

Architectural variation, building height, and the restorative quality of urban residential streetscapes

Pall J. Lindal^{a,*}, Terry Hartig^b

^a Faculty of Architecture, Design & Planning, University of Sydney, Sydney, NSW, Australia

^b Institute for Housing and Urban Research, Uppsala University, Sweden

ARTICLE INFO

Article history:

Available online 3 October 2012

Keywords:

Attention restoration theory
Complexity
Enclosure
Multiple mediation analysis
Urban densification

ABSTRACT

With increasing urban densification, built environments that can promote restoration will become more important. Well-designed residential streetscapes might support restoration, but little research has considered the physical attributes that matter in this context. Taking guidance from research on environmental preferences, the present study considers the effects of entropy (aggregate architectural variation) and building height on judgments of restoration likelihood for urban residential streetscapes. Physical attributes of buildings (roofline silhouette, surface ornamentation, number of floors) were systematically manipulated in 145 computer-generated images of residential streetscapes. In a web-based procedure, participants ($N = 263$) in each of several independent groups rated the streetscapes on one of several psychological variables, including being away, fascination, restoration likelihood and preference. Multiple mediation analysis used the images as units of analysis, with the respective group mean scores on the psychological variables as the data for the images. The effect of entropy on restoration likelihood was positive, whereas the effect of building height was negative. Being away and fascination together fully mediated the effects of entropy on judgments of restoration likelihood. The effect of building height was only partially mediated, and then by being away and not fascination. The results provide guidance for the design of more psychologically sustainable urban residential environments.

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1. Introduction

Significant research attention has been directed to the kinds of environments that support psychological restoration. Scholars have mainly focused on the restorative advantages of natural versus urban environments (e.g., Hartig, Mang, & Evans, 1991; Ulrich et al., 1991). Such research has however often treated “natural” and “urban” as global, undifferentiated environmental categories (cf. Velarde, Fry, & Tveit, 2007). Several studies have considered the restorative potential of more specific urban settings and offered a more positive view of possibilities for restoration in the urban context (e.g., Hartig, Korpela, Evans, & Gärling, 1997; Herzog, Maguire, & Nebel, 2003; Hidalgo, Berto, Galindo, & Getreivi, 2006; Nasar & Terzano, 2010; Staats, van Gemerden, & Hartig, 2010; White et al., 2010). To date, however, research has not adequately addressed how specific architectural characteristics of urban residential settings might serve psychological restoration. Further

research on this topic is needed, as a large and growing number of people worldwide must satisfy their everyday needs for restoration in and around an urban residence.

The present study addresses this research need. It considers how specific physical attributes of urban residential streetscapes might be varied through design to enhance possibilities for restorative experiences. The physical attributes in focus are the roofline silhouette, surface ornamentation, and height of buildings. We selected these physical attributes for two main reasons. First, they have immediate practical relevance for a contemporary urban design challenge: increasing residential densities while maintaining livability (cf. van den Berg, Hartig, & Staats, 2007). Second, previous research suggests that these physical attributes affect environmental preferences (e.g., Stamps, 1999a, 1999b, 2005a). Given the strong associations found between environmental preferences and aspects of restorative experience (e.g., van den Berg et al., 2007; Korpela & Hartig, 1996), we anticipate that the chosen physical attributes will affect assessments of restorative quality.

In the following, we first provide some background on restorative quality. We then elaborate on our rationale for the selection of

* Corresponding author. Tel.: +46 7 3333 5526.

E-mail address: pall.jakob.lindal@gmail.com (P.J. Lindal).

the physical attributes as we lay out the conceptual model tested in the empirical work.

1.1. Restorative quality in environments

Restoration involves the renewal of physical, psychological, and/or social resources diminished in ongoing efforts to meet everyday demands (Hartig, 2004). Restoration has come into focus in research on environment, behavior and design because of its significance for adaptation and health. Without sufficient restoration, conditions of resource inadequacy may become chronic, and this can entail negative consequences for effective functioning, well-being, and health (Hartig, 2007).

To understand how features of the built urban environment might affect psychological restoration, the present study draws on attention restoration theory (ART) (Kaplan & Kaplan, 1989; Kaplan, 1995). The theory is concerned with a capacity to direct attention, which is a cognitive resource required for effective functioning in contemporary urban societies. People commonly rely on this resource in daily life, as in performing paid work, wayfinding, and monitoring the behavior of others. Directing attention involves the effortful inhibition of other, more appealing or interesting stimuli. When exercised over time, the inhibitory mechanism on which directed attention depends is assumed to become fatigued. This attentional fatigue can entail a variety of problems, such as ineffective work performance, failure to pick up important cues on appropriate behavior, and increased irritability.

To mitigate attentional fatigue, ART proposes that people can benefit from entering situations characterized by four restorative qualities. *Being away* involves a sense of distance from daily routines and the projects that require directed mental activity. *Fascination* refers to an effortless form of attention engaged by features of the environment or exploration of the environment. *Extent* refers to the scope for involvement with the environment as well as the degree of coherence and order in the environment; the person should be able to explore without getting lost or confused. *Compatibility* refers to the degree to which the environment supports the person's activities; it concerns the match between what the person wants to do, can do, and must do. Theoretically, all four qualities or components of the restorative experience can be described as mediators of the relationship between the physical environment and restoration (e.g., Hartig, Kaiser, & Bowler, 1997). Following the approach used by Nordh, Hartig, Hagerhall, and Fry (2009), however, the present study focuses only on being away and fascination.¹ We assume that being away and fascination are influenced by physical attributes of the environment, and that they in turn affect a person's judgments about the likelihood of restoration in an environment that he or she could choose to pass through.

1.2. Selection of physical attributes relevant for restorative experience

Much research has considered characteristics of urban environments that can hinder restoration, such as variation in sound (e.g., Evans & Cohen, 1987). Few studies have directly addressed physical characteristics of built urban environments that positively

affect restorative experience (e.g., Hidalgo et al., 2006). Many studies have however assessed people's preferences for different built urban environments. Preference is strongly associated with judgments of restoration likelihood, at least for some categories of environments, such as urban parks (Nordh et al., 2009). Also, some research has described restoration as a mediator between the physical environment and preference (Hartig & Staats, 2006; Staats & Hartig, 2004; Staats, Kieviet, & Hartig, 2003; van den Berg, Koole, & van der Wulp, 2003). These results suggest that the literature on preferences for urban environments can provide guidance in the identification of physical attributes that affect restorative experience in urban settings.

In the following, we consider three physical attributes of the urban environment that research has found to be related to preferences, and so which can be considered for their effects on perceived restorative qualities such as being away and fascination and in turn the likelihood of restoration seen in a given environment. The three physical attributes are the number of turns in the building silhouette, the amount of façade ornamentation, and building height (number of floors); research suggests that these attributes indirectly affect preferences through their effects on two perceptual variables, complexity and enclosure (e.g., Stamps, 1999a, 2005b).

1.2.1. Architectural variation, perceived complexity, and preference

Complexity has been defined variously as the number of elements present in a scene (e.g., Herzog, Kaplan, & Kaplan, 1982) and more particularly as the "noticeable difference" between elements (Rapaport & Hawkes, 1970, p. 109). In their analysis of environmental preferences, Kaplan and Kaplan (1982) propose that people have an innate need to be involved in the environment, meaning that they gather information which they can then make sense of and integrate into mental representations that support effective functioning. In their framework, the complexity perceived in a scene is considered an important determinant of preference because it encourages exploration and offers immediate involvement with the environment.

Studies on complexity and preference for natural and/or urban scenes have however reported mixed results, ranging from weakly negative to strongly positive (Stamps, 2004), with some results showing an inverted-U relation (e.g., Imanoglu, 2000) and others a positive linear one within content categories (e.g., Kaplan, Kaplan, & Wendt, 1972). One reason for the inconsistency may have to do with differences in the range of complexity captured with the different stimulus sets. For example, if the stimuli capture only low to moderate levels of complexity, then the uncovered relationship may be linear and positive, but if the stimuli capture a broader range of complexity, then the relationship may be an inverted-U. Aside from differences in the characteristics of the stimuli used in different studies, Herzog (1989) suggested that the lack of a clear definition of complexity could explain the inconsistency in results concerning the relationship between complexity and preference.

Stamps (1999a) pointed out that terms used to describe complexity in the urban environment, such as visual richness and diversity, are vague, and he considered low-level geometrical concepts to be more appropriate for representing complexity in design. Such concepts can be applied to the silhouette and surface features that affect the level of complexity perceived in a building façade. Stamps (1999a) claimed that both silhouette and surface features reliably influence visual preference through perceptions of complexity. In the following, we review literature concerning the effect of silhouette and surface attributes on perceived complexity, and in turn on preferences.

1.2.1.1. Variation in the silhouette. Researchers have long considered the number of turns in a form's silhouette, or the number of

¹ As we will explain later in the paper, we understood that features of the study set-up, visual stimuli, and instructions to participants would limit variability in extent and compatibility. Anticipating problems with estimation due to range restriction, and following the example of Nordh et al. (2009), we chose to not include those measures in our model tests. By not including measures of these variables, we also simplified data collection.

points that construct a geometric shape, to be predictive of subjective responses (Attneave, 1957). Studies have shown that perceived complexity is strongly positively associated with the number of turns in skyline silhouettes (Heath, Smith, & Lim, 2000; Nasar & Terzano, 2010; Stamps, 2002, 2003). Stamps (1999a) compared preferences for building façades with different shapes and concluded that façades with five turns were preferred over those with four turns. Although in this latter study Stamps did not formally test whether perceptions of complexity mediated the relationship between number of turns in the silhouette and preference, the pattern of relationships seen across the studies indicates that this is a plausible model.

1.2.1.2. Variation in surface features. Stamps (1999b) argued that the physical determinants of surface complexity can be represented in a clear and objective way by utilizing the theory of visual perception developed by van der Laan (1983). Accordingly, he proposed that elements with lengths of 1/7–1/49 of the façade length would be perceived as surface details. He also claimed that increasing the amount of the area of the building façade covered by elements within the length of 1/7–1/49 of the façade length would increase the perceived surface complexity (Stamps, 1999a). He found that perceived surface complexity increased with increased window and door trims and ornaments that fit within these size ranges (Stamps, 1999b). In other work, Stamps (1999a) found that building façades with shingles, one ornament, cornice and door and window trim were preferred over façades without those elements; however, this work did not check whether the relationship between physical attributes and preference was mediated by perceived complexity (Stamps, 1999a).

1.2.1.3. Entropy. To this point we have not referred to the spatial differentiation of the urban environment. When people move through an urban residential area, however, they commonly pass along a series of blocks, covered to varying degrees by buildings and bordered by streets. The block thus seems to be an appropriate visuo-spatial unit of analysis when considering design variables that might influence the perception of urban residential environments. However, in terms of perceived complexity, ratings of residential blocks may provide different results compared to ratings based on individual buildings within those blocks. For example, a block which consists of a number of identical buildings may be perceived as uniform, even though each building alone may have a highly complex appearance. On the other hand, if a block consists of buildings that all differ from one another, it may be perceived as highly complex and heterogeneous, even if each individual building has a plain appearance.

To deal with this issue, Stamps (2002) recommended the assessment of entropy. Entropy is a mathematical formulation which aggregates objective variations that provide a basis for subjective evaluations of visual diversity, as shown in Equation (1):

$$H_{\text{factor}} = - \sum_{i=1}^{n_{\text{levels}}} p_i \log_2 p_i \quad (1)$$

In the equation, H_{factor} is the entropy, p is the probability of occurrence of a level of a factor i , and the summation is over the levels of the factors. Entropy provides an objective approach to representing the visual diversity of a block by utilizing the frequencies of given design features within the block. If all buildings within a block are identical, that is, the levels of all factors are the same, then the entropy equals zero. The maximum level is reached when every building differs from the others on all factors or attributes. Stamps (2003) found a strong positive linear

correlation between levels of entropy and perceived diversity, both for laboratory stimuli and realistic scenes.

Studies suggest that a positive correlation exists between entropy and preference, up to a certain level. Stamps (2002) found that entropy based on the number of turns in the façade silhouette for rows of houses correlated strongly and positively with ratings of pleasantness. He took the terms “pleasure” and “preference” to be synonymous and so assumed that pleasantness ratings could be taken as indications of preference. In another study, he found a weak negative correlation between the entropy of residential block façades and pleasantness (Stamps, 1994; as cited in Stamps, 2003). Conceivably, this reflects on a curvilinear association; after a point (e.g., entropy = 12), increasing aggregate variation becomes less preferred in the urban environment (see Stamps, 2003).

In sum, variation in the silhouette and surface attributes of the multiple buildings in adjacent blocks can be combined on the streetscape level into an aggregate measure of architectural variation. This objective measure, entropy, is a positive predictor of perceived complexity. Across its lower range, entropy also appears to be positively related to preference. Given that environmental preferences are positively related to the possibility of restoration, increase in entropy, at least across its lower range, can be expected to relate positively to the likelihood of restoration seen in streetscapes. As judgments of restoration likelihood are presumably sensitive to perceptions of restorative quality, it is appropriate to consider how entropy might affect the restorative quality that a person sees in an urban residential streetscape. We anticipate that streetscapes with higher entropy will evoke fascination and being away to a greater degree, as they have more to attract and hold attention and they offer more opportunities for shifting one’s focus away from routine mental contents and everyday demands. Thus, we expect that increase in architectural variation will positively affect judgments of the likelihood of restoration via its positive effects on perceptions of the potential for being away and fascination.

1.2.2. Building height, perceived enclosure, and preference

Different lines of theory and empirical research converge in assigning importance to physical environmental attributes that affect a sense of being enclosed or surrounded in ways that limit movement or visual access (cf. permeability; Stamps, 2005a). According to the spatial layout hypothesis, initially proposed by Epstein and Kanwisher (1998), a particular area in the human brain, called the parahippocampal place area, responds strongly with spatially enclosed layouts, but only weakly with separate objects or faces. Subsequent studies have supported the hypothesis (Epstein & Ward, 2010), suggesting that this sensitivity to enclosing features of the environment may be a product of natural selection (Holden, 2000) (for further discussion, see Stamps, 2005a, 2005b).

A sense of enclosure in the urban environment can be generated with unbroken blocks of buildings, which represent the “walls” of an outdoor room in which streets and sidewalks represent the “floor” and the sky is the “ceiling” (Ewing & Hardy, 2009). In a meta-analysis, Stamps (2005a) found a strong correlation between the percentage of vertical solid surfaces that hindered visual and locomotive permeability (e.g., a brick wall) and ratings of enclosure. Related to this, Stamps (2005a) tested the effect of the height of buildings around a plaza on perceived enclosure and found that increasing the height (i.e., the percentage of vertical solid surfaces) increased the sense of enclosure; however, it appears that the relationship was not linear, in that a greater difference in rated enclosure was found between two- and four-story buildings than between four- and six-story buildings. From the different findings, drawn from numerous studies, it can be inferred that, to a point, the height of a continuous block of

buildings along a street, together with the height of buildings at the distal end of the street, will affect the sense of enclosure.

In line with the proposition that a neurological basis for responding to enclosure emerged through human evolution, environmental preferences have long been thought to reflect an innate sensitivity to possibilities for gaining shelter. Specifically, Appleton's (1996) prospect-refuge theory assumes that aesthetic evaluation of the environment considers environmental features that would have had significance for survival during earlier stages of human evolution. In those evolutionary contexts, survival would have been enhanced by being able to see potential predators in time (prospect) and being able to hide from them, as in an enclosed space (refuge). In theory, then, people should tend to prefer environments that provide at least some degree of apparent enclosure; however, empirical results on the relationship between physical attributes, perceived enclosure and preference in built urban settings give a complicated picture. Using scenes from urban environmental categories, Herzog (1992) found that his subjects tended to not like large, unstructured, open spaces, just as they tended to not like enclosed settings and blocked views. They most preferred a category with smaller spaces well-structured in depth. These results suggest that moderate levels of enclosure are preferred over both very low and very high levels. Similarly, Alkhresheh (2007), taking safety and sense of comfort as indicators of preference, showed that they had an inverted U-shaped relationship with the degree of enclosure in streetscapes, as manipulated with the ratio between building heights and street width (ranging from 1:6 to 6:1). These results were however obtained with images of streets without a building at the end to block the view. As Stamps (2005a) has shown, depth of view strongly affects perceived enclosure in a negative way; the greater the depth, the lower the sense of enclosure. Thus, the most preferred building height for a street of a given width may depend on whether the view down the street is blocked by another building, as is common in urban settings.

In sum, it appears that the height of buildings along a street increases a sense of enclosure, and that the sense of enclosure is related to environmental preferences, though the direction of the relationship depends on whether enclosure is in the lower range or in the upper range. Given that preferences for residential streetscapes are related to the possibility for restoration, we expect that judgments of restoration likelihood are also sensitive to physical attributes that affect the degree of enclosure. This expectation is reinforced by the results of a study on restorative quality in urban spaces by Galindo and Hidalgo (2005). They found that openness (which can imply lower enclosure) was positively associated with being away and fascination, which we expect to positively affect judgments of restoration likelihood. Thus, we expect that physical attributes which increase enclosure within the middle- to upper-range, such as building height, negatively affect judgments of the likelihood of restoration, via their negative effects on perceptions of being away and fascination.

1.3. Overview of the present study

The present study focuses on the likelihood of restoration that people perceive in urban residential streetscapes that they might pass while walking, as mediated by experiences of being away and fascination. Those qualities of restorative experience are studied here in relation to several specific physical attributes: the height of the buildings along the street together with the number of turns in the roofline and amount of surface decoration on those buildings, combined on the streetscape level into a measure of entropy. These physical attributes of buildings in streetscapes were varied systematically in a set of computer-generated images. Independent

groups of participants rated the images on the possibilities for experiencing being away, fascination, and restoration if walking through the streetscape. The respective group mean ratings were calculated for each variable for each streetscape, and data analyses treated the streetscape as the unit of analysis. The analyses of primary interest in this study addressed the following hypotheses:

1. At the lower end of the entropy scale, increasing streetscape entropy positively affects judgments of restoration likelihood.
2. The influence of streetscape entropy on judgments of restoration likelihood is mediated by the experiences of (a) being away and (b) fascination.
3. Streetscape building height negatively affects judgments of restoration likelihood.
4. The influence of streetscape building height on restoration likelihood is mediated by the experiences of (a) being away and (b) fascination.

These hypotheses are summarized in Fig. 1.

An important feature of the present work is the line of reasoning used to identify physical attributes for study. We reasoned that in the absence of literature on specific physical features of urban residential environments that support psychological restoration, we could turn to the literature on environmental preferences. This reasoning was encouraged by two facts: many empirical studies have described relations between specific physical environmental attributes and environmental preferences, and several studies have described positive relationships between preference and either change characteristic of restoration or ratings of the likelihood of restoration. To check on the validity of this reasoning, we also collected data on perceived complexity, perceived enclosure, and preference from additional groups of participants, following the same procedures used for the restorative quality and restoration likelihood variables. In addition to checking on whether perceived complexity and enclosure were sensitive to our manipulations of physical attributes as could be expected on the basis of previous research, we could use these data to examine the relationships that perceived complexity and enclosure had with preference as well as the relationship that preference had with restoration likelihood.

2. Methods

2.1. Visual stimuli

The study involved computer-generated simulations of streetscapes, each of which had a block of residential buildings on either side. Uniform spatial criteria were adopted for the blocks shown in the simulations. Each block was 96 m long and consisted of 12 8-m wide buildings. In addition, two buildings were located at the distal end of the streetscape to close off the space.

All buildings were built on sunken cellars and were one to three stories high (story height = 2.5 m).² The individual buildings differed slightly in height, depending on whether the roof type was flat or peaked (30° angle). In sum, the total height of a building ranged from 5.0 m (for one-story buildings with flat roofs) to 11.6 m (for three-story buildings with peaked roofs). Each building had four windows on each level and a center-aligned set of steps from the sidewalk to the main door at the first floor, with or without a handrail.

The blocks of buildings on the two sides of the street were separated by 14.4 m, a distance taken up by a street (6 m wide),

² According to the International Code Council (ICC) International Residential Code (2006), a minimum ceiling height is 7' (approx. 2.1 m).

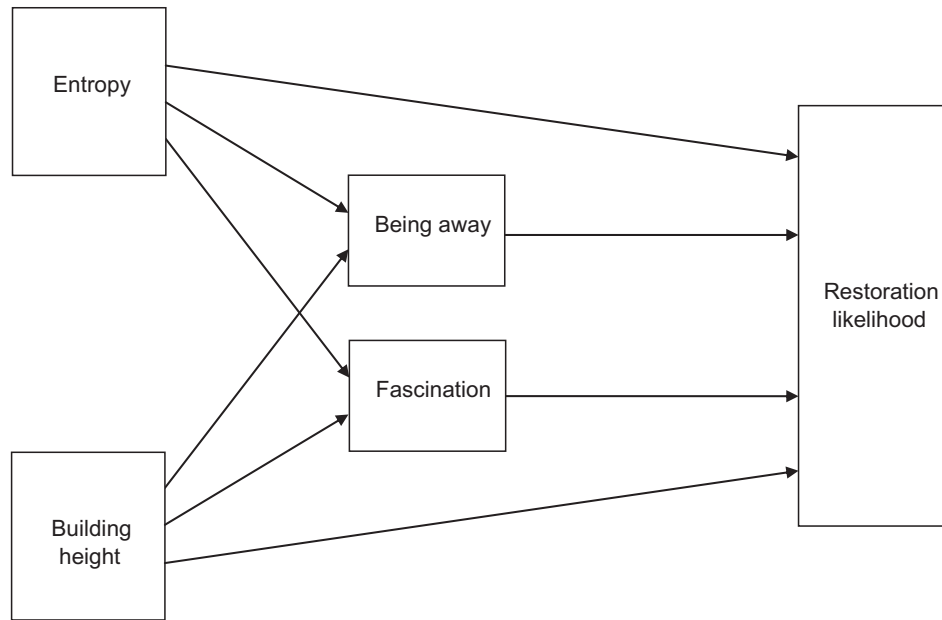


Fig. 1. Mediation model with being away and fascination as mediators of the effects of physical environmental components of urban streetscapes on judgments of restoration likelihood.

sidewalks (each 2 m wide, from the edge of the street to the foot of the doorsteps) and 2.2 m wide “intermediate spaces” defined by the sidewalk, building walls and doorsteps.³ The street had T-shaped intersections at both ends. The viewing position was at the near end, looking down the middle of the street. Street lamps and traffic signs were included in the streetscape, but no cars, people or animals were included.

The 26 buildings in each streetscape were randomly arranged along the blocks on either side (24 buildings) and at the distal end (2 buildings). Randomization was accomplished with a random number generator, with numbers corresponding to specified locations. All of the buildings in a given streetscape had the same number of stories (1–3), so that the only additional variation in building height was due to the slight height difference between flat and peaked roofs.

Silhouette and surface attributes were systematically varied both on the individual building level and on the streetscape level. On the individual building level, the silhouette was manipulated in terms of having a flat roof or a peaked roof, whereas the surface was manipulated in terms of the amount of ornament, trim and roof cornice on the façade. The sizes of the surface additions were in the range of 1/7–1/49 of the total façade width (after Stamps, 1999b). For an individual building, the surface details had the following two levels: either none or an ornament, a cornice, and door and window trims together. In addition, the buildings varied with the presence versus absence of handrails on the doorsteps. Note that the surface details were manipulated as a set, with a building having either no surface details or all surface details (including handrails) together. With the exception of the handrails, the design of the surface details was adopted from Stamps (1999a).

On the streetscape level, the surface and silhouette attributes were presented on one of seven levels, where each level

represented a certain number of buildings within the streetscape sharing the same silhouette attribute or set of surface attributes (e.g., 50% of the buildings had a peaked roof or the set of surface details) (see Table 1). To combine the levels of surface and silhouette attributes, streetscapes were created according to a 7×7 matrix for each of the three levels of building height.

The manipulations of building height, roofline, and surface attributes thus resulted in an image pool of 147 (i.e., $7 \times 7 \times 3$) virtual streetscapes. The streetscape models were developed in Google SketchUp 7[®] (free version), a three-dimensional computer simulation program. To increase realism, overlay photos were applied as textures to all visible surfaces within the model. As a default, Google SketchUp 7[®] offers blue, cloud-free sky. The sun position can be adjusted freely according to date and time of day. To prevent shadow-projection from the buildings, which would add a dimension to the environment not under consideration in this study, these parameters were set for June 21 at 12:00 AM, when the sun is highest in the sky over the northern hemisphere (i.e., the summer solstice).

When a streetscape was completed, a virtual camera was positioned at the center of the near end of the street, 12 m from the corners of the blocks separated by the street down which the view was oriented. This distance was chosen to ensure that the participants could clearly see the façade decoration down the street. The height of the virtual camera was set at 1.75 m to get an eye-level

Table 1

Levels representing the percentage and number of individual houses within a streetscape that have a particular physical attribute (e.g., peaked roof).

Level	% of buildings	# of buildings
1	0%	0
2	15%	4
3	35%	9
4	50%	13
5	65%	17
6	85%	22
7	100%	26

³ The sidewalk and street widths are neither extremely wide nor extremely narrow by published standards for residential blocks. For example, the Australian Model Code Minimum Sidewalk Width is 3.9 ft (approx. 1.2 m) and Pavement Width for major access streets are 18.0–21.3 ft (approx. 5.9–7.0 m) and for minor access are 16.4–18.0 ft (approx. 5.4–5.9 m) (Ewing, 1994).

perspective for an adult of moderate height. To prevent skewness or distortion in the screenshot, the virtual camera was aimed at the midpoint of the screen. This arrangement meant that the roof tops of the buildings nearest to the camera were cut out of the image if they were higher than two stories.

When the camera had been properly adjusted, the screenshot was rendered in V-Ray v1.5.1 for SketchUp® (demo version) for photorealistic simulation of color and light. V-Ray v1.5.1 is a rendering engine equipped with global illumination (GI), which is indirect illumination based on a dome of light that is emitted around the scene (Chiang, Alomar, & Barrero, 2008). For outdoor settings as presented in this study, V-Ray provides a sun and sky lighting model which allows physically accurate recreation of the sun and sky effects (Chiang et al., 2008). GI was therefore set to the sky option. Because the sun and sky model is very bright under standard conditions, the virtual camera must be adjusted to physical mode, in which it counteracts the brightness by imitating a real camera's response to the light (Chiang et al., 2008). In the physical mode of V-Ray, default settings were chosen, that is, for a still camera that simulates a real-life still photo camera, shutter speed of 300 and film speed (ISO) of 125.

2.2. Variables in the analyses

2.2.1. Physical variables

With silhouette and surface attributes contributing to architectural variation on a streetscape level, entropies for each of those factors were calculated (see Equation (1)) for all seven levels shown in Table 1, resulting in entropy values of $H = 0$ (total uniformity, for levels 1 and 7), 0.62 (for levels 2 and 6), 0.93 (for levels 3 and 5) and 1 (for level 4). As the factors were independent, the total entropy for a streetscape was the sum of their respective entropy values, and thus ranged from 0 (all buildings identical on both factors) to 2 (50% of the buildings shared the same attributes on both factors). In addition to entropy, analyses included building height with three levels (one-, two- and three-stories).

2.2.2. Psychological variables

Independent groups rated each of the streetscapes on one of six psychological variables, all of which were measured with a single item. The ratings for likelihood of restoration (*I would be able to rest and recover my ability to focus in this environment*), fascination (*There is much to explore and discover here*), being away (*Spending time here gives me a break from my day-to-day routine*) and preference (*I like this environment*) were given with an 11-point scale (0 = *not at all*, 10 = *completely*). For perceived complexity and perceived enclosure, the participants responded to the statement "*I perceive this streetscape as ...*" using 11-point scales (for complexity, 0 = *simple*, 10 = *complex*; for enclosure, 0 = *open*, 10 = *enclosed*). The items for preference and restoration likelihood had been used by Nordh et al. (2009), a forerunner to this study. The items for fascination and being away, also used by Nordh et al., were taken from the Perceived Restorativeness Scale (PRS) (Hartig, Kaiser, et al., 1997).

2.3. Procedure

Data collection was carried out via the internet. Participants received a recruitment flyer via personal email or the global social networking website Facebook with a link to the website. A snowballing distribution procedure was used; recipients were asked to spread the request for participation via personal email or to members of their separate Facebook networks. The purpose of the study and other necessary information (e.g., regarding informed consent) were presented at the website, along with a link to start

running the study. When started, each participant was presented with a series of 73 or 74 images, each of which was to be rated on only one of the psychological variables. The variable for rating was randomly selected by the computer. The participant was also asked to provide some background information, including age in years, gender, nationality, and familiarity with the kind of environments shown in the images (0 = *completely unfamiliar*, 10 = *very familiar*).

Participants who were to rate the images on one of the three variables related to restorative experience (i.e., being away, fascination, restoration likelihood) received the following scenario before they began the rating task: "*Imagine that it is afternoon and you are walking alone from work to home. You are mentally tired from intense concentration at work and you appreciate having a chance to stroll and recover before you have to go home to solve various matters.*" The scenario was meant to provide a standardized, plausible and relevant context for the rating task (cf. Herzog, Black, Fontaine, & Knotts, 1997; Nordh et al., 2009; Staats et al., 2003). In that it specified a condition of directed attention fatigue, it was suited to the restoration likelihood rating, which referred to attention restoration. Also, in that it specified the purpose and activity the participant was to bear in mind, the scenario restricted the range of variation in compatibility due to other than physical environmental variations. We therefore considered the measurement of compatibility as described in ART to be unnecessary. No scenario was presented prior to the ratings of complexity, enclosure, and preference.

2.4. Participants

Participation was entirely voluntary. The sample consisted of 263 Icelanders (62% women). They ranged in age from 19 to 70 years ($M = 40.0$, $SD = 10.9$). In general, the degree of familiarity with the kind of urban environment presented in the image was low-to-moderate among the participants ($M = 4.76$, $SD = 2.56$). This was not surprising, as comparable environments do not presently exist to any great extent in Iceland, and opportunities for experiencing them in everyday life are thus severely limited there. On the other hand, participants can have experienced environments similar to the ones presented through travel or through media presentations of foreign countries, and this presumably fed into the variability in familiarity observed in the sample.

2.5. Statistical analysis

In the present study, the images of streetscapes are the units of analysis, and the physical variables used in analyses reflect variability on the streetscape level. The values for the physical variables resulted from researcher manipulations, whereas the psychological variables were measured with participant ratings. Each image was rated on each of the six psychological variables, though each of the participants rated the images for only one variable. From 39 to 49 participants provided ratings of the images for the given variable. The mean of their ratings for each image was used for further analysis. Due to mistakes made during the generation of the questionnaire for completion via the internet, two streetscapes had to be dropped from further analysis, leaving 145 images.

The main analyses assessed the strength of the direct effects of entropy (i.e., combinations of surface and silhouette attributes) and building height (i.e., number of stories) on judged likelihood of restoration. These analyses also estimated mediation of the relationship between physical environmental features and restoration likelihood by both being away and fascination. We used the regression-based approach developed by Preacher and Hayes (2008a) for these analyses. This approach is particularly suited to testing models that include multiple mediators, such as ours.

Table 2
Descriptive statistics and correlation matrix for the variables under study, calculated looking across the streetscape images.

	M	SD	Min	Max	1	2	3	4	5	6	7
Being away ^a	2.73	0.59	1.27	3.88	1						
Fascination ^a	3.17	0.63	1.70	4.42	0.46**	1					
Restoration likelihood ^a	3.86	0.59	2.33	5.23	0.72**	0.54**	1				
Entropy ^b	—	—	—	—	0.24**	0.31**	0.24**	1			
Building height ^b	—	—	—	—	-0.17*	0.04	-0.37**	-0.02	1		
Perceived complexity ^c	4.61	0.77	2.37	6.24	0.28**	0.59**	0.28**	0.52**	0.02	1	
Perceived enclosure ^d	7.48	1.54	4.43	9.93	-0.18*	-0.08	-0.41**	0.49**	0.96**	0.38**	1
Preference ^a	3.11	0.71	1.50	4.67	0.54**	0.62**	0.72**	0.05	-0.23*	0.30**	-0.30**

Note. Values in the correlation matrix are for Pearson correlations. * $p < 0.05$; ** $p < 0.01$.

^a Ratings given on an 11-point scale (0 = not at all, 10 = completely).

^b Higher values indicate higher levels.

^c Ratings given on an 11-point scale (0 = simple, 10 = complex).

^d Ratings given on an 11-point scale (0 = open, 10 = enclosed).

Different approaches to testing mediation have some nomenclature in common (e.g., Baron & Kenny, 1986; Preacher & Hayes, 2008a). Path c represents the total effect of the independent variable X on the dependent variable Y , path c' represents the direct effect of X on Y , path a represents the effect of X on the hypothesized mediating variable M , and path b represents the effect of M on Y . Paths a and b thus carry the indirect effect of X on Y . In mediation models with only one mediator, the indirect effect is quantified as ab (Baron & Kenny, 1986). In multiple mediator models such as the one in focus here, however, each of j mediators contributes a specific indirect effect ($a_j b_j$) to the total indirect effect of X on Y . The total indirect effect is therefore quantified as $\sum(a_j b_j)$. This implies additional challenges for estimation.

Our application of the multiple-mediator approach developed by Preacher and Hayes (2008a) followed their recommendation regarding bootstrap estimation of the indirect effects. With bootstrapping, estimates of the various parameters of interest are obtained for repeated subsamples of cases taken (with replacement) from the sample. This process is to be repeated k times ($k \geq 1000$), yielding empirical, nonparametric sampling distributions for all j values of a_j and b_j , and so in turn the specific and total indirect effects. The estimates obtained in this way [means for the values from the k bootstrap samples; Preacher & Hayes, 2008b] are indicated with an asterisk (*). The bootstrap confidence interval (CI) is acquired by ranking the k values of $a_j b_j^*$ from low to high. The values which define the upper and lower 100($\alpha/2$)% of the distribution of $a_j b_j^*$ set the limits of the CI. With $k = 5000$, as recommended by Preacher and Hayes, and the conventional $\alpha = .05$, the lower and upper limits of the CI would be the 125th and 4876th values of $a_j b_j^*$. If the CI does not include zero, the indirect effects are statistically significant.

The percentile bootstrap CI is built on an empirical approximation of the sampling distribution of the indirect effect, which is not necessarily normally distributed. According to Preacher and

Hayes (2008a), the percentile bootstrap CIs can be improved by using bias-corrected (BC) intervals (see Efron, 1987; Efron & Tibshirani, 1993, for technical details).

The Preacher and Hayes' (2008a) approach had important advantages for the test of our mediation model. First, we could assess mediation by fascination in the context of mediation by being away (and vice versa). Second, we could compare being away and fascination with regard to the amount of the effect of the environmental attributes transmitted to perceived restoration likelihood.

Analyses were completed using SPSS 16.0 software and SPSS macros published by Hayes (accessible at <http://www.afhayes.com/spss-sas-and-mplus-macros-and-code.html>; see the INDIRECT macro).

3. Results

3.1. Effects of architectural variation and building height on restorative quality and restoration likelihood ratings

The rated mean values of the two restorative quality variables, being away and fascination, were generally low and fell within a narrow range (see Table 2). There was a quite strong positive bivariate correlation between these two variables, and both correlated strongly and positively with restoration likelihood. Like the restorative quality variables, the ratings of restoration likelihood tended to fall at the lower end of the scale, and within a narrow range. Images with low, high and intermediate values for restoration likelihood are given in Fig. 2.

In the regression analysis, the two environmental variables explained 65.78% of the variance in restoration likelihood (see Fig. 3). With adjustment for building height, the total effect (c) of entropy on restoration likelihood was positive and significant, in keeping with Hypothesis 1. With the mediating variables in the



Fig. 2. Streetscape images with the lowest, closest to average and highest likelihood of restoration ratings, calculated looking across the participants who provided the ratings. (From left to right) The streetscape image with lowest mean rating for restoration likelihood ($M = 2.33$, $SD = 1.62$); the streetscape image with the closest-to-average mean rating for restoration likelihood ($M = 3.86$, $SD = 1.81$); the streetscape image with highest mean rating for restoration likelihood ($M = 5.23$, $SD = 2.02$).

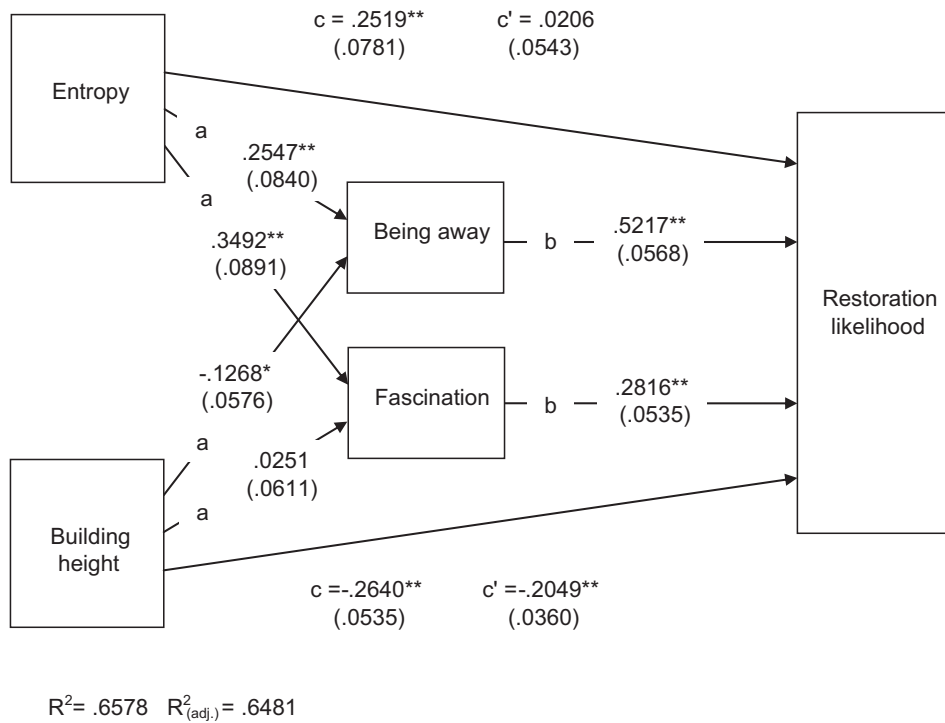


Fig. 3. Mediation model with being away and fascination as mediators of the effects of physical environmental components of urban streetscapes on judgments of restoration likelihood. Unstandardized multivariate regression coefficients are shown with the corresponding standard errors in the parentheses. The paths marked *a* represent the effects of the physical components on the mediators. The paths marked *b* represent the effects of the mediators on restoration likelihood. The paths marked *c* represent the effects of the physical components on restoration likelihood before adjustment for the mediators, though with adjustment for the other physical environmental component. The paths marked *c'* represent the effects of the physical components on restoration likelihood after adjustment for the mediators. The difference between the values for *c* and *c'* represents the sum of the indirect effects transmitted through the two mediators. $N = 145$. * $p < .05$; ** $p < .005$.

model, the direct effect (*c'*) of entropy became insignificant; however, the total indirect effect (*ab*) of entropy on restoration likelihood was significant and the specific indirect effect was significant for each of the mediators, in keeping with **Hypotheses 2a and 2b** (see **Table 3**). The statistical contrast of those indirect effects was not significant, indicating that the specific indirect effects through being away and fascination did not differ much in size (see **Table 3**). In sum, higher levels of entropy engendered higher levels of being away and fascination, which in turn engendered greater estimates of restoration likelihood.

With adjustment for entropy, the total effect (*c*) of building height on restoration likelihood was negative and significant, in accordance with **Hypothesis 3** (see **Fig. 3**). With the two mediators

in the model, being away mediated the association between building height and likelihood of restoration, in keeping with **Hypothesis 4a**. As shown in **Fig. 3**, the higher buildings decreased the sense of being away, which in turn diminished the estimates of restoration likelihood. Contrary to expectations (**Hypothesis 4b**), fascination did not mediate the relationship between building height and restoration likelihood. Accordingly, the contrast indicated that the specific indirect effect transmitted through being away was greater than the indirect effect transmitted through fascination (see **Table 3**). The direct (*c'*) effect of building height on restoration likelihood remained significant despite the inclusion of being away and fascination in the model, indicating that not all of the negative influence of building height on judgments of restoration likelihood was mediated by the restorative quality variables.

Table 3
Indirect effects of the association between the environmental components and restoration likelihood, through being away and fascination.

	Point estimate	BC ^a 95% confidence interval	
		Lower	Higher
Entropy			
Total indirect effect	0.23	0.10	0.37
Being away	0.13	0.04	0.25
Fascination	0.10	0.04	0.17
Being away vs. fascination	0.03	-0.06	0.15
Building height			
Total indirect effect	-0.06	-0.14	0.02
Being away	-0.06	-0.13	-0.01
Fascination	0.01	-0.03	0.05
Being away vs. fascination	-0.07	-0.14	-0.02

^a BC (bias corrected confidence interval; see **Efron, 1987**) based on bootstrapped estimates.

3.2. Checks on assumptions underlying the selection and manipulation of physical attributes

In additional analyses we checked the validity of our reasoning about the utility of the preference literature for identifying features of the built urban environment that could affect restoration. That reasoning had led us to focus on physical attributes that in addition to practical relevance also had been found to relate to preference, directly or indirectly through perceived complexity or enclosure.

On average, the streetscapes elicited low-to-moderate ratings of complexity and rather high ratings of enclosure (see **Table 2**). Perceived complexity correlated strongly with the manipulations of physical attributes represented in our entropy measure, whereas perceived enclosure was almost perfectly correlated with building height (see **Table 2**). Preference for the streetscapes was on average quite low; none of them was well-liked. Nonetheless, preference

did increase with increase in perceived complexity across the lower range captured with our images, and it decreased as perceived enclosure increased across the upper range. The most puzzling correlation among these variables is the one between entropy and preference, which was quite weak. Preference and restoration likelihood were nonetheless strongly and positively related, additional affirmation of the validity of the approach.

4. Discussion

In this study, we attempted to shed light on physical attributes of the urban residential environment that can influence possibilities for restoration. We did so by systematically manipulating attributes of blocks of buildings along a residential street as shown in computer-generated images. The attributes included building height, the number of turns in the skyline silhouette, and façade details, with the latter two combined into a measure of entropy on the streetscape level. The results indicate that these attributes influenced judgments regarding possibilities for restoration. Specifically, the data are consistent with the expectation that higher levels of architectural variation in the urban residential environment would be regarded as more restorative, at least within the lower register of entropy (*Hypothesis 1*). Further, in line with *Hypotheses 2a and 2b*, the two restorative qualities, being away and fascination, mediated the relationship between streetscape entropy and the judged likelihood of restoration. Having more architectural variation in the environment apparently meant more opportunity for the engagement of effortless attention, as with exploration and discovery, which is assumed to be an important premise for attentional restoration. Increasing the details of the façades and overall variation on the streetscape level also created circumstances that promoted a sense of being away. The mean values for being away and fascination correlated strongly across the set of images, even though they were based on data from independent groups of raters.

The results further indicate that greater building height affected restoration likelihood negatively (*Hypothesis 3*). The latter result can partly be explained by the regression results which indicated that being away mediated the effect of building height on restoration likelihood (*Hypothesis 4a*). Higher buildings reduced the sense of being away, which in turn reduced the expectation that restoration would take place. Contrary to our expectations (*Hypothesis 4b*), fascination did not significantly mediate the relationship between building height and restoration likelihood. It would seem that, while the higher buildings increased the number of elements to look at (i.e., windows and window frames), after adjustment for entropy building height did not of itself do more to engage fascination.

In sum, our results are in line with those of other studies demonstrating that different urban residential environments are seen to provide different opportunities for restorative experience (e.g., Herzog et al., 2003; Hidalgo et al., 2006; Staats et al., 2010). At the same time, the study extends previous research on restorative opportunities seen in urban residential settings. It does so through the systematic manipulation of specific physical attributes of buildings in streetscapes and through the assessment of mediation by perceptions of restorative quality.

The study also illustrates the use of the literature on environmental preferences in specifying the physical attributes to study with regard to restorative experience and in guiding the manipulation of those attributes. For the most part, the pattern of associations among the variables studied agrees well with previous research on preferences and with the notion that people tend to like environments that support restoration. The one exception is the somewhat puzzling lack of association between entropy and preference. Conceivably, the range of entropy studied was too narrow. When Stamps (2003) found that preference increased with

increase in entropy, he considered a range in entropy from 0 to 12. In the present study, entropy ranged only from 0 to 2.

The study has some other limitations, aside from the limited range of entropy represented in our images. One of them concerns the people who rated the images on the psychological variables. Some members of our sample of Icelanders had little familiarity with the kind of streetscapes shown in our images. This does not render their data irrelevant. Design processes can lead to the construction of environments that are unfamiliar to the people who will come to occupy them, and their evaluations of the proposed environments are relevant to a decision about whether or not to proceed to construction. This said, it is of interest whether the results obtained for people familiar with such environments would differ from those for people unfamiliar with such environments. We did consider this possibility, but for some of the psychological variables, few people who reported high familiarity provided ratings of the images.

A second possible limitation of the study has to do with our use of single-item measures for the psychological variables. We used single-item measures to avoid exhausting our participants, given the large number of streetscape images we asked them to rate. We cannot be certain whether any added reliability from having relatively fresh participants outweighed any non-reliability due to the use of single-item measures, but we assumed that participant exhaustion would be the greater problem. As it stands, single-item measures are not necessarily inferior to multi-item measures (e.g., Gardner, Cummings, Dunham, & Pierce, 1998), and complexity, enclosure, and preference have frequently been measured with single items over several decades of research on environmental evaluation (e.g., Kaplan et al., 1972). No such tradition has yet been established for measures concerned with restorative experience, but the single-item restoration likelihood measure has been used in several previous studies and proven sensitive to environmental variations as expected (e.g., Hartig & Staats, 2006; Nordh et al., 2009; Staats & Hartig, 2004; Staats et al., 2003). Also, the measures of being away and fascination are taken from widely used multi-item measures that typically demonstrate high internal consistency (e.g., Hartig, Kaiser, et al., 1997; Hartig, Korpela, et al., 1997). Still, if our single-item measures did have relatively low reliability, then the estimates of association we have reported can be considered conservative.

A third possible limitation of the study follows from the use of two-dimensional color images to represent the streetscapes, which raises issues of validity. It may for example be difficult to judge the restorative value of an environment without having a sense of the wider surroundings. Countering such validity concerns, in a meta-analysis, Stamps (1990) found a strong correlation ($r = 0.86$) between environmental evaluations obtained on-site and those obtained with photographs (see also Hartig, Korpela, et al., 1997; Stamps, 2010). Still, we acknowledge that such stimuli do constrain the environmental experience in relevant ways. For example, we anticipated that our images would limit variation in the experience of extent as described in ART (e.g., the streetscapes had a simple and uniform spatial arrangement of buildings).

Aside from economy, we had an important practical rationale for our use of two-dimensional color images to represent the streetscapes. We consider this study an initial step in capitalizing on high-performance graphical and display technology, so far little used in studies on restorative environments (cf. Valtchanov, Barton, & Ellard, 2010; Valtchanov & Ellard, 2010). The image-creation techniques applied here offer a promising alternative to traditional, photo-based methods. They enable the creation of highly realistic, interactive three-dimensional virtual urban environments, in combination with the systematic manipulation of independent variables and control for confounding variables (cf.

Rohrman & Bishop, 2002). Therefore, the technology used in the present study provides a platform for experiments in which subjects virtually “move around within” a 3D simulation. The virtual technology might be used to understand restorative experience in “field settings,” as the many practical difficulties to be overcome in implementing field experiments (see e.g., Hartig, Evans, Jamner, Davis, & Gärling, 2003) have so far limited the number of environments compared in studies of restorative effects. In line with these ideas, some research affirms that an interactive 3D computer-generated natural environment can promote restoration (Valtchanov et al., 2010; Valtchanov & Ellard, 2010). Part of the originality of the present study lies in the systematic approach to the creation of images that, on the basis of associations between physical attributes and evaluations such as preference and/or restorative quality, can be selected for incorporation in virtual environments that can be used to assess actual restoration. We are currently pursuing work with virtual environments built with images from the present study, selected on the basis of their restoration likelihood scores. Development of this approach can ultimately provide a basis for design decisions concerning planned environments.

Another feature of the present study indicates another direction for future research. We turned to the preference literature to derive hypotheses about physical components of environments that could affect restorative quality and the likelihood of restoration. We did so for two reasons. First, previous research has uncovered strong associations between preference and judgments of restoration likelihood, and it has described restoration as a plausible cause of preference (e.g., Staats & Hartig, 2004; Staats et al., 2003). Second, there is little specific information about attributes of physical environments that affect restoration and judgments of restoration likelihood, but there is much information about attributes of physical environments that affect preference (albeit not always consistent). To substantiate the assumption that the preference literature provides guidance for research on restorative environments, we assessed correlations between the physical attributes in our streetscape images and perceptions of complexity and enclosure. We also assessed the correlations that perceived complexity and enclosure had with preference. Some readers will have recognized that with these data we had the possibility of doing further analyses. For example, we could have determined whether the effect of the physical attributes on preference was mediated by complexity and enclosure. We might also have tested an expanded model in which the physical attributes affect the perceptual variables, which in turn affect the restorative qualities, which in turn affect restoration likelihood. We had good reasons for not performing these analyses. Doing so would have distracted from the main point of this study while adding length and complexity to an already long and complex paper. Also, tests of the kind of expanded model just described should be performed in conjunction with a closer theoretical analysis of the relationships among psychological predictors of preference (e.g., complexity) and restorative qualities of environments (e.g., fascination). We think work in this direction would be worth pursuing.

With regard to practical implications, the present results support the discussion of links between restoration, urban densification and sustainability. Theoretically, densification may offer some ecological advantages, such as better possibilities for residents to rely on collective transportation instead of private cars. At the same time, densification may increase people's exposure to noise and crowding, just as the amount of urban green spaces and other outdoor opportunities for restorative experiences diminish (van den Berg et al., 2007; Nordh et al., 2009). Our results affirm that densely built urban residential settings need not lack restorative quality, and that the design of the built environment can play

a significant role in affecting perceptions regarding possibilities for restoration. Such information is needed in the effort to create urban environments that are sustainable in social and psychological terms as well as in ecological terms.

Author notes

The first author carried out this study while a guest researcher at the Institute for Housing and Urban Research, Uppsala University. He thanks the Institute for generous support during his visit. The authors also thank the anonymous reviewers for their constructive comments.

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