window. Images depicted either no diversity, or diversity in one (low), two (moderate), or three (high) different plant characteristics. Standard error bars are shown for each group. Lowercase letters denote differences between diversity groups.

of diversity ($M = 7.05$, $S.E. = .10$), $F(1, 271) = 67.90$, $p < .001$, Partial $\eta^2 = .20$, moderate diversity ($M = 6.90$, $S.E. = .11$), $F(1, 271) = 44.27$, $p < .001$, Partial $\eta^2 = .14$, and high diversity ($M = 6.77$, $S.E. = .14$), $F(1, 271) = 32.85$, $p < .001$, Partial $\eta^2 = .11$ (Fig. 5).

3.4. Restorative value of the concrete roof and the most preferred living roof

The potential restorative value of the concrete roof and the most preferred living roof was assessed based on participant responses to the question "To what extent do you feel that you would be able to rest and recover your attention while looking at this view?" Participants believed that they would be significantly more likely to be able to rest and recover their attention while looking at the living roof with taller flowering green grassy vegetation ($Mdn = 9.00$) compared to looking at the view with the concrete roof ($Mdn = 1.00$) ($Z = -14.25$, $p < .001$). These results were obtained using a Wilcoxon Signed Ranks Test.

4. Discussion

While all living roof images were more preferred than a bare concrete roof, there were significant and meaningful differences between different types of living roof vegetation. As predicted, plant life-form, foliage colour and vegetation height influenced preference across all living roof images, such that a tall, grassy life-form and green foliage were most preferred. Higher preferences for grassy life-forms were more pronounced in combination with green foliage, which is similar to preferences for meadow roofs in English residential settings (White & Gatersleben, 2011). Although no studies have specifically examined preferences for different types of grasslands, evolutionary accounts of preference demonstrate that even though preferences for savannah landscapes with scattered trees and an easy-to-traverse grassy understory are highly preferred (Kaplan & Kaplan, 1989; Kaplan, 1987; Orians & Heerwagen, 1992; Ulrich, 1983), flat grassy areas tend to be much less preferred (Kaplan, 1983). However, our results suggest that in an elevated urban environment, with height provided by surrounding buildings, defined areas of grassy vegetation alone can be highly preferred. Establishing the taller green grassy vegetation typically used for ground-level greening on living roofs may be difficult due to limited water availability in shallow substrates. In an effort to expand current living roof plant palettes, recent research has identified and tested novel plant groups including grass-like monocots which grow in habitats with similar conditions to those found on living roofs (Farrell, Szota, Williams, & Arndt, 2013). This avenue of research provides a promising option for creating visually preferred living roofs, which can also provide important restorative and environmental benefits.

Exploring preferences for vegetation height revealed an important link with participants' connection with nature. While those with stronger connections provided higher preference scores across all images, they also tended to distinguish between higher and lower-growing vegetation more than those with weaker connections with nature. That is, those reporting progressively lower scores on the CNS were more likely to assign increasingly similar preference ratings across images regardless of vegetation height. Feelings of connectedness with nature, such as "a sense of oneness" or community with the natural world (Mayer & Frantz, 2004), have not yet been examined in the context of landscape preference. This finding may help account for discrepant results in previous studies such as White and Gatersleben (2011) where the issue of vegetation height polarised interviewees. Their research revealed that lower-growing vegetation was viewed as either "neat" or "boring" and taller vegetation was labelled either more "natural" or "messy" (p. 95). Alternatively, those with a higher emotional connection with nature may be responding to the perceived ecological functioning of the living roof vegetation. That is, they may be distinguishing more between lower vegetation – viewed as having less ecological value – and taller vegetation – viewed as being more natural and providing greater ecosystem services (Gobster, 1994). This research highlights a possible role for connections to nature in predicting landscape preferences and is an avenue for future research.

Participants also seemed to value landscape health, as high preferences for green vegetation and flowering were found for all living roof images. This is consistent with previous research (Akbar et al., 2003; Balling & Falk, 1982; Orians & Heerwagen, 1992; Todorova et al., 2004). Lower preferences for grey foliage and red foliage in spite of previous research showing preferences for grey foliage for hedges (Kendal et al., 2008) and red foliage for trees (Kaufman & Lohr, 2004) may reflect participants' perception of plant stress (Grant, 2006) or poor landscape conditions (Williams & Cary, 2002) or alternatively, the context specificity of landscape preference (cf. Gobster et al., 2007; Purcell et al., 1994). Although flowering

presents a practical problem for living roof plants as it is heavily tied with seasonality (Todorova et al., 2004), this research highlights the importance of maximising flowering across the year. This may be achieved by using plant palettes with summer, autumn and spring flowering species (Dagenais et al., 2009) as found in wildflower meadows.

Complexities arose when exploring diversity, with higher levels of diversity preferred overall, but preferences for the taller green grassy living roof decreasing with higher levels of diversity. Preferences for high diversity over moderate diversity was somewhat surprising considering research suggesting highly diverse landscapes may be perceived as confusing (Kaplan & Kaplan, 1989; van den Berg & van Winsum-Westra, 2010), however effect sizes for differences in preference were relatively small overall, accounting for less variance in participant responses than other vegetation characteristics. Researchers looking at preferences for meadow vegetation in Switzerland (Lindemann-Matthies & Bose, 2007; Lindemann-Matthies, Junge, & Matthies, 2010) have, however, found that participants tended to prefer – and design for – high levels of species diversity, landscape structure and colour. When looking at diversity preferences for each of these vegetation characteristics, participants preferred mixed foliage colour over mixed life-form and mixed vegetation height. This is consistent with Hands and Brown (2002) who found that preferences for ecological rehabilitation sites improved with increasing amounts and diversity of foliage colour.

Contrary to the overall preference for high diversity, participants assigned the taller green grassy living roof lower preferences with increasing diversity. Even though very low levels of diversity can be perceived as boring (Kaplan & Kaplan, 1989; van den Berg & van Winsum-Westra, 2010), this preference may reflect the novel elevated context of living roofs and the highly complex nature of the urban vista (Ulrich, 1993). This suggests opportunities for creating living roofs which can provide visual relief in cities. Although the most preferred living roof vegetation showed no diversity in plant characteristics, species richness can be incorporated by using different plant species which are similar in life-form, height and foliage colour. Species rich living roofs have important environmental benefits and can enhance urban biodiversity values and improve stormwater mitigation (Berndtsson, 2010; Brenneisen, 2006; Oberndorfer et al., 2007). However, for the least preferred living roofs, incorporating a diversity of life-form, foliage colour and height may help improve preferences and in turn, their public acceptability (Jorgensen & Gobster, 2010).

This study is one of the few examining preferences for succulent life-forms. Succulents received lower preferences than grassy life-forms, which mirrors findings from a study of living roofs on English residential buildings (White & Gatersleben, 2011). Together these findings suggest that low preferences for succulents in a living roof context may be common across nationalities, living roofs and building types. As we did not specifically examine succulents per se, but shrubby succulent-like life-forms, these results extend previous research and suggest that lower preferences may also be assigned to plants with similar shrubby life-forms. To enhance public acceptability of succulent or shrubby living roofs, landscape architects could consider important landscape characteristics such as flowering and increasing diversity.

In addition to enhancing public acceptability, designing highly preferred living roofs may provide opportunities for cognitive restoration. Participants' reports that views of the taller, flowering, green, grassy image would enable them to rest and recover their attention supports findings from Loder (2010). This cross-sectional study of over 900 employees in America and Canada revealed that views of living roofs influenced employees' perceived ability to concentrate. Attention Restoration Theory (Kaplan & Kaplan, 1989) and Psycho-Evolutionary Theory (Ulrich, 1983; Ulrich et al., 1991) suggest that views of preferred vegetation promote psychological and physiological restoration. In turn, this may influence employee outcomes like mood, stress, fatigue and cognitive performance (cf. Kaplan & Kaplan, 1989; Tennessen & Cimprich, 1995; Ulrich et al., 1991). However, these theories have not yet been studied in the context of living roofs and have had limited applicability across organisational settings. This is an important area for future research and has implications for healthy workplace design as well as for designing healthy and sustainable cities.

The results of this study show that preferences for living roof vegetation are influenced by vegetation characteristics and diversity. It should be noted, however, that the images used in this study depicted a single viewpoint. Not all living roofs will be viewed from this angle, at this distance on a CBD building, although the broad preference for meadow-style living roofs has also been identified in English residential settings (White & Gatersleben, 2011). In addition, it is in such dense CBD settings where living roofs are most likely to have the greatest benefits for people overlooking them. As such, CBD office workers were identified as the ideal participants for this study. However, it should be noted that overall, participants were highly educated, largely female employees from large organisations and this should be taken into account when interpreting these results.

5. Conclusion

Our research provides a new perspective on living roof vegetation preferences and further highlights their potential psychological benefits. It provides evidence-based criteria for designing highly preferred living roofs and suggests desired plant characteristics that can be implemented across different vegetation types, living roofs and climates. Our study builds on ground-level preference and landscape aesthetics research and adds to the existing research on living roof preferences. These findings extend evolutionary accounts of preference to a novel and elevated urban landscape, suggesting new directions for future urban greening research. Possible links with human well-being can provide new drivers for implementing living roofs as a source of readily accessible vegetation for urban employees. Visual access to living roof vegetation through window views has the potential to provide psychological restoration, improve mood and attention and reduce stress which has implications for workplace performance. Creating visually preferred living roofs is also likely to enhance their public acceptability and contribute to the growth and direction of the living roof industry.

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