Restorative Environmental Design for Densifying Cities

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Statement of originality

This thesis is my original work, and it has not been submitted, in whole or in part, for a degree at this or any other university. Nor does it contain, to the best of my knowledge and belief, any material published or written by another person, except as acknowledged in the text.

Pall Jakob Lindal

Approval of the Human Ethics Committee

The Human Ethics Committee of the University of Sydney granted approvals for this research:

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Abstract

The urban population around the world is growing rapidly. Although increasing urbanization has positive aspects, it has also raised concerns about environmental, economic and social sustainability. As response, some design and planning solutions emphasize greater densification of urban areas. Research has however not been able to show that urban density enhances sustainability in a consistent manner. One possible explanation might be the neglect of psychological factors within the compact city practice. Restorative environmental design (RED) that builds in part on theory and empirical research concerned with restorative environments is one approach to addressing this problem. To date, however, the empirical results behind RED as applied to urban densification are quite limited, and the purpose of this thesis work is to provide more empirical substance to reinforce the foundation of RED for use in this context.

This work is based on four papers. The first paper is an introduction to the restoration perspective on human-environment relations in general and to research on environmental supports for psychological restoration more specifically. It provides a starting point for the empirical work in this thesis by identifying some specific research gaps with regard to the restorative potential of urban environments. The three remaining papers report a sequence of empirical studies that focus on specific physical components and characteristics that affect the restorative potential of urban streetscapes. Taking guidance from the preference literature when choosing relevant characteristics, the first two of the remaining papers report the results of studies that used digitally created static images to present streetscapes in which different characteristics had been systematically manipulated. Aggregate ratings for the respective image

sets were obtained from adult Icelanders through an internet-based procedure. The results of multiple-mediator regression analyses found architectural variation (presented as entropy), number of street trees, their arrangement along the street, presence of flowers, and presence of grass to positively affect ratings of the likelihood of restoration, with the effects mediated by one or both of the restorative quality variables being away and fascination. The results also demonstrated a negative effect of building height on judgments of restoration likelihood, as mediated by a reduced sense of being away.

In a third study, reported in the fourth paper, ratings of restoration likelihood obtained in the earlier empirical studies were found to predict actual restoration experienced by members of a separate sample. Two three-dimensional interactive virtual neighbourhoods were constructed from streetscapes that in the two previous studies had differed in term of restoration likelihood. Participants who "walked" through the low restoration likelihood neighbourhood showed a negative shift in affective balance while those who navigated through the higher restoration likelihood neighbourhood showed a positive shift in affective balance. This effect became stronger after adjustment for the participants' own perceptions of restorative quality (being away and fascination) in the assigned streetscape.

The results of this dissertation work show that the restorative potential of residential urban environments depends on specific architectural components and design characteristics, which indicates the relevance of RED for densifying cities. The results provide guidance for the design of more psychologically sustainable urban residential environments. The studies also demonstrate strategies for using digital imaging and virtual technologies in pursuing the further research that is needed in this area to strengthen the empirical foundations of RED. Finally, this

work encourages authorities and practitioners to apply a restoration perspective in their efforts to create urban environments that are sustainable not only in ecologic terms, but also in terms of basic human needs.

Acknowledgements

To complete a PhD degree, persistence and hard work are necessary, but not sufficient. One must also be supported. I have been fortunate during my PhD studies to be supported by many great people.

Professor Terry Hartig. The first time I contacted Terry was in July 2008 to ask if he would be willing to supervise me if I would become a visiting student at Uppsala University. He said “yes”. My family and I arrived Sweden in mid-March 2009 and since then I have enjoyed the privilege of working with Terry, who is not only a scholar of an ultimate quality but also one of the greatest persons I have ever met; supportive, fair-minded, reliable, generous, and importantly, with a good sense of humor. In one word - topnotch! Thanks Terry!

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Contents

Tables

Figures

Inclusion of published or submitted book chapters / papers

Book chapter

Published book chapter: Chapter 3; pages 30-65.

Hartig, T. & Lindal, P. J. (2012). The restoration perspective: Linking nature experience with health. Translated into German and forthcoming in L. Kruse (Ed.), Natur, Naturwahrnehmung, Naturschutz: Nachhaltige Entwicklung aus Sicht der Psychologie. Sankt Augustin, Germany: Academia Verlag.

As lead author of "The restoration perspective: Linking nature experience with health," I confirm that Pall Jakob Lindal made the following contributions to the chapter as co-author:

- Literature search, sourcing and review
- Substantial writing and critical appraisal of content

My contribution was in literature search, writing, editing, commentary and discussion consistent with the lead author status.

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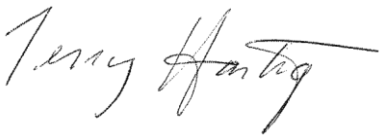

Papers

Published paper: Chapter 4; pages 66-99.

Lindal, P. J. & Hartig, T. (2013). Architectural variation, building height, and the restorative quality of urban residential streetscapes. *Journal of Environmental Psychology*, *33*, 26–36.

As co-author of the paper, "*Architectural complexity, building height, and the restorative quality of urban residential streetscapes,*" I confirm that Pall Jakob Lindal made the following contributions to the paper:

- Literature search, sourcing and review
  - Study design
  - Conduct of study
  - Analysis of the data
- Writing and critical appraisal of content
- Corresponding author for communication with the journal

My contribution was in consultation on research design and methods, writing, editing, commentary and discussion consistent with the co-author status.

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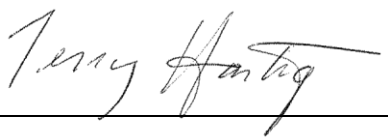

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- Literature search, sourcing and review
  - Study design
  - Conduct of study
  - Analysis of the data
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- Corresponding author for communication with journal

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- Literature search, sourcing and review
  - Study design
  - Conduct of study
  - Analysis of the data
- Writing the paper and critical appraisal of content
- Corresponding author for communication with journal

My contribution was in consultation on research design and methods, writing, editing, commentary and discussion consistent with the co-author status.

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Work presented in conferences and seminars

Conferences

Lindal, P. J. & Hartig, T. (2012). Effects of urban street vegetation on judgments of restoration likelihood. Paper presented at the European Network for Housing Research (ENHR) conference. Lillehammer, Norway, June 24-27.

Lindal, P. J. & Hartig, T. (2011). Psychological restoration in virtual urban environments: Correspondence between measured restoration and restoration likelihood judgments. Paper presented at the Annual meeting of the Swedish Area Group in Environmental Psychology. Gävle, Sweden, November 9-10.

Lindal, P. J. & Hartig, T. (2011). Psychological restoration in virtual urban environments: Correspondence between measured restoration and restoration likelihood judgments. Paper presented at the 9th Biennial Conference on Environmental Psychology. Eindhoven, The Netherlands, September 26-28.

Lindal, P. J. & Hartig, T. (2010). The impact of streetscape complexity and enclosure on restoration likelihood. Paper presented at the Annual meeting of the Swedish Area Group in Environmental Psychology. Lund, Sweden, November 10-11.

Lindal, P. J. & Hartig, T. (2010). The impact of streetscape complexity and enclosure on restoration likelihood. Paper presented at the 21st IAPS Conference: Vulnerability, Risk and Complexity: Impacts of Global Change on Human Habitats. Leipzig, Germany, June 27 – July 2.

Lindal, P. J. (2008). The importance of different built urban environments in environmental restoration. Paper presented at the 20th IAPS Conference: Urban diversities, biosphere and well-being: Designing and managing our common environment. Rome, Italy, July 28 – August 1.

Lindal, P. J. (2008). Theories and evidence on the impact of the urban environment on restoration. Paper presented at the 3rd International Conference on Interdisciplinary Social Sciences. Prato, Italy, July 8 - 11.

Lindal, P. J. (2008). The importance of the built urban environment in environmental restoration. Proceedings of the Environmental Design Research Association 39th Annual Conference: Linking Differences/Defining Actions. Edmond, OK, USA, May 28 - June 1.

Lindal, P. J. (2007). Psychological influence of trees in urban environment. Paper presented at the Symposium on the Role of Trees to Improve Comfort and the Environment. Reykjavik, Iceland, September 27.

Seminars

Lindal, P. J. (2012). Is the nature nurturing? Landvernd - the Icelandic Environment Association's Lecture Series: From Awareness to Action: Environmental Behavioural Change, The Nordic House, Reykjavik, Iceland, 17 October.

Lindal, P. J. (2012). Designing for restoration. Institute for Housing and Urban Research, Uppsala University, Gävle, Sweden. 15 May.

Lindal, P. J. (2012). Green or gray? About restorative environments. Faculty of Psychology, University of Iceland, Reykjavik, Iceland. 28 March.

Lindal P. J. (2011). Complexity, enclosure, and the restorative quality of urban streetscapes. Institute for Housing and Urban Research, Uppsala University, Gävle, Sweden. 26 April.

Lindal, P. J. & Djikstra, K. (2008). The nature of theory: The discussion of restorative theories. Faculty of Architecture, Design & Planning, University of Sydney, Australia. 11 April.

Lindal, P. J. (2008). Research Pilot 2. Faculty of Architecture, Design & Planning, University of Sydney. Australia. 7 March.

Lindal, P. J. (2007). The effects of scale, complexity and style of buildings in relation to natural elements in urban environments on people's restoration. Faculty of Architecture, Design & Planning, University of Sydney, Australia. 12 December.

Lindal, P. J. & Moorapun, C. (2007). Computer simulation. Faculty of Architecture, Design & Planning, University of Sydney, Australia. 7 November.

Preface

Reykjavik, Iceland. One night in the autumn, 2004, my partner and I decided to go for a walk. The weather was nice as we walked from our home, which was somewhat close to the old city centre, chatting about all and nothing. We were deep into our conversation when we turned left and walked down the oldest section of the main shopping street. All of the sudden my partner stopped and said, "*Have you ever noticed that we always end up here?*" "*I don't know ... really?*" She smiled, "*Yes, absolutely ... we always take the left turn and end up here! Why do we never take a right turn?*" I just shrugged my shoulders. A very good question - why did we unintentionally always end up at the same spot? "*Well ... when thinking ... this section of the street just makes me feel better. Agree?*" She nodded, "*Oh yeah ... the architecture makes you feel comfortable ... small old buildings, diversity ...*" Being the son of an architect, I had always been surrounded by discussions of architecture and planning, but never from the psychological perspective. I had never heard anyone talk explicitly about architecture and psychology at the same time.

A few months later, the local authority in Reykjavik put forward a list of old buildings along the main street that should be torn down in the coming years as part of the modernization of the city centre. On 12 February, 2005, the newspaper *DV* addressed this issue under the heading, "*These buildings will disappear.*" As a response, I wrote my first newspaper article, in which - referring to my own experience – I asked if the psychological importance of these buildings had ever been considered. Subsequently, I started to search on the internet for further information and came across something called "*environmental psychology*", which seemed to be

highly relevant. Would it be possible to affect the discussion if study results would indicate the psychological benefits of these buildings for people? Would it be possible to do research on what types of buildings are the most beneficial? Who is studying environmental psychology?

A year and a half later, I came across the Environment, Behaviour & Society (EBS) Research Group at the University of Sydney, run by Professor Gary T. Moore. It looked exciting. To make a long story short, I applied, got accepted, and presented my ideas for the first time in person to Gary at his personal library on the 5th floor at the Wilkinson Building on May 10, 2007.

"*I want to make a typology where experts, authorities or laymen can just flip through to find what design is the most psychologically beneficial at any given time!*" "*Do you think that is manageable in a PhD?*" "*YES!*"

Without doubt, I underestimated this work or overestimated my capabilities or both. Six years and a lot of experience later, I have completed this PhD work. It is clearly not as extensive as initially proposed, but as the Chinese philosopher Lao-tzu said, "*A journey of a thousand miles begins with a single step.*"

Chapter 1 - Urban design for psychological restoration: The practical context of the work

The world population is growing rapidly. In the beginning of the 18th century, it counted one billion, but by 2011 it had reached seven billion (United Nations Population Fund, 2011). At the same time, the urban environment has rapidly grown and is expected to grow further in coming decades. Although urbanization has positive aspects, this development has raised environmental, economic and social concerns, and the discussion about sustainable development, or "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (United Nations General Assembly, 1987), has become more important.

Over the past decades, urban development has strongly leaned towards sprawl, characterized by low density, homogeneity in land use, low transport connectivity and automobile dependence. A high demand for land for housing and transport purposes has negatively affected natural areas, ecosystems and biological diversity, and increased pollution due to longer and more frequent trips by car. Health problems have also been related to urban sprawl, which is considered to be one of the greatest hinders to sustainability (e.g., Arbury, 2005; Frumkin, Frank & Jackson, 2004).

As opposed to urban sprawl, urban densification, characterised by high density and mixed land use, is thought to facilitate sustainability within the urban environment. Proponents claim that densification supports environmental, economical and social sustainability, by minimising

land occupation for construction, reducing car-usage, and supporting physical and social activity (e.g., Arbury, 2005). Despite seemingly widespread agreement on the advantages of the compact city model among professional and political institutions, Neuman (2005) notes, however, that empirical research has not established a consistent positive relationship between densification and enhanced sustainability. Despite other useful explanations, van den Berg, Hartig and Staats (2007) point out that the intensive focus on ecological sustainability might have shadowed the importance of social and psychological factors for this context and that attention to them could open up critical perspectives on densification as a means to enhance sustainability.

An extensive literature on psychological effects of dense urban living conditions recommends alertness to the possibility of adverse outcomes (e.g., Evans & Cohen, 1987; Evans, Wells, & Moch, 2003). For example, crowding and noise, which often occur in dense urban environments, impose demands on people and highlight basic issues in adaptation to the environment. One such issue is the recurrent need for psychological restoration. By ensuring that urban dwellers have opportunities to fulfil their needs for psychological restoration, intelligent densification measures may enhance public health and individual well-being while also supporting the pursuit of sustainability.

A restorative environment can be defined as an environment that both permits and promotes restorative experience (Hartig, 2004). Studies considering the potential of different environments to promote restoration have suggested the relevance of this approach for urban design by demonstrating that different urban settings support restoration to different degrees (e.g., Hartig, Korpela, Evans, & Garling, 1997a; Kaplan & Kaplan, 1989; Kaplan, Kaplan, & Ryan, 1998; Staats, van Gemerden, & Hartig, 2010). With inputs from this research, a new

design approach, restorative environmental design (RED), has been proposed. This novel design approach is in part based on the theoretical background and empirical work concerned with restorative effects of nature experience for people living in urbanized societies. It emphasizes environmentally friendly building technologies and promotes the linkage between human and nature as well as focusing on how the built environment can provide psychological benefits. However, as Velarde, Fry and Tveit (2007) point out, the restorative environments literature has so far provided quite limited information on the role that specific physical components and characteristics of the environment play in restorative experience.

In sum, in a world that is increasingly becoming urbanized, it is important to strengthen the positive link between urban density and sustainability. Therefore, design and planning solutions that combine the advantages of urban densification as well as offering opportunities to fulfil needs for restorative experience seem necessary. RED that emphasizes the importance of fulfilling these needs can be considered a valuable approach in this context. However, as a source of information on how to densify the urban environment without compromising the possibilities for restorative experience in an urban residential context, the restorative environments literature seems to be quite limited. Therefore, more empirical work reinforcing the foundation of the design approach seems urgent.

In the following chapter, additional background information about key topics and concepts will be provided. These include the urban environment and urban densification, restoration and restorative environments, complexity and enclosure. The next chapter also introduces theoretical background on restorative experience, studies and findings, and other aspects of the research context that form a basis for the work carried out for this dissertation.

Chapter 2 - Background

The purpose of this chapter is to identify, define and discuss central terms and concepts used in this research, and to describe how they are to be understood within the works put forward in this thesis. These terms and concepts have appeared regularly in the restorative environments scientific literature as well as the literature of other disciplines.

2.1 The urban environment

A generally accepted definition of "urban environment" does not exist, but among social scientists, the concept usually refers to an area of higher population density than adjacent areas (McIntyre, Knowles-Yánez, & Hope, 2000). Broadly speaking, the urban environment can be considered as a combination of two main components; the built environment and the unbuilt environment. In this thesis, the focus will be on the built urban environment. The built urban environment has no widely accepted definition either, but Handy, Boarnet, Ewing, and Killingsworth (2002) claim that it is thought of as having three main elements; the transportation system, which refers to the physical infrastructure and service for various modes of transportation; the land use, which refers to how different types of activities are distributed across different spaces or areas, and; the design, which refers to the city planning and the arrangement, appearance and function of the physical elements and spaces.

Currently, streets occupy around 25-35% of all developed urban land (Jacobs, 1997). According to Carmona, Heath, Oc, and Tiesdell (2003), urban streets can be defined as "*linear three-dimensional spaces enclosed on opposite sides by buildings*" (p. 147) and have through the

history been considered as one of the foundations of the urban landscape, as their design and planning heavily affect urban settings and urban life (Gehl, 1987). Aside from being a fundamental part of the transport infrastructure, streets provide, due to their proximity to residences, opportunities for social activities (Jacobs, 1993). They may also afford more recreation to people than parks, and historically they are among the places where urban dwellers have spent the most time outdoors (Getz, Karow, & Kielbaso, 1982).

2.2 Urban sprawl and urban densification

The urban environment seems to strongly attract people, and in the last 200 years the urban population has grown at an exponential rate. Whether attributed to economic opportunities or to the atmosphere, eventfulness, possibilities, and diversity not found elsewhere, living in the urban environment seems to be beneficial to many. The rapid increase cannot be traced only to growth in the world population, as the proportion of people who are urban dwellers has also accelerated immensely during this period of time. According to the Population Reference Bureau (2012), the global proportion of urban dwellers in 1800 was 3% but exceeded 50% in 2008, which implies a shift from 30 million to more than 3 billion people. This development shows no sign of stopping, and the United Nations (2011) estimate the proportion to become more than 70% in 2050, counting more than 6 billion people.

As a consequence of the increasing urban population, the urban environment has rapidly spread out and through the decades, and various design and planning paradigms have been implemented to deal with the needs of this growing population. One of the most prominent paradigms has involved offering residences in greener and quieter suburbs as a counterweight to

urban environments long described as dirty, crowded, noisy, polluted, and harsh places where people must confront a surfeit of stimulation (Evans and Cohen, 1987; Milgram, 1970; Moser & Robin, 2006). With the aim of creating a more beneficial urban environment, this paradigm has fuelled the development of low density, homogenous and car-oriented urban environment, commonly referred to as "urban sprawl" (Frumkin, et al., 2004). Although possibly beneficial to some people in some respects, such sprawling development has entailed widespread environmental devastation, increasing pollution, higher expenses for transportation and other services, increasing health problems and less social capital, which explains why it is considered a challenge to ecological, economical, and social sustainability (Frumkin, et al., 2004).

Over the last decades, policy prescription in most Western societies has increasingly introduced the idea of compact city as an alternative to the urban sprawl (e.g., Jensen, Christensen, & Gram-Hanssen, 2011). This urban design paradigm focuses on the importance of urban densification, and it is commonly characterized as a high-density and mixed-use urban form that offers environmental, economical and social benefits believed to contribute to sustainability (Jenks, Burton, & Williams, 1996). In comparison to urban sprawl, proponents argue that the idea of a compact city supports urban intensification, where an infill development is practiced in existing urban areas rather than in suburbs which in turn preserves adjacent natural areas and ecological diversity (e.g., Arbury, 2005). Due to increasing compactness, urban densification reduces greenhouse gas emission as residents can live closer to work and shops and can rely on different modes of more environmentally friendly travel, such as walking, biking or using public transport, rather than personal cars. Economically, a dense urban environment is viable as aspects of the infrastructure such as roads, public transport, electricity, sewerage

systems and water supply utilities can be provided cost-effectively on a per capita basis. In terms of social benefits, urban densification and mixed uses can be related to social cohesion, equity, accessibility, cultural development and increasing sense of security in public spaces.

Although many consider the compact city as the most promising form of urban environment for sustainability ends, the relationship between urban density and sustainability seems to be quite vague (Jensen, et al., 2011). Lin and Yang (2006) state that empirical work analysing the relationship between urban density and sustainability is lacking, and in a literature review, Neuman (2005) concludes that existing empirical data demonstrate an inconsistent relationship between urban density and sustainability. As a possible explanation, van den Berg et al. (2007) point out that the neglect of social and psychological factors within the compact city practice may fuel unsustainability. Similarly, Kellert (2005) and Gehl (2010) claim modern urban design and planning paradigms have strong tendencies to overlook some human needs, for example by prioritizing space for cars, creating monotonous buildings and environments in large scale, and limiting access to natural areas and elements. However, if properly designed, van den Berg et al. (2007) think that the compact city can be viable. To help address the existing sustainability challenges with the compact city idea, they suggest taking advantage of knowledge about restoration and restorative environments.

In the following section, the concept of restoration, its theoretical underpinnings and some approaches to measurement will be introduced. The basic features of the RED approach will also be described, some relevant empirical results will be presented, and some information gaps will be identified.

2.3 Restoration, restorative environments and restorative environmental design

2.3.1 Restoration and restorative environments - definition and theoretical background

Hartig (2004) put forward a widely accepted definition for restoration as "*the process of renewing, recovering, or re-establishing physical, psychological, and social resources or capabilities diminished in ongoing efforts to meet adaptive demands*" (p. 273). These resources or capabilities used to adapt to the environment and which are sensitive to depletion can be, for example, the ability to focus on projects at work, the physical energy necessary to get through the workday, or being able to rely on support from friends and family. As the resources or the capabilities become depleted, it becomes more difficult for people to function effectively. For example, due to an inability to focus, they might not be as productive at work as they want to be or they might show inappropriate behaviour in social settings. Although restoration processes concern normal forms of depletion in everyday life, irregular and insufficient restoration can evoke many negative consequences for health and well-being (Hartig, 2007).

All restoration occurs within the context of some activity, and all activity occurs within some environment. As mentioned above, a restorative environment is one that both permits and promotes restoration. So far, research on restorative environments mainly has been guided by one or both of the two most prominent theories in the field. Although sharing some common features, the theories deal with different forms of resource depletion and highlight different antecedents and outcomes.

Attention restoration theory (ART; Kaplan & Kaplan, 1989; Kaplan, 1995) assumes that a person will eventually experience attentional fatigue, or depletion of a directed attention capacity, when concentrating on a particular task over a time. This is due to the prolonged and/or

intensive use of a cognitive mechanism that is essential for excluding competing stimuli or ideas not relevant to the task. Experiencing attentional fatigue can entail various negative consequences; one might make more errors when performing a task, feel more irritated, and have difficulty in planning and executing appropriate actions. As the struggle to pay attention is the central reason for directed attention fatigue, giving the inhibitory mechanism a rest should restore attentional effectiveness. ART postulates that being in an environment that does not require the use of directed attention should serve the purpose, but the overall restorative potential is seen as determined by four interrelated restorative qualities of person-environment exchanges; being away, fascination, extent and compatibility. *Being away* refers to how well the environment supports a sense of distance or freedom from daily routine and the projects that require mental activity. Kaplan (1995) stresses the importance of being psychologically rather than physically away, as one might hardly experience restoration in new settings if still struggling with old thoughts. When feeling away, restoration is supported if the environment supports engagement with objects, events or processes of exploring and making sense of the environment so that one can rely on effortless, interest-driven attention (*fascination*) in the encounter with the environment and so rest the inhibitory mechanism. If the environment is coherent and rich enough for perceptual and conceptual or imaginary experience (*extent*), the fascination is sustained more efficiently. Furthermore, if the environment matches with one's needs, inclinations or purpose at the time and the degree of information available in the environment supports the required and intended activities (*compatibility*), the restoration process will be enhanced more effectively. According to the Kaplans, these four restorative qualities are

commonly found in natural environments, but they claim that a wide spectrum of environments is capable of offering restorative experience.

The second major theory about restorative environments is the psycho-evolutionary theory (PET) (Ulrich, 1983; Ulrich, Simons, Losito, Fiorito, Miles, & Zelson, 1991) which concerns psychophysiological stress reduction. Based on the work of Berlyne (1970) and Zajonc (1980), the theory assumes the initial affective response to the environment is universal and adaptive, and motivates an action appropriate to increase the likelihood of well-being and survival. The affective reaction is based on very limited processing of information about the environment referred to as "preferenda"; a class of indistinct gross, structural visual properties and stimuli. In settings considered favourable for survival, assumed to be characterized visually by gross structure, gross depth properties, a focal point and natural contents such as vegetation and water, a liking or interest reaction will occur rapidly and without conscious thought, motivating approach behaviour and initiating restoration in people who are experiencing stress. However, in unfavourable settings, reactions like dislike and fear will take place, triggering or exacerbating stress and avoidance behaviour. The strength and direction of this process is set by the person's internal states based on past and current history, as he/she enters the visual encounter. Immediately, after the onset of the initial affect response, the theory supposes that cognitive processing will occur, which involves recognition, identification and much broader evaluation of the situation.

Although the theories differ substantially in their views regarding the resources affected by restoration, in the following subsections covering methods and empirical findings, the focus will be on the complementary view the theories can provide. As directed attention fatigue and

stress may occur simultaneously as well as separately, a view of the theories as complementary better serves the purpose of the present work.

2.3.2 Measurement issues and related empirical findings

As a rubric covering multiple physical and psychological processes, restoration and the restorative experience have been measured in various ways in different environments. A substantial body of work has focused on measuring actual restoration, which involves capturing the psychological and physical changes (e.g., in attention, emotional states, heart rate and blood pressure) people experience during or after a visit in a given environment (Hartig, 2011). For example, with a view to multiple restoration processes, Hartig, Evans, Jamner, Davis, & Gärling (2003) collected data on cardiovascular activity, emotional states, and attention before, during and after a walk in a natural or urban environment. They found that the walk in the natural environment promoted restoration, while the walk along streets in the urban environment seemed to exacerbate stress and attentional fatigue. Similarly, Valtchanov and Ellard (2010) collected data on skin conductance, heart rate, attention, and emotional states, before, during and after navigating through an interactive, virtual three-dimensional natural, urban or geometrical environment. The results indicated that the navigation in the virtual nature promoted restoration across all measures except attentiveness. On the other hand, the navigation through the virtual urban environment decreased heart rate, attentiveness, and negative affect while virtual "walk" through the geometrical environment also decreased heart rate and attentiveness. The main advantage of this approach to measurement is that it immediately indicates the impact of the environment on people in terms that can more directly be related to health and well-being than other ways of representing restorative experience. On the other hand, measuring actual

restoration can be costly; it might be difficult to find suitable research settings, equipment and time-consuming procedures may be expensive on their own and sample sizes might have to be relatively large as some effects of interest might be subtle (Hartig, 2011).

Another type of measurement involves judgments about the likelihood of experiencing restoration should one visit a given environment, which has typically been presented with photographs. As a need for restoration must exist for restoration to happen, studies using this measure commonly include a scenario intended to establish the level of a need for restoration. The scenario indicates in which particular condition (e.g., having a strong need for attentional restoration) the participants are to imagine themselves being when giving their evaluation of the environment. One important advantage of this approach is the possibility to use single-item measures for the psychological variables of interest, which can be very cost-effective and convenient. As ratings of restoration likelihood are assumed to rely on participants' previous restorative experience in various environments, the method serves well for studies that aim to evaluate environments that, because they do not yet exist (i.e., they are proposed design and planning alternatives), cannot be used in studies of actual restoration (Hartig, 2011). However, the main disadvantage of this approach is the uncertain correspondence between the perceived likelihood of experiencing restoration and the actual restoration experienced. Will people in need of restoration actually become more restored in environments that have gotten high ratings on restoration likelihood than in environments with lower likelihood of restoration ratings? To the best of my knowledge, this question has not yet been addressed empirically. If results from studies using restoration likelihood as an outcome are compared to those using actual restoration as an outcome, quite similar trends in the outcomes can be recognized (e.g. Hartig et al., 2003;

Staats, Kieviet, & Hartig, 2003; van den Berg, Koole, & van der Wulp, 2003; Staats & Hartig, 2004; Hartig & Staats, 2006). This indicates a gross correspondence between these two measurement approaches.

The third form of measurement to mention here is perceived restorative quality, which refers to the experience participants have with the qualities of person-environment exchange described in ART as supporting restoration (i.e., being away, fascination, extent, and compatibility). As such, the measure is relevant for testing mediating processes between the environment and restoration. Supporting this notion, Nordh, Hartig, Hagerhall, & Fry (2009) indicated the mediating role when finding judgments of two restorative qualities (being away and fascination) given by two separate groups to be strongly affected by objectively measured physical characteristics of small urban parks and in turn to strongly predict judgments of restoration likelihood given by the third group. Like the restoration likelihood measure, the measure of perceived restorative quality taps into previous experiences people have had with various kinds of environments and can provide information that serves efforts to design restorative environments (Hartig, 2011).

2.3.3 Restorative environmental design for urban densification

Due to the importance of restoration for effective functioning in everyday life, health and well-being, restorative quality has been considered as an important component of environmental quality. Based on one or both theories about restorative environments, a growing body of empirical work has focused on the kinds of environment that support restorative experience.

In line with the two theories, numerous studies, carried out in both laboratory and field settings, have reported relatively greater restorative effects of the natural environment over other

environments (e.g., Berman, Jonides, & Kaplan, 2008; Hartig, Mang, & Evans, 1991; Hartig, & Staats, 2006; Hartig et al., 2003; Ulrich et al., 1991). The picture seems to be more complicated than one could think, however, as these studies strongly tend to divide the environment into two distinct, narrow categories; natural versus urban environments. As a result, they fail to reflect the vast diversity found in both types of environments and so may overestimate the restorative value of some natural environments and underestimate the restorative value of some urban settings (cf. Velarde et al., 2007). Supporting this point, several studies have found that people assign different restorative potentials to different urban settings (Hartig et al., 1997a; Herzog, Maguire, & Nebel, 2003; Hidalgo, Berto, Galindo, & Getrevi, 2006; Staats et al., 2010; White, Smith, Humphryes, Pahl, Snelling, & Depledge, 2010) with some results showing that some urban settings have a perceived restorative potential similar to or greater than that of some of the natural environments studied (e.g. Herzog et al., 2003; Nasar & Terzano, 2010). This should not be understood as a devaluation of natural environments as restorative places. Rather, it should be taken as an indication of the restorative opportunities the urban environment might offer if properly designed and planned.

RED is a practical approach which builds in part on theory and empirical research concerned with restorative environments (e.g., Kaplan et al., 1998; Kellert, 2005). Based on the premise that a restorative environment must simultaneously permit and promote restorative experience, RED pays attention to negative features and processes as it seeks to avoid or limit causes of stress and attentional fatigue in the environment (e.g., traffic, pollution, noise). Simultaneously, it emphasizes the value of positive features and processes by providing or restoring characteristics which promote restorative experience. As an alternative to traditional

approaches which aim to enhance sustainability by calling attention to the negative consequences and appealing to negative emotions (cf. Corral-Verdugo, 2012), RED concerns the features of the physical environment that might positively affect people and consequently also motivate more sustainable patterns of behaviour (e.g., Hartig, Kaiser, & Bowler, 2001; Hartig, Kaiser, & Strumse, 2007). But, implementing RED as a tool for urban densification can seem somewhat problematic as the empirical literature the design approach relies on is in need of further development. Although numerous studies have provided information about the restorative potential of the urban environment, some common urban settings have received little attention. Of particular interest here, streetscapes have largely been neglected, although they are prominent elements of the broader urban environment and urban infrastructure, and they will have fundamental importance for the compact city paradigm. For example, empirical studies concerning the restorative influences of architectural characteristics and greenery in streetscape settings hardly exist. As a result, the empirical literature on restorative environments provides limited guidance for RED as applied to streetscapes in densifying cities.

To come around the gap in empirical work on restoration in the built urban environment, the preference literature might offer insights, as several studies indicate a strong correlation between preference and restoration (e.g. Hartig & Staats, 2006; Nordh et al., 2009; Staats & Hartig, 2004; Staats et al., 2003; van den Berg et al., 2003). In the following section, information will be provided about how different constructs, shown to be influential for environmental perception and highly relevant for urban densification, also affect preference judgments. Thus, research on environmental preferences can provide valuable guidance for the empirical work the RED relies on.

2.4 Preference research as a guide for restorative environmental design

2.4.1 Complexity and entropy

It is conventional in Western societies to regulate architectural design in urban environments through design laws and regulations (e.g., Stamps, 2000). One commonly regulated design principle concerns visual complexity; laws and regulations serve to promote visual diversity, richness or variety and to avoid monotony or chaos. In line with this convention, many studies have suggested the importance of complexity for preference evaluations (e.g., Akalin, Yildirim, Wilson, & Kilicoglu, 2009; Imamoglu, 2000).

In their preference framework, Kaplan and Kaplan (1982; 1989) consider complexity as one of four main informational determinants of environmental preference. The framework assumes that, as an evolutionary heritage, people need to be involved with the environment to acquire information, which they can make sense of and integrate into mental maps that support effective functioning. When viewing a scene, complexity is considered as a determinant of preference as it encourages exploration and offers immediate involvement with the environment. Due to the prevalence of concerns about complexity in urban design rules and regulations, the role of the construct as a determinant of preference evaluations, and the fact that the level of complexity can be changed independently from the levels of density, it is highly relevant to study the relationship between visual complexity and restorative experience with a view to the design of dense urban environments.

In the field of environmental aesthetics, complexity has commonly been defined as the number of elements present in a scene (e.g., Herzog, Kaplan, & Kaplan, 1982). In comparison to other environmental variables, the interest in complexity can be traced quite far back,

presumably due to its immediate relevance for environmental perception. By systematically testing artificial stimuli, Berlyne (e.g., 1960, 1974) found the relationship between complexity and preference to have an inverted U-shaped, i.e. low and high complexity stimuli were least preferred but stimuli having an intermediate level of complexity were most preferred. However, the picture becomes more complicated when preference is tested with stimuli from the physical environment as some studies have supported Berlyne's finding of an inverted U-shaped relationship between complexity and preference (e.g., Akalin et al., 2009; Imamoglu, 2000) while other indicate a linear relationship between the two variables (e.g., Devlin & Nasar, 1989; Kaplan, Kaplan, & Wendt, 1972; Nasar, 1984). A meta-analysis based on 1,820 stimuli and data from 6,280 participants, seems to demonstrates this inconsistency, as across studies the correlation between the two variables was found to range from -.11 to .97 (Stamps, 2004a). This inconsistency opens up for speculation. One possible explanation might be the lack of a clear definition of complexity (Herzog, 1989). Stamps (e.g., 1994, 1999a, 2004b) suggests that the verbal terms describing complexity, such as “richness”, “diversity” and “variety”, which all refer to how much information settings contain, are too subjective and vague. He suggests that buildings and blocks of buildings with known amounts of diversity can be created in an objective and systematic way by applying a mathematical formula for informational disorder, or entropy (e.g. Stamps, 2003, 2010a). The fundamental equation for entropy is Equation 1, in which H is the entropy, p is the probability of occurrence of a level of a factor, and the summation is over the levels of the factors.

$$H_{factor} = -\sum_{i=1}^{nlevels} p_i \log_2 p_i$$

Equation 1. Entropy formulation

As entropy is based on frequencies of different characteristics or design features in the environment, entropy is zero if all elements in the environment are identical which means that there is no informational disorder, whereas maximum entropy is reached when all elements are unique.

The entropy formulation can be applied to various types of stimuli and different environmental conditions (Stamps, 2010a). For studies on the built urban environment, entropy can be used to determine the complexity of individual buildings as well as blocks of buildings, but these elements might influence perception of the urban environment differently. For example, a city block might have a uniform appearance if it consists of a number of identical buildings even though each building per se could be perceived as having a highly complex appearance. Similarly, a city block consisting of a number of buildings that individually look plain could be perceived as having a heterogeneous appearance if the buildings all differ from one another.

According to Stamps (2004b), entropy is a valid indicator of visual diversity; a meta-analysis based on 133 stimuli from the built environment and 523 participants indicated a strong positive correlation (r = .73) between entropy and perceived diversity. On the other hand, the relationship between entropy and preference seems to be less certain. Stamps (2004b) found significant heterogeneity in study results focusing on the relationship between entropy and

pleasure[1], with some studies finding negative correlations and others positive ones. The direction of the associations may depend on the specific features of the built environment covered by the entropy calculation. For example, entropies for the facades of old buildings, signs and residential contextual fits correlated negatively with pleasure ($-.60 < r < -.21$), whereas entropies for building colour, scale, shape, articulation, openings and openings colour correlated positively ($.57 < r < .97$) (Stamps 2003, 2004b). Attempts to find an inverted U-shaped correlation between pleasure and entropy have so far not done so (Stamps, 2003, 2004b).

In sum, variations in architectural attributes or architectural complexity of the built urban environment can be objectively indicated as levels of entropy. Although showing mixed results, the empirical work has demonstrated entropy as influential for environmental preference. Given that preferences are informative with regard to restorative potential, the empirical research indicates the likely relevance of complexity when designing built urban settings that can serve the need for restorative experience. Research is needed which directly addresses this possibility.

2.4.2 Enclosure

Another feature of the environment that strongly affects perception is enclosure. The importance of enclosure is such that neurophysiologic studies (e.g., Epstein & Kanwisher, 1998; Epstein & Ward, 2010) have demonstrated a special region in the brain, the parahippocampal place area (PPA), that reacts directly to spatially enclosed layouts but not to separate objects and faces.

[1] Stamps (2002a) takes the terms "pleasure" and "preference" to be synonymous and uses them interchangeably, assuming that pleasantness ratings are indications of preference.

As any enclosing elements in environments can be considered a barrier affecting the range of vision and locomotion, Stamps (2005a, b) recommends the use of visual and locomotive permeability in research concerned with the evaluation of enclosure. In a meta-analysis, Stamps (2005b) found a strong positive correlation between perceived enclosure, which is a function of how easily one thinks that one could see or move through a boundary, and the percentage of vertical solid surfaces (e.g., a brick wall) that hindered visual and locomotive permeability. Similarly, by presenting images of indoor spaces of different sizes surrounded to different degrees by permeable regions, Stamps (2010b; Experiments 1 & 2) could conclude that the visual permeability of the boundaries showed a strong positive correlation with perceived enclosure, whereas the size of the floor within the boundaries, which indicated locomotive permeability, was negatively related to enclosure judgments. Stamps (2011) compared the height of space boundaries and the size of the horizontal area within the boundaries on perceived enclosure and found that height affected perceived enclosure to a greater extent than the horizontal area. 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 increased the sense of enclosure.

From a theoretical point of view, the importance of enclosure relates to survival through the sense of safety. According to prospect-refuge theory (Appleton, 1996), the chances of survival should be greatly enhanced if one is being able to spot a possible enemy in advance and have the opportunity to escape and hide from it. Therefore, it can be assumed that people prefer environments that simultaneously seem to provide opportunities for viewing the surroundings and for hiding or refuge, and that this might give rise to an inverted U-shaped relationship

between enclosure and preference. Supporting this notion, in a study using urban environmental categories, Herzog (1992) found higher preference for a category that consisted of smaller spaces with high spatial organization than for categories characterized by open and undefined environments, blocked views or enclosed settings that all turned out to be equal in preference ratings. Similarly, by presenting 42 static open ended streetscape images, Alkhresheh (2007) found an inverted U-shaped association between levels of enclosure and preference, using safety and sense of comfort as indicators of preference.

Government and planning authorities around the globe have favoured high-rise buildings as a means to increase sustainability within the compact city paradigm (Shin, 2010). However, scholars like Evans (2003) and Gehl (2010) have pointed to the possibility of negative psychological consequences of this development trend. Given the relationship between building height and perceived enclosure, and the relationship between the degree of enclosure and preference, more knowledge on the influences of building height on restoration seems necessary for the creation of psychologically sustainable dense urban environments.

2.4.3 Vegetation along streets

Being in contact with nature arguably is a basic human need, and such a need might explain the fact that, throughout history, a link to nature has been a common approach to improving urban quality (Kellert, 2005). In keeping with this view, a large body of empirical evidence describes access or residential proximity to green space as a health resource for urban residents (e.g., Groenewegen, van den Berg, Maas, Verheij, & de Vries, 2012; van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012). In efforts to densify urban environments, however, this value seems too often be set aside, and this might partly explain the lack of

correlation between urban density and sustainability (van den Berg et al., 2007). Urban densification commonly involves high demands for exploiting areas available for construction, and this in turn threatens the continued existence of green urban spaces. With decreasing amounts of urban green spaces, street vegetation will become increasingly important. Getz et al. (1982) claimed that trees along streets may be just as important for residents as having them in parks.

Empirical research provides some information on how different components or characteristics of street vegetation affect preference and so might affect their restorative potential. For example, trees have been found to be the strongest single predictor of preference in streets when compared to other natural elements such as hedges, flowers, grass and soil, and flowers were more preferred as elements for street-side plots than bare soil, grass or hedges (Todorova et al., 2004). Tree arrangement and tree size have also been shown to affect preference judgments, as people tend to prefer a symmetrical arrangement of vegetation along streets over an asymmetrical arrangement (Weber, Schnier, & Jacobsen, 2008) and larger trees over small ones (e.g., Schroeder, Flannigan, & Coles 2006; Heimlich, Sydnor, Bumgardner, & O'Brien, 2008).

In sum, given the correlations found between preference and different measures of restoration, it can be assumed that the preference literature can help to guide studies that support RED. In the absence of research on specific features of the built urban environment that affect restorative potential, one can look into the preference literature to identify specific physical attributes of environments that affect preference and so which could affect restorative experience. When implementing the novel RED approach in densifying urban areas, streets

might be considered as important settings where urban residents have opportunities for restorative experience. Preference studies indicate that architectural properties, such as entropy and the height of buildings along streets, can contribute significantly to environmental preference evaluations. Similarly, and in line with studies revealing the importance of nature and natural elements for psychological restoration, the preference literature identifies street vegetation and its arrangement as potentially valuable resources for RED.

2.5 The utility of virtual environments for restorative environmental design

To address the aforementioned research gaps, the enormous improvements in computer and display technology made over that last twenty year offer valuable methodological approaches.

Studies of restoration likelihood and restorative quality have relied on static real-life images (Hartig & Staats, 2006; Nordh et al., 2009) or videos (Karmanov & Hamel, 2008) presented in laboratory settings where irrelevant environmental factors and confounding variables can be controlled. User-friendly graphics editing programs (e.g., Adobe Photoshop, GNU Image Manipulation Program (GIMP)) provide possibilities to edit static real-life images to systematically manipulate the characteristics of the environments shown. With real-life video clips, it may be more difficult to achieve the desired precision in manipulations as the graphical editing requires a substantially higher level of expertise and financial resources. Though these techniques have their merits, they also are criticized. Much of the critique against these approaches concerns the issue of "ecological validity", as the studies are carried out in settings quite far from the real, outside world, and they rely on passive experience as the participants

statically watch the environment presented without having opportunities to interact with it or control their path through it.

In comparison, in studies of actual restoration (e.g., Hartig et al., 1991; Hartig et al., 2003; Johansson, Hartig, & Staats, 2011) and in some studies of restorative quality (e.g., Hartig et al., 1997a), the researchers have carried out data collection in field settings where participants could freely interact with the environment and find their way through it. However, in field settings, a systematic manipulation of environmental properties is very challenging, and confounding variables and the effects of unrelated environmental stimuli, which may interfere with the restorative experience, can raise problems.

As a novel methodological approach in the field of restoration studies, powerful and rapidly developing computer technologies can be considered as an alternative, as they open up for the creation and presentation of highly realistic, interactive, three-dimensional virtual environments in which almost every visual aspect of the physical environment can be precisely manipulated and confounding factors strictly controlled (de Kort & IJsselstein, 2006; Depledge, Stone, & Bird, 2011; Rohrmann & Bishop, 2002). Along with the development of these possibilities in graphical environmental creation, their simplicity and accessibility, both literally and in financial terms, have also been greatly enhanced. For example, a free version of the three dimensional modelling software Trimble SketchUp® (previously known as Google SketchUp®) can be downloaded directly from the internet. With a very simple interface and marketed under the slogan "*3D for everyone*" (Sketchup, 2012), Trimble SketchUp® is a powerful and very convenient tool to generate three-dimensional built urban environment of interest for empirical testing. For static, photorealistic image creation or walk-through animation, user-friendly

rendering engine plug-ins (e.g., VRay for SketchUp®) can easily and cost-effectively be added to the program. For photorealistic, interactive display, the three-dimensional Trimble SketchUp® models can be imported to video game development tools (e.g., Unity 3D®), many of which are free of charge but which might require some skills and knowledge in 3D modelling. According to Frey, Hartig, Ketzel, Zinkernagel, & Moosbrugger (2007), video game technology seems to be a promising approach for psychological experiments, and due to a highly developed and very user-friendly interface, even useful with for participants who are unfamiliar with three-dimensional virtual environments and video games.

As earlier mentioned, the advantages of this approach have rarely been utilized in studies on restoration. In light of similar outcomes when compared with other studies on restoration, the few studies done using the approach (e.g., Valtchanov & Ellard, 2010; Valtchanov, Barton, & Ellard, 2010) speak to its methodological relevance. Also relevant to the validity of this approach, Stamps (2010c) showed in a meta-analysis with data from 6,323 participants and 967 environments, a strong correlation (r = .82) when comparing subjective evaluations from onsite and dynamic media. What the literature does not yet include is a systematic application of these methods leading from static digital images that can be rated on restorative quality and restoration likelihood to the assessment of actual restoration in different interactive, tree-dimensional virtual environments constructed from the previously evaluated static images.

2.6 Aims, structure and study objectives

The aim of the present work is to investigate empirically the influences of architectural characteristics and vegetation on restorative experiences in urban residential streetscapes. Given

evidence of a strong correlation between preference and restorative experience, guidance was taken from research on environmental preferences and with a view to the practical demands of densification. Entropy (aggregate architectural variation) and the height of buildings, the number, size and arrangement of street trees, and flowers and grass beside buildings were chosen as environmental components for examination in this work. The present work also considers the correspondence between two forms of measurement relevant to understanding restoration; ratings of the likelihood of experiencing restoration in a given setting, and measurement of actual restoration considered in attentional and affective terms. The choice of measurement form corresponds with different modes of stimuli presentation, digitally created static images and interactive, three-dimensional, virtual environments.

The theoretical and empirical work in line with these aims is presented in the following four chapters. Chapters 3 - 6 are based on papers that are, respectively, forthcoming, published, resubmitted after an initial peer review, or recently submitted for publication in a scientific journal. Chapter 3 (or Paper I) is a theoretical paper and Chapters 4 - 6 (or Papers II - IV) are empirical papers. The hypotheses and research questions of the respective papers are outlined below.

Chapter 3 provides an introduction to research on environmental supports for psychological restoration, with an emphasis on the natural environment as a setting for restoration. The fundamental premises of the restoration perspective are set out, along with discussion of environmental design and management measures aligned with that and other perspectives on human adaptation to the environment. The chapter provides a review of studies

considering restoration as a link between nature and health. It also points to the need for research on how nature and natural elements can be integrated into the built urban environment to enhance restorative experience, and how architectural characteristics of the built environment can serve restoration needs.

Chapter 4 is a report of an experiment that focused on how specific architectural properties of residential streetscapes can support psychological restoration. Taking guidance from the preference literature, building height, facade ornamentation and roof type were chosen as relevant characteristics of city blocks along a street, given the interest in RED combined with urban densification. With systematic manipulation of these architectural properties in static digital images, the study investigated their impacts on judgments of restoration likelihood. Furthermore, the study tested the role of two theoretical constructs from restorative environments theory as mediators between the physical environment and judgments of restoration likelihood. More specifically the following hypotheses were addressed:

4.1 At the lower end of the entropy scale, increasing streetscape entropy positively affects judgments of restoration likelihood.

4.2 The influence of streetscape entropy on judgments of restoration likelihood is mediated by the experiences of (a) being away and (b) fascination.

4.3 Streetscape building height negatively affects judgments of restoration likelihood.

4.4 The influence of streetscape building height on restoration likelihood is mediated by the experiences of (a) being away and (b) fascination.

Chapter 5 is a report of an experiment that dealt with the question of whether the introduction of street trees, grass and flowers to the streetscapes shown to have the lowest and highest restoration likelihood in the preceding study would further affect ratings on restoration likelihood. Again, taking guidance from the preference literature, five vegetation variables were tested: the number of trees, their arrangement along the street, their size, the presence versus absence of grass beside buildings, and the presence versus absence of flower beds beside buildings.

The analyses dealt with the following hypotheses:

Judgments of restoration likelihood increase with:

5.1 Increases in the number of street trees.

5.2 Increases in the size of street trees.

5.3 The presence of street trees on both versus only one side of the street.

5.4 The presence of grass.

5.5 The presence of flowers.

In addition to assessing the independent effects of the different vegetation variables on ratings of restoration likelihood, the extent to which those effects were mediated by ratings of being away and fascination, are tested. Furthermore, the study took interest in whether the ratings of restoration likelihood for streetscapes depended on the overall amount of street vegetation.

Chapter 6 is a report of an experiment that focused on the correspondence between the ratings of restoration likelihood measured in the two earlier studies and actual restoration experienced by members of an entirely different sample when navigating through one of two

virtual three-dimensional urban neighbourhoods constructed from streetscapes previously shown to differ in ratings of restoration likelihood.

Two sets of hypotheses were tested.

6.1 Participants that experience the neighbourhood previously rated as more restorative will show more improvement in their performance on a test of attention as well as a greater improvement in affective balance.

6.2 These differential effects of the virtual neighbourhoods on attention and affect will be mediated by being away and fascination.

The dissertation concludes with general discussion in Chapter 7, which covers the main findings, their implications, and limitations and directions for future studies.

Chapter 3 - Paper I: The restoration perspective: Linking nature experience with health.

Hartig, T. & Lindal, P. J. (2012). The restoration perspective: Linking nature experience with health. Translated into German and forthcoming in L. Kruse (Ed.), Natur, Naturwahrnehmung, Naturschutz: Nachhaltige Entwicklung aus Sicht der Psychologie. Sankt Augustin, Germany: Academia Verlag.

3.1 Introduction

Urbanization entails less access to natural areas. This fact has motivated efforts to protect existing natural areas from further urban development, to establish large urban parks, and to bring trees and other representations of "nature" into urban spaces where people might see and value them, as with pocket parks, street trees, roof greening, and green walls. These efforts have succeeded in part because many people believe claims that contact with the natural environment serves mental and physical health. It seems they are willing to accept these claims because personal experience affirms their veracity. Despite this popular support, however, such claims have sometimes been swept aside on the grounds that they are merely romantic or nostalgic notions which stand in the way of "progress."

Some romantic notions may however have greater depth than proponents of such progress have supposed, as indicated by work done in recent decades in environmental psychology (cf. van den Berg et al., 2007). Researchers in the discipline have articulated theory and conducted empirical studies that have increased the plausibility and rigor of claims about benefits of contact with nature for mental and physical health. This work may make it more difficult to dismiss the arguments put forward by citizen groups, environmental organizations, and other interested parties who are trying to preserve and enhance opportunities for contact with nature close to the urban places where so many people now live and work. At the same time, the work in environmental psychology has added nuance and suggested qualifications to claims about nature and health, which sometimes have appeared excessive or insensitive to the influence of the societal context in which encounters with nature occur. This work can thus be counted as a significant contribution from environmental psychology to the intelligent pursuit of

sustainability, which recognizes that sustainability goals have cultural, social, and psychological aspects as well as ecological ones. Intelligent sustainability measures reflect an understanding that technological solutions can fail if they neglect how people behave and the social and cultural context in which that behaviour occurs.

In this chapter, we provide an introduction to a fundamental component of the psychological research on the nature-and-health topic. In doing so, we work from a perspective on relations between people and the environment that emphasizes the mundane needs that people have for psychological restoration as well as the varying potential of environments for supporting restoration. This restoration perspective is particularly important for research on nature and health; restoration has long been recognized as a commonly sought after outcome with visits to natural areas (Knopf, 1987), and a growing body of evidence substantiates the view that restoration is a key pathway through which contact with nature can positively affect health (Health Council of the Netherlands, 2004; de Vries, 2010; Hartig et al., 2011).

In the following, we first set out the fundamental premises of the restoration perspective and discuss environmental design and management measures that are aligned with that and other perspectives on human adaptation to the environment. We then review research that has treated restoration as a pathway linking nature with health, particularly for members of urban populations. Following that, we discuss the need for research on ways to combine natural and architectural features in urban settings to meet the restoration needs of residents. This is an environmental planning and design issue that will grow in importance as urban populations grow and concerns about sustainable urban development intensify.

3.2 The Restoration Perspective: One View on Human Adaptation

Individual adaptation to environmental change has long been a central concern of research and theory in environmental psychology (Saegert & Winkel, 1990). This concern has found expression in three areas of inquiry, which respectively concern processes of stress, coping, and restoration. These areas complement each other; they have to do with related aspects of adaptation, but they differ in their emphases. Work on environmental stress has emphasized the demands from the environment that challenge adaptation, as well as the changes that take place in people as they face those demands with the resources that they have available. Work on coping has emphasized the psychological, social, material and other resources that people use when trying to meet demands imposed by the environment, as well as the strategies they adopt for using the available resources. Work on restoration has emphasized the processes through which people restore cognitive, social and other resources that have become depleted in their efforts to meet environmental demands, and the various components of environmental experiences that support restoration of the depleted resources (cf. Saegert and Winkel, 1990).

Each of these areas of inquiry builds on distinctive theoretical and practical premises. Those premises constitute particular perspectives on adaptation as a fundamental issue in relations between people and the environment. The theoretical premise of the stress perspective is that when a person continuously faces heavy demands, then adaptation can fail, as reflected for example in poor physical or mental health. To prevent that failure, interventions can seek to reduce the burden of demands that people face. In contrast, the theoretical premise of the coping perspective is that a person can meet even very heavy demands over long periods if he or she has sufficient physical, psychological, material and social resources. Interventions that make

resources more readily available to people, or which help people to make better use of the resources already available to them, can help them to better maintain adaptation. In turn, the theoretical premise of the restoration perspective acknowledges that a person can have ample protection from environmental demands and abundant resources at hand and yet still need periodic restoration. In pursuing goals, in sustaining social relations, in doing many of the activities that add meaning to life beyond merely surviving, a person unavoidably depletes some of his or her resources. To continue with his or her activities while also maintaining adaptation to the environment, he or she must restore resources that have become depleted. Interventions that enhance people's opportunities for restoration can help them to more easily, quickly, and completely restore those resources. The premises of the three perspectives are summarized in Table 3.1 (cf. Hartig, 2001, 2008; Hartig, Bringslimark, & Patil, 2008).

Table 3.1. Perspectives on human adaptation to the environment with associated environmental design approaches.

	Stress Perspective	Coping Perspective	Restoration Perspective
Theoretical Premise	Heavy demands can undermine adaptation.	Readily available resources support adaptation.	Adaptation requires periodic restoration.
Practical Premise	Interventions can eliminate or mitigate demands.	Interventions can enhance the availability of resources.	Interventions can enhance opportunities for restoration.
Design Approach	Protective	Instorative	Restorative

Each of the three perspectives on adaptation has been a guide to environmental interventions since early humans began to build, if not far earlier (James, 2011). Their respective practical premises have over this long span of time been expressed in a great variety of environmental design and management measures. The different measures might be categorized according to the premise upon which they are based, as shown in Table 3.1. Examples of what can be called protective environmental design include walls and roofs that shelter people from the elements, and so eliminate or mitigate some demands, such as exposure to rain and snow, the sun and cold. Examples of instorative environmental design improve access to resources in order to deepen or strengthen the ability of people to meet demands. They include arrangements for heat and water indoors that make those resources available to people where and when they need them most; paths and roads that extend people's reach to other places and so open up access to social contacts, material resources, and innovations; and playgrounds and gardens that stimulate learning and challenge people to develop new capabilities.

Restorative environmental design may seem indistinguishable from protective environmental design in some respects. For example, roofs and walls that shelter people from harsh weather and predators might also help them to sleep more soundly. Restorative environmental design has an important distinguishing characteristic, however; it goes beyond elimination or mitigation of demands to provide environmental features that promote restoration. An urban park ordinarily does more than provide residents with a quiet place to escape from everyday demands; it also provides pleasant distractions that pull visitors' thoughts away from the demands they face, thereby sustaining psychological restoration.

Various other features of the built environment may have restorative as well as protective and instorative value. Windows provide protection from the elements while also letting in light that enables people to perform activities indoors. If a window also provides a view onto pleasant natural scenery, then it may also promote restoration during breaks from work (e.g., Kaplan, 1993, 2001). Still other features may not serve any protective function, but they may promote restoration for people who are in need of restoration and they may also give an instorative boost of positive feelings to those who do not need restoration at the moment. Indoor plants and pictures of nature in windowless interior spaces might provide such dual benefits (e.g., Bringslimark, Hartig, & Patil, 2009, 2011).

The considerable overlap of the different categories of interventions should not come as a surprise, as the premises on which they rest concern inseparable and to an extent mutually defining aspects of adaptation. Environmental interventions can therefore serve adaptation in three ways simultaneously, by supporting protective, instorative, and restorative functions. The built environment thus stands as a set of complementary adaptive capabilities, continuously employed or available on demand. Yet, interventions that are guided by one perspective on adaptation may work against requirements for adaptation indicated by another perspective. For example, a new building in an already dense urban area may provide needed housing in an area with attractive employment opportunities, but it may come at the cost of green space that the current residents value as a setting for restoration (cf. Hartig, 2007).

3.3 Restoration as a Pathway Linking Nature Experience and Health

The interventions guided by the stress, coping and restoration perspectives have a profound relevance for the present discussion; over the long course of human history they contributed to the process through which, in some societies, "nature" became distinguished from the built or artificial environment (Hartig & Evans, 1993). In many places, people have sought to distance themselves from the harsher aspects of the natural environment and the demands of living off the land, and they have moved into houses and cities in pursuit of safety, comfort, and ways of making a living that are less susceptible to capricious forces of nature. Perhaps this fact has made it easier to dismiss as a romantic notion the claim that contact with nature promotes health; the claim would seem to neglect the hardships imposed by the kind of rural existence that would provide abundant contact with nature. Such a dismissal would however ignore the possibility that relatively brief contacts with the more pleasant and unthreatening aspects of the natural world could still be important for the well-being of the many people who enjoy the comforts and amenities of an urban lifestyle. This significance of contact with nature for urban residents comes not least from the support it can provide for restoration. Dismissal as romantic "fluff" the claim that contact with nature promotes health would also inappropriately discount the efforts that people have made over time to maintain contact with preferred aspects of the natural world in urban surroundings. Ståhle (2008) has asserted that there hardly exists a city without greenery, and in indoor settings that offer no visual contact with the outdoors, people may bring in plants and other nature surrogates as forms of compensation (Bringslimark et al., 2011).

In the following, we will review research that has treated psychological restoration as a plausible pathway through which contact with nature could affect the health of members of urban populations. Before proceeding to the review, however, we will more carefully define some key terms, the meanings of which have been left largely implicit in the foregoing.

3.3.1 Definitions

Three terms need closer specification here. The first is "nature experience". The research that we will review does not deny the importance of the objective physical environment, but it assigns heavy weight to the subjective experience of the environment. It assumes that people are continuously engaged in perceiving, evaluating, and assigning meaning to the events and conditions in the world around them. The term "nature experience" reflects the assumption that health benefits follow from a person's experience of an environment, and not only their mere presence within it. The "nature" encompassed by this term is comprised of seemingly natural features and processes that people ordinarily can perceive without special instruments or sensory aids. It includes trees and forests, other vegetation, weather, seasonal variations, the movement of water in rivers and streams, waves rolling in at shorelines, and so on. This meaning of "nature" overlaps substantially with the meaning of "natural environment", which is commonly used to refer to a large outdoor area with little or no apparent evidence of human presence or intervention (Pitt & Zube, 1987). Consequently, "nature" and "natural environment" are used somewhat interchangeably in this research area. This said, research has recognized that settings such as urban parks, botanical gardens, and golf courses may be as thoroughly designed, shaped, and organized as any urban centre, yet may be perceived as natural because they mainly consist of trees, other vegetation, and other natural-appearing features. Further, research has

acknowledged that a person might have some sense of being in a natural environment while actually being situated in what objectively could be described as an artificial environment. This may particularly be the case with regard to visual aspects of the natural environment (or the natural landscape; Daniel, 2001), as when a person views natural scenes presented in photographs, films, video or virtual reality set-ups. Finally, despite the great variation in environments and environmental features of interest here, most research in the area has concerned places that most people can see or visit. Rather than polar regions, sand deserts, high mountains, and other wild places, most of the research concerns seemingly natural environments and natural features that are benign, close to home, and shared with other people. At the same time, most if not all of the literature on nature experience and health concerns people in urbanized societies who may be less sensitive to differences between the natural and artifactual than, for example, indigenous people who live continuously in "natural" or "wilderness" environments. Additional discussion of these definitional issues is provided by Wohlwill (1983), Hartig and Evans (1993), and Hartig et al., (2011)

The second term needing closer specification here is "health". The World Health Organization (WHO; 1948) has defined health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." This widely disseminated definition seems utopic and unrealistic, but it has important heuristic advantages. In calling attention to a person's physical, mental, and social condition, it affirms a view of health as multi-dimensional, and so invites consideration of how health arises from the interplay of multiple factors. In directing attention to well-being, it invites consideration of subjective aspects of health, since well-being has a crucial subjective aspect. Attention to the subjective aspect of

health aids appreciation of how psychological, social and cultural factors can come to work in chronic ill health as well as in the maintenance of good health under even very difficult circumstances, as discussed by Antonovsky (1979). In downplaying the idea that health involves an absence of symptoms, the WHO definition affirms the importance of preventive as well as curative measures. This affirmation, together with acknowledgement of the multi-dimensionality of health, implies a need for a greater variety of actors in the health enterprise than does a definition that frames health in terms of symptoms in need of treatment. Medical professionals will continue to play a key role in caring for the ill, but other professionals also can assume responsibility for preventing disease and promoting well-being in individuals and populations. The disease prevention work can aim at positive as well as negative aspects of human-environment relations. For example, environmental health professionals can promote health not only by identifying and removing toxic agents, but also by supporting salutogenic contacts with nature (Frumkin, 2001). Thus, some of the preventive work can be organized, for example, under the restoration perspective.

The third term needing closer specification here is "restoration." The term serves as a rubric that covers a variety of processes through which people restore the adaptive resources or capabilities that they use to meet the ordinary demands of life. Physiological resources include the ability to mobilize physical energy for action aimed at some demand, whether acute, as when hurrying to catch a bus, or persistent, as when working hard over an extended period to meet a deadline. Psychological resources include the ability to maintain the necessary focus on some task at hand, even when noise or other distractions make it harder to concentrate. Social resources include the various forms of help or support provided by family, friends, and co-

workers at home, at work, and elsewhere. Because a person depletes various resources in meeting everyday demands, a potential or need for restoration arises regularly. New demands will certainly come along, so the person must secure adequate possibilities for restoration or risk not being able to meet those demands. Over time, a lack of adequate restoration can translate into problems with mental and physical health.

Restoration has environmental requirements; it will not occur under all circumstances. The research reviewed in the next section describes in psychological terms the environmental conditions considered to support restoration. Here, it suffices to say that restoration has two basic requirements. First, the environment permits restoration. While in the environment, a person can be relatively free of the demands that gave rise to the need for restoration in the first place. Second, the environment promotes restoration. Some demands are in a sense portable, and not closely tied to any one place; a person could feel troubled and ruminate over them almost anywhere. However, some environments have features and afford activities that attract and hold attention. By drawing a person's thoughts away from demands, those features and activities can lead the person into a restorative experience and prolong it. This presence of positive features, and not only an absence of negative ones, underlies the definition of a "restorative environment" as an environment that promotes, not merely permits, restoration.

We now turn to review research that has considered whether and how nature better promotes restoration than other environmental options commonly available to members of urban populations. Our review is meant to be illustrative rather than exhaustive. We proceed from research on immediate effects of brief encounters with nature, to research concerned with cumulative effects of repeated encounters with nature over a longer period, to research that

describes the implications for population health of access to natural environments. Along the way we discuss some of the theoretical and methodological issues with which researchers have had to contend.

3.3.2 Research concerned with immediate effects of brief encounters with nature

Much of the empirical research concerned with nature as a restorative resource has focused on brief encounters with nature during time away from demands. Such brief encounters can be referred to as discrete restorative experiences (Hartig, 2007). Research has focused on the degree to which environments potentially available to the person at the time would actually support some form of restoration. For members of an urban population, these could include urban public spaces of an almost entirely built character, such as streets, shopping areas, and squares, or green spaces dominated by trees, grass, and other seemingly natural features.

To date, much of the research on discrete restorative experiences has been experimental, and it has been guided by one or both of two theories. The two theories deal with different forms of resource depletion and emphasize different outcomes. They thus offer different views on what happens during restoration. The theories are alike, however, in that they treat nature as a particularly significant setting for restoration. We will outline the two theories before going on to discuss the experimental research that they have guided.

Attention restoration theory (ART; Kaplan & Kaplan, 1989; Kaplan, 1995) deals with a depleted capacity for directing one's attention. This condition, referred to as attentional fatigue, follows from overuse of an assumed cognitive mechanism that filters out or inhibits stimuli which are not relevant to the task is at hand, which may not be interesting in and of itself. Attentional fatigue entails a variety of negative consequences, including errors in performance,

difficulty in planning and executing appropriate actions, and irritability. The authors of ART sees restoration from attentional fatigue occurring when a person can gain psychological distance from tasks, the pursuit of goals, and the like, in which he or she routinely must direct attention (*being away*). When away in this sense, restoration is promoted if the person can rely on effortless, interest-driven attention (*fascination*) in the encounter with the environment. When the person can let his or her attention go to that which is interesting, he or she can rest the assumed cognitive inhibitory mechanism. If at the same time the person experiences the environment as coherently ordered and of substantial scope (*extent*), then fascination can be sustained. The theory also acknowledges the importance of the match between the person's inclinations at the time, the demands imposed by the environment, and the environmental supports for intended activities (*compatibility*). The Kaplans argue that these four restorative components commonly hold at high levels in natural environments, but they do not claim that only natural environments are restorative; they have also contributed to research on restorative experiences in museums (Kaplan, Bardwell, & Slakter, 1993) and monasteries (Ouellette, Kaplan, & Kaplan, 2005). Whether attention restoration takes place in a natural environment or some other environment, it should become manifest in, among other things, a renewed ability to focus, as evidenced by an improved ability to complete tasks that require concentration.

In contrast to ART, psycho-evolutionary theory (PET; Ulrich et al., 1991; see also Ulrich, 1983) concerns psychophysiological stress reduction. It emphasizes the beneficial changes in physiological activity and emotions that can occur in a person while viewing a scene. For a person who is experiencing acute stress after a situation that involved challenge or threat, viewing a scene might open into recovery from stress. This initially depends on visual

characteristics of the scene that can rapidly evoke an emotional response of a general character, such as interest or fear. This response is thought to take place without a conscious judgment about the scene, and indeed it can occur before a person can make such a judgement. The characteristics of the scene that evoke the response include gross structure, gross depth properties, and some general classes of environmental content, including natural features. The process of stress recovery would go something like this: a scene with moderate and ordered complexity, moderate depth, a focal point, and natural contents such as vegetation and water would rapidly evoke positive emotions and hold the person's attention, displacing or restricting negative thoughts and allowing a decline from the high level of physiological arousal that had occurred with the foregoing stress. The roles of natural contents and visual characteristics in this process have evolutionary underpinnings, according to Ulrich; humans are biologically prepared to respond rapidly and positively to environmental features that signal possibilities for survival. Restoration should become manifest in self-reports of improved positive emotions and reduced negative emotions, and in declines in physiological parameters such as blood pressure, heart rate, and muscle tension.

One might emphasize particular differences between the theories, but here we would rather point out that they offer complementary views on what can happen in a restorative experience, as stress and directed attention fatigue may sometimes arise alone and sometimes coincide (for more details, see Hartig, 2007). Departing from one or both of the theories, empirical studies have typically built on their common view of environmental features that promote restoration, and so have estimated the effects of different amounts of natural features in actual or photographically simulated environments.

Experiments on discrete experiences in different environments have shed light on what happens between a person and an environment that helps restoration proceed. They have tested hypotheses about the emergence of particular kinds of restoration outcomes within particular amounts of time, in the interest of assessing the validity of theoretical claims and establishing an empirical basis for practical measures. With guidance from PET, experiments have tested predictions about immediate physiological and emotional effects of viewing natural versus urban environments following exposure to a stressor. They have shown that, within just a few minutes, simply looking at scenes of nature can more completely return physiological activity toward pre-stressor levels than can looking at ordinary urban outdoor scenes (Ulrich et al., 1991) or sitting in a room without a view (Hartig et al., 2003). Scenes of nature can also quickly evoke more positive emotions and reduce negative emotions compared to scenes of urban outdoor spaces (e.g. Ulrich, 1979; van den Berg et al., 2003). With guidance from ART, experiments have tested predictions about performance on attentional tests, during or immediately after viewing or walking in actual or simulated natural and urban environments (e.g., Hartig et al., 1991; Hartig et al., 2003); however, they have proceeded with less certainty about how long it should take for those effects to emerge. Enhanced attention restoration with photographic simulations of natural versus urban environments has not consistently emerged after 7-20 minutes (cf. Berman et al., 2008; Hartig, Böök, Garvill, Olsson, & Gärling, 1996; van den Berg et al., 2003; Berto, 2005), but in field experiments differential effects have appeared after longer periods, from 20 to 50 minutes, spent walking in either a natural or urban environment (Berman et al., 2008; Hartig et al., 1991, 2003).

Recent years have witnessed a tremendous growth of interest in this research area, and many new studies have reported findings in line with predictions based on one or both of the two theories. The more recent studies have helped to advance the research area by broadening the kinds of environments under study (for example by comparing wilder to more tended or managed natural environments; Martens, Gutscher, & Bauer, 2011); by improving measurement, as with regard to the working of the inhibitory cognitive mechanism postulated by ART (Laumann, Gärling, & Stormark, 2003; Jahncke, Hygge, Halin, Green, & Dimberg, 2011; Raanaas, Evensen, Rich, & Sjöström, 2011); by looking to the manner in which different environments satisfy the particular restoration needs of particular segments of the population, such as people with mental illness (Roe & Aspinall, 2011); and by considering particular modes of encounter with the natural environment. In this latter regard, the Japanese practice of *shinrin-yoku*, or "forest bathing", has received substantial attention in recent years. It involves sitting quietly and in a deliberate way breathing in the forest air, often in groups, as well as walking at a low level of intensity. A recent program of experimental research sponsored by the Japanese government has resulted in several studies that have reported beneficial short-term emotional and/or physiological effects of this practice (e.g., Morita et al., 2007; Park et al., 2007, Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2009; Tsunetsugu, Park, Ishii, Hirano, Kagawa, & Miyazaki, 2007).

Recent reviews have presented a positive view of the experimental research as it bears on the relatively greater restorative quality of natural environments. Some of these reviews have also affirmed the validity of particular theoretical claims. For example, Kaplan and Berman (2010) selectively reviewed studies that affirmed the plausibility of the attentional mechanism

specified in ART. There are however also critical inputs to this literature. A systematic review by Bowler, Buyung-Ali, Knight, & Pullin (2010) could not conclude that contact with nature had a beneficial effect on attention. Their meta-analyses led them to conclude that contact with the natural environment lowered anger and sadness, but they could not conclude on the basis of the available evidence that contact with nature yielded attentional benefits. Yet, the study by Bowler et al. does itself have significant limitations. Only a rather small number of studies had the necessary research design features, including the availability of pretest and posttest measures. For this reason, they did not differentiate among quite different measures of attention in their meta-analysis. The literature includes findings of no or weak effects that were obtained with presumptive measures of attention that may not have tapped into the inhibitory mechanism on which directed attention is assumed to depend. Another limitation follows from the fact that too few studies had collected physiological measures during the time spent in the environment. Their meta-analysis only considered change from the pretest to the posttest; however, one study has demonstrated that ambulatory blood pressure can follow strikingly different trajectories during a walk in a natural versus urban environment, in contrast to pretest and posttest measures that show no effect of environment (Hartig et al., 2003). All of this said, Bowler et al. seem to have done about as well as could be done with the studies available, and they have contributed to the vitality of this area of research by challenging an overly rosy view of the findings. The area is still quite young, and there is still much room for development.

3.3.3 Research concerned with the cumulative effects of repeated encounters with nature

Knowing what happens in a discrete restorative experience is important, but one such experience will ordinarily do little to support adaptation in the long run. For this reason, researchers have also tried to measure cumulative effects of available environments that varied in restorative quality. The assumption underlying such work is that people who can access environments of relatively high restorative quality during those periods when restoration can occur will realize greater restorative benefits over the long run than they would by spending the time in environments of lesser restorative quality. Working from this assumption, researchers have focused their attention on people in their everyday contexts, where they would ordinarily and regularly find possibilities for restoration over an extended span of time. In doing this work, they have typically treated the amount of nature in the environment or access to a natural area as a positive indication of restorative quality.

The residential context has attracted much of the attention in studies of cumulative effects. The focus is easily understandable. Given that most people spend a large proportion of their waking as well as sleeping hours within their dwelling or in the area around it, variations in restorative quality there if anywhere could reasonably be expected to have cumulative effects. Some of the evidence for an association between residential access to nature and lower risk of poor health comes from large surveys and epidemiological studies (e.g., de Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Grahn & Stigsdotter, 2003; Korpela, Ylén, Tyrväinen, & Silvennoinen, 2010; Stigsdotter, Ekholm, Schipperijn, Toftager, Kamper-Jørgensen, & Randrup, 2010). Consider, for example, work done for the Dutch Vitamin G project. This project likened contact with nature to intake of a vitamin; even if only in small amounts, contact with

nature may serve processes that are fundamental for maintaining health and well-being. One study in the project joined geographic information systems-based measures of green space with health data from a survey completed by more than 250,000 people in The Netherlands (Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006). It found that a smaller percentage of people reported less-than-good health if they had more green area in the vicinity of the residence. Another study done for the Vitamin G project found additionally that access to green space buffered residents from the ill effects of stressful life events (van den Berg, Maas, Verheij, & Groenewegen, 2010; cf. Wells & Evans, 2003).

Some of these studies did not or could not assess the extent to which people actually engaged in restorative activities in nearby natural areas, so they only could assume that repeated restorative contacts with nature played a role in the association uncovered. Some research has however also tried to get at the processes through which cumulative effects could have come about. Notable in this regard are studies of low-income housing residents in Chicago by Kuo and Sullivan (e.g., 2001; Kuo, 2001). Those residents came to occupy their housing through something like a natural lottery, with assignment to particular apartments made by the public housing authority. Kuo and Sullivan grouped their study participants according to the amount of trees and other greenery around the buildings in which they lived. Thus, the residents in their sample had varying opportunities for seeing trees from their windows, socialising with friends and neighbours in shady green places, and so on. Although the amounts of greenery involved were quite modest, the residents in the greener circumstances did better on a standardized test of attention than the residents in buildings with barren surroundings. The particular test of attention they used has also been used in studies of acute effects of discrete restorative experiences, but in

this research it was used as an indication of a persistent deficit in the ability to direct attention. The residents' performance on the attentional task in turn predicted their ability to manage major life issues, as well as the amount of aggressive and even violent behaviour that they had directed at members of their family (according to their own reports). The data suggest that difficulties in managing major life issues and aggressive behaviour may stem from a weakened ability to focus attention, which in turn has implications for the ability to plan and to inhibit inappropriate behaviour. Kuo and Sullivan thus provided suggestive, plausible evidence that repeated instances of more effective attention restoration supported by visual and physical access to greenery cumulatively can have better effects on behaviours that have substantial significance for individuals, families, and society. Taylor, Kuo and Sullivan (2002) tested a similar set of hypotheses with children living in the same low-income housing area. They reported that the greener the view that 7-12 year old girls had from their residence, the better they performed on attentional tests, and the better they could inhibit impulses and delay gratification. Again, the results suggest that repeated occasions of more effective attention restoration can show as cumulatively better effects on important outcomes.

The residential studies so far discussed have all focused on a primary residence. Although this is reasonable, a primary residence has an obligatory character and must satisfy a variety of demands. A desire for easy access to natural areas for restoration may therefore have little influence on the choice of location. This contrasts with the motivational picture for a second residence. In some countries, such as Sweden, families often own a second home specifically because it supports restorative activities in natural surroundings (Müller, 2004). Indeed, in Sweden such second residences are referred to as leisure homes (*fritidshus*). Two recent

longitudinal studies used official Swedish register data to investigate whether leisure home ownership prevented adverse health outcomes. The first study included over 42,000 employed adults living in the most densely populated municipalities comprising Sweden's three major urban areas (Stockholm, Malmö and Göteborg). Analyses showed that the men in the study population had significantly lower odds of early retirement for health reasons after several years of followup if they owned a leisure home, compared to men who did not own a leisure home (Hartig & Fransson, 2009). A similar prospective association was not found for women. Indeed, among women who had the most education and the highest incomes, ownership of a leisure home was attended by a *higher* likelihood of early retirement for health reasons. For some women, the leisure home may be another domestic setting in which they still bear more responsibility for cooking, cleaning and other household chores. Rather than helping them to restore, leisure homes may impose additional unwanted demands (see also Fransson & Hartig, 2010, for which the outcome was early death). The gender difference here serves as another reminder that contacts with nature occur in contexts with social and cultural features that can open or close possibilities for restorative benefits for some people at some times.

The workplace is another everyday context in which people must regularly find opportunities for restoration, and over an extended span of time. Here, too, researchers have taken interest in cumulative effects of discrete restorative experiences and the influence of environmental variations on those effects. For example, Kaplan (1993) discussed the potential cumulative value of "micro-restorative experiences" in workplaces, emphasizing that a worker might more effectively restore the cognitive resources needed for work if he or she could from time to time look out a window onto natural features such as trees and vegetation. Although she

did not deny the importance of taking breaks away from the desk or workstation, Kaplan argued that brief micro-restorative experiences while at one's desk could play an important role in reducing attentional fatigue because the worker must face that immediate work setting more continuously. Results from one workplace study reported in her paper suggested that workers who had window views onto natural features had greater satisfaction with their job. In a second survey study, workers who had a view onto natural features gave more positive evaluations of the job and reported higher life satisfaction more generally. More recently, Bringslimark and colleagues (2007) found that self-reported sick leave was negatively associated with the presence of indoor plants within view from the work station.

Researchers interested in cumulative effects of restorative experiences have also studied people in healthcare settings. Many people can count on spending some time in hospitals, clinics, and doctors' offices over the course of their life, and visits to such places may be quite stressful. The best known of the studies in this area, Ulrich's (1984) seminal study of environmental effects on recovery from surgery, started from awareness of the stress and anxiety that people often face in hospital settings. A patient already concerned about a threat to health, and perhaps waiting for a painful procedure, can hardly benefit from an unfamiliar environment that is experienced as sterile, noisy, or otherwise unpleasant. Ulrich studied the records for patients who, after they had surgery, were sent for recovery to a room that had a window view of either trees or a brick wall. During the second through fifth day of their stay, those with the tree view used less potent pain killers than similar patients who had a view of a brick wall. Those with tree views also stay fewer days in the hospital after surgery on average, and they received fewer negative evaluations from nurses. This study, although modest in size, has proved influential in

discussions of hospital design, perhaps because the outcomes studied are so important to patients, staff, administrators and insurers alike.

Surprisingly, few researchers have attempted to replicate Ulrich's (1984) study. A recent longitudinal quasi-experiment by Raanaas and colleagues (2012), however, considered a somewhat similar situation. Over a two-year period, they looked at whether the view from the bedroom window affected change in the self-reported physical and mental health of more than 270 patients going through a program at a rehabilitation center in the Norwegian mountains. Patients there suffered from lung and heart diseases and spent four weeks in a demanding rehabilitation program suited to their particular condition. On arrival, the patients were assigned to a room by a center administrator; they were not able to choose their own room. Some rooms had windows that offered an unobstructed view to the surroundings, while in other rooms the view was blocked to varying degrees by parts of the center or other buildings. The researchers found that an unobstructed view to the mountain area around the center appeared to better support improvement in self-reported health during the program. The conclusion was however qualified; the degree of change varied with gender and diagnostic group. For example, for women, a blocked view from the bedroom seemed to negatively influence change in physical health, whereas for men, a blocked view appeared to negatively influence change in mental health. The type of view also appeared to affect behaviour; patients who had an unobstructed view to the natural surroundings were more likely to stay in their bedroom when they wanted to be alone, compared to those patients who had a blocked view

The studies we have referred to give a sense of the different contexts in which the cumulative effects of restorative contacts with nature have been studied. The studies also

illustrate the different methodological approaches used and the different kinds of outcomes that reflect on health in a broad sense. Together with the results of the true experiments of discrete restorative experiences, studies of this kind offer further support for the idea that nature experience serves health. They are however still open to criticism. For example, the self-selection of healthier people into healthier (greener) residential contexts is a common concern. Some of the studies just mentioned could address that concern to some degree by identifying situations in which people came to occupy their housing through a quasi-random process (i.e., the studies in Chicago public housing by Kuo and colleagues, the study of patients in the Norwegian rehabilitation center by Raanaas and colleagues). Beyond such standard concerns, however, there is a more subtle critical point, which involves the level of analysis used in the research. We turn now to address this issue, in the course of presenting studies that have compared populations rather than individuals.

3.3.4 Research on the implications for population health of access to natural environments

Studies that focus on individuals have important advantages. For example, they are suited to describing the "mechanisms" or pathways through which the experience of nature can come to affect individual health. They do however have some shortcomings. Notably, variations in health across populations, or within a population across time, are not necessarily explainable through reference to individual-level factors (Rose, 1985; Syme, 1996). For example, it would be difficult to identify tobacco use as a risk factor for lung cancer from studies that sampled individuals from a population in which all of the adults smoked heavily, since there would be little variation in tobacco use. Without variation in the exposure, there cannot be covariation with

a health outcome. Covariation of tobacco use with lung cancer can however be detected by comparing the incidence of lung cancer in a population of heavy smokers to the incidence of lung cancer in a population in which few people smoke. Thus, population studies can help to identify associations that may be difficult if not impossible to detect with studies of individuals, and they can provide another perspective on the practical implications of individual level results.

Consider, for example, the results of a recent study by Richardson, Mitchell, Hartig, de Vries, Astell-Burt, and Frumkin (2012). Looking across 49 of the largest cities in the USA, they investigated whether mortality rates for one year were lower in cities that had more greenspace. The amount of greenspace was determined using data from the American National Land Cover Database, which were extracted from satellite images with a 30-meter cell resolution. The researchers took particular interest in whether the amount of greenspace explained mortality rates for stress-related diseases, such as heart disease, that might be prevented by greater access to urban green spaces and natural areas; however, they also looked at other mortality rates, including mortality from all causes. The results went against expectations. The amount of green space was not significantly associated with mortality from the specific causes studied. Moreover, surprisingly, greener cities had significantly *higher* mortality from all causes. What could explain this result, which goes against the many findings from individual-level studies? As the researchers point out, in the USA, greener cities also tend to sprawl more, and to have transportation systems based on travel by car. The higher levels of car dependency in green but sprawling cities may wash out benefits of green space for health as measured on the population level. An important implication of this result is that urban planning must take care to coordinate green space provisions with other societal functions such as transportation and housing; simply

expanding the overall amount of greenspace – a recommendation that could follow from studies of individuals – may have unwanted effects.

Individual-level and population-level research may not always disagree, of course, and the practical rationale behind both types of research ordinarily refers to interventions that change the environmental conditions in which many people could spend time. Consider the following statements: "*As with regular sleep, regular access to restorative environments can interrupt processes that negatively affect health and well-being in the short- and long-term. For urban populations in particular, easy pedestrian and visual access to natural settings can produce preventive benefits. Environmental strategies for health promotion that improve opportunities for restoration can offset limitations of individual-based behavioural change approaches …, and they complement approaches focused on preventing, eliminating, or mitigating stressor exposures …* " (Hartig et al., 2003, p. 122).

Such statements refer to the potential value of efforts to improve the "average" restorative quality of the everyday environments of urban populations. This approach may be particularly important for people who otherwise must face difficult life circumstances and have few options for escaping a demanding everyday environment (see e.g., Mitchell & Popham, 2008). We turn now to discuss the need for research on ways to combine natural and architectural features in urban settings to better serve the restoration needs of residents. As we noted at the outset, this is an environmental planning and design issue that will grow in importance as urban populations grow and concerns about sustainable urban development intensify.

3.4 Design with Nature for Restorative Urban Spaces: Research Needs

Looked at globally, the urban population is expected to grow for decades to come. The United Nations (2009) has estimated that the proportion of the human population living in cities will increase to approximately 70% by 2050. This global growth in the urban population will in all likelihood be accompanied by growth in the geographical extent of many specific urban areas. The relationship between population growth and spatial expansion of urban areas will depend on a variety of factors, including but not limited to the residential density of neighbourhoods, the locations of different kinds of services, and the transportation system on which residents and others must rely. Such factors are among the targets of efforts to reduce the ecological impacts of urbanization and urbanicity. For example, collective forms of transportation and travel by foot and bike are more feasible with high residential densities and short distances between residences, workplaces and services. Such facts have encouraged efforts to slow the geographical spread of urban areas and make cities more compact, following for example principles stated in the Charter of the New Urbanism (Congress for the New Urbanism, 2001).

As Neuman (2005) has observed, however, available evidence indicates that compactness and sustainability have a rather uncertain correspondence. A neglect of psychological factors can help to explain why densification is of itself not a sure path to a more sustainable urbanicity (van den Berg et al., 2007). By neglecting basic issues of human adaptation, densification measures may have unwanted consequences for public health and individual well-being that thwart the pursuit of sustainability. Research on urban stress has over many years described harmful effects of noise and crowding like that often experienced in public spaces, transport settings, and residential contexts in cities (e.g., Glass & Singer, 1972; Evans & Cohen, 1987). And, as

described at length above, research on restoration has described the potential value of contact with nature for members of urban populations in particular. Densification measures may increase the likelihood of stressful experiences, and at the same time they may entail a loss of outdoor spaces that would otherwise serve the restoration needs of the local residents.

The contrasting messages from research on urban stress and restoration in nature seem to affirm the thinking behind design strategies that historically have promoted the integration of the natural and the built in urban areas, such as the urban parks of Frederick Law Olmsted (1870) and the garden cities inspired by Ebenezer Howard (1902). Ours is a retrospective assessment, however, and it may only apply in broad outline. The immediate issue here is how psychological research can inform future spatial planning and urban design measures that aim to serve ecological goals through densification. Can those measures be implemented so that they also maintain or increase the average restorative quality of the environments which residents, non-resident workers, and others can access in the time they have for restoration?

To be sure, research on the restorative effects of natural environments is already being put to use in this context. For example, it has been cited in support of calls for the protection of natural areas near the growing urban population of Stockholm, Sweden (e.g., Länsstyrelsen i Stockholms län, 2003). Yet, the extant research has some significant limitations as an aid to raising the restorative quality of urban settings. This is particularly true for the experimental studies, which otherwise are valued for the support that they lend to causal claims. For one, experiments done to date may overstate the restorative advantages of natural over urban environments. Both environmental categories encompass great variation, but that variation has not been well-represented in the experiments done so far. Rather, experiments have measured

restoration in a small number of comparison environments. In contrast, studies that have used broader environmental sampling together with simple ratings of restorative quality have obtained substantially different ratings for different urban sites, from parking garages to pedestrian malls (e.g., Hartig, et al., 1997a; Herzog et al., 2003; Hidalgo et al., 2006). Indeed, some urban settings have drawn higher ratings of restorative quality than some natural settings (e.g., Herzog et al., 2003; Nasar & Terzano, 2010). It follows that research is needed which considers whether the differences seen with simple ratings of restorative quality are reflected in differences in restorative effects actually measured during discrete experiences in different urban settings, and whether some urban settings can support restoration in a positive sense rather than through the absence of stressful conditions such as noise and crowding.

A second practical limitation of findings from experiments on restorative effects of natural environments is described by Velarde et al. (2007). They pointed out that a simple comparison between a single natural environment and a single urban environment provides little information about the specific characteristics of those environments that should be addressed through specific design measures. Again, then, research should look under global distinctions, as between "natural" and "urban", and consider the specific attributes of different urban settings that support restoration.

A third limitation has to do with the distinctiveness of the environmental categories involved. Experiments that have found a restorative advantage of a natural versus an urban environment may encourage an overly narrow view of the categories as distinct rather than overlapping. Yet, as we noted earlier, urban areas commonly have some greenery, and the possibilities that forms of "urban nature" afford for restorative experiences in otherwise built

surroundings may be profoundly important. Rather than imply that the natural and the built might be kept separate, research in support of design measures would do well to address the ways in which natural and built features can be combined in urban settings to better support restoration.

In pointing out the limitations of the extant experimental research and related research needs, we do not mean to imply that no relevant work has been done. Several strands of existing research have apparent relevance to efforts to improve the "average" restorative quality of the everyday environments of urban populations by looking at the integration of natural and built features. Some of this work has moreover specifically considered the possibility that design with urban nature can offset the potential negative effects of urban densification. For example, Nordh et al. (2009) recognized that, if well-designed, small urban parks and green spaces could have restorative quality comparable to that of much larger parks. If so, in a densely built city, a system of widely distributed small parks and green spaces could serve the restoration needs of residents as well as or better than a few large parks distributed around the periphery. Using photographs, Nordh et al. obtained ratings of restoration likelihood and other psychological variables for 74 small (< 3000 m^2) parks and green spaces in Scandinavian cities. Restoration likelihood was framed in terms of how completely one would be able to rest and recover an ability to focus if, during a break from work, one were to spend time in the environment shown in the photograph. Nordh et al. treated the parks as units of analysis, and estimated the average ratings of restoration likelihood on the basis of components such as grass, water, trees, bushes, low ground vegetation, flowers, and hardscape (such as paving stones). They found that the parks with more trees, bushes and grass had higher ratings of restoration likelihood. This may seem unsurprising, but

the results contrast with the common practice of using low-maintenance hardscape rather than vegetation in small urban spaces. Greener spaces with less hardscape may cost more to install and maintain, but they may also better serve restoration needs, and their value as a restorative resource might be set against the additional cost. Further research can build on the example set by Nordh et al., with its broad environmental sampling and its focus on specific physical attributes that can be manipulated by design (see also Nordh, Alalouch, & Hartig, 2011).

Trees and other vegetation along streets can also play an important role in a densely built city. Green streets can links small urban parks in an overall green structure, and they can serve as restorative amenities for people in their residences and workplaces, whether they are active outdoors or sitting inside looking out. So far, little empirical work has addressed this possibility (cf. Kaplan, 2001); however, the literature on environmental preferences offers some insights. Several studies have found strong correlations between preferences for different environments and ratings of either their restorative quality or the likelihood that one can restore there (e.g., Purcell, Peron, & Berto, 2001; Staats & Hartig, 2004; Staats et al., 2003; Nordh et al., 2009). Assuming that preferences do reflect on restorative quality and the likelihood of restoration, at least for some types of environments, the potential restorative value of street trees is suggested by the greater preference shown for streets with trees than for streets without them (e.g., Kalmbach & Kielbaso, 1979; Smardon, 1988; Sommer, Guenther & Barker, 1990; Wolf, 2009; though compare Hitchmough & Bonugli, 1997). Other natural elements in street settings seem to have received less research attention, but the studies we located suggest that they have effects on preference like those seen with street trees. For example, Todorova et al. (2004) found a higher preference for streets lined with flower beds than for streets without flowers. Their study

participants also described such streets as more restful. Future research can address the gap in literature concerning the effects of different forms of vegetation and combinations of different natural elements in urban surroundings (cf. Nordh et al., 2009).

In discussing research on ways to combine natural and built features to better support restoration in urban settings, we have so far taken the built environment as given. Yet, the potential benefits of urban nature should be considered in conjunction with the characteristics of buildings around parks and along streets. As it stands, though, little work has been done that bears on how the architectural characteristics of buildings in city blocks of themselves might positively affect restoration and assessments of restorative quality (cf. Hidalgo et al., 2006). One might look again to the preference literature for insights. Studies that have examined preferences for urban settings in which streets figure prominently, however, have considered perceptual qualities underlying preference, such as openness, enclosure and the depth of views (Herzog, 1992; Nasar, 1984). Although they may help to explain preference for different kinds of urban built environments, they may offer little insight on the effects of specific architectural characteristics. Stamps (e.g., 1994, 2002a, 2003) has made helpful contributions in this regard by testing the effect on preference of specific architectural properties of blocks or rows of individual residential buildings. In these studies, he systematically manipulated properties, such as facade details, scale, colour, shape, and the articulation of buildings arranged in a block or row. His results demonstrate the relevance of these properties for preference ratings. For example, using images of blocks of seven buildings, Stamps (1994) found a higher preference for homogenous block façades (either a plain façade with few details and a flat roof or a detailed façade with peaked roofs) in comparison to blocks that had a mix of the two kinds of façade. Such

contributions notwithstanding, the preference literature offers rather little guidance concerning the combinations of architectural and natural elements that might make for urban streets of higher restorative quality. To our knowledge, no empirical research has looked at the interactive effects of specific built and natural features in this regard, though it seems reasonable to expect that the inclusion of urban nature will do more to increase restorative quality in some built settings than in others. For example, streets lined with ugly or uninteresting buildings may be regarded more positively if they are also lined with trees that mask the displeasing facades. Trees may not be regarded as positively if they conceal beautiful buildings.

Technological developments will make it easier to address the research gaps that we have mentioned, with a focus on the design of urban environments under different densification scenarios. In many of the studies done to date, participants have provided simple ratings of restorative quality or restoration likelihood for environments that were presented as static images (e.g., Herzog 1992; Weber et al., 2008; Nordh et al., 2009) or with videos (e.g., Nasar, 1984). In recent years, digital imaging and display technology have evolved in ways that greatly enhance and extend this basic approach. For example, digital imaging capabilities make it possible to create realistic static images of possible future environments, with systematic manipulation of key design variables (e.g., façade details, kind and amount of greenery) and strict control of potential confounding variables, such as weather variations. In a recent meta-analysis, Stamps (2010c) found that subjective evaluations obtained with static images and dynamic media agreed well with evaluations obtained on-site (correlations around .80). Such a result speaks to the validity of using imaging technology for assessments of the restorative quality of future urban environments. Going further, the new technologies also make it possible to study the restorative

effects of different, highly realistic, three-dimensional virtual environments in laboratory settings. Implementation of this approach still involves many challenges, but it also appears to offer significant advantages (de Kort, IJsselsteijn, Kooijman, & Schuurmans, 2003). For example, it enables participants to virtually "move" within environments in which key physical characteristics have been systematically manipulated and confounding variables have been held constant. In describing these possibilities, we do not mean to imply that on-site studies of restorative quality and restorative effects are relegated to the past. We do however want to emphasize that the research needs to be addressed concern the design of urban environments that may not yet exist.

3.5 Concluding Comments

In this chapter, we have provided an introduction to research on psychologically restorative effects of contact with nature, a fundamental component of the research on the broad nature-and-health topic. We have overviewed different kinds of evidence that substantiates the view that restoration is a key pathway through which nature experience can positively affect health, particularly for members of urban populations. We have also noted some of the limitations of the existing research, and we have pointed out some promising directions for future research, particularly with regard to ways in which architectural and natural features can be combined to meet the restoration needs of urban residents. Research on this topic can yield knowledge that can guide the densification of urban areas in ways that do not impose excessive demands nor undermine possibilities for needed restoration. As we have noted, this is an

environmental planning and design issue that will become increasingly important as urban populations grow and concerns about sustainable urban development intensify.

Intelligent sustainability measures demonstrate an understanding that technological solutions can fail if they neglect basic aspects of human behaviour and the social and cultural context in which behaviour occurs. As Kellert (2005) has warned, low-impact or "green" buildings may serve sustainability goals poorly if their users do not enjoy them, see fit to maintain them, and keep them in use over the long run (see also Kellert, Heerwagen, & Mador, 2008). A similar understanding is represented for a larger spatial scale in Beatley's (1999) description of green urbanism. By shedding light on the significance of contact with nature for members of urban populations, the work on restorative values of nature experience that we have discussed stands as a significant contribution to the intelligent pursuit of sustainability.

Chapter 4 - Paper II: Architectural complexity, building height, and the restorative quality of urban residential streetscapes

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4.1 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., Ulrich et al., 1991; Hartig et al., 1991). Such research has however often treated "natural" and "urban" as global, undifferentiated environmental categories (cf. Velarde et al., 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 et al., 1997a; Herzog et al., 2003; Hidalgo et al., 2006; Nasar & Terzano, 2010; Staats et al., 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, et al., 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., Korpela &

Hartig, 1996; van den Berg et al., 2007), 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 the physical attributes as we lay out the conceptual model tested in the empirical work.

4.1.1. 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, behaviour 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 behaviour 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 behaviour, 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, 1997b). Following the approach used by Nordh et al. (2009), however, the present study focuses only on being away and fascination.[2] 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.

4.1.2. 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

[2] 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.

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 et al., 2003; van den Berg et al., 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; Stamps, 2005b).

4.1.2.1 Architectural variation, perceived complexity, and preference

Complexity has been defined variously as the number of elements present in a scene (e.g., Herzog et al., 1982) and more particularly as the "noticeable difference" between elements (Rapoport & 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, 2004a), with some results showing an inverted-U relation (e.g., Imanoglu, 2000) and others a positive linear one within content categories (e.g., Kaplan et al., 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.

Variation in the silhouette. Researchers have long considered the number of turns in a form´s silhouette, or the number of 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; Stamps, 2002a; 2003; Nasar & Terzano, 2010). 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.

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).

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 (2002a) 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:

$$H_{factor} = -\sum_{i=1}^{nlevels} p_i \log_2 p_i \qquad \text{Equation 1}$$

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 (2002a) 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.

4.1.2.1 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, b).

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 & Handy, 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.

4.1.4. 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:

4.1 At the lower end of the entropy scale, increasing streetscape entropy positively affects judgments of restoration likelihood.

4.2 The influence of streetscape entropy on judgments of restoration likelihood is mediated by the experiences of (a) being away and (b) fascination.

4.3 Streetscape building height negatively affects judgments of restoration likelihood.

4.4 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. 4.1.

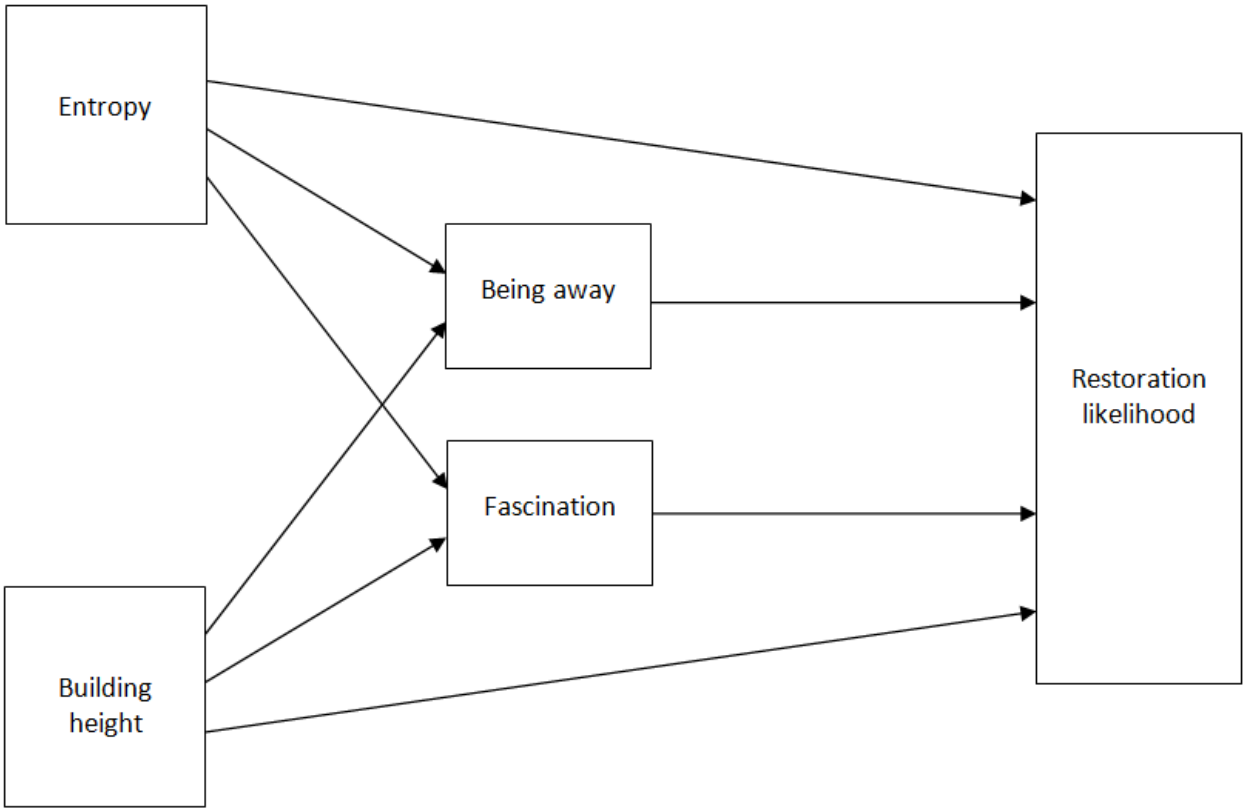

Fig. 4.1. Mediation model with being away and fascination as mediators of the effects of physical environmental components of urban streetscapes on judgments of restoration likelihood.

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.

4.2 Methods

4.2.1 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).[3] 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

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

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), 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.[4]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,

[4] 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).

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 4.1). To combine the levels of surface and silhouette attributes, streetscapes were created according to a 7 x 7 matrix for each of the three levels of building height.

Table 4.1. 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

The manipulations of building height, roofline, and surface attributes thus resulted in an image pool of 147 (i.e., 7 x 7 x 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 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 colour 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.

4.2.2 Variables in the Analyses

4.2.2.1 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 4.1, 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).

4.2.2.2 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 et al., 1997b).

4.2.3 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, Fountaine, & 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.

4.2.4 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.

4.2.5 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. Different approaches to testing mediation have some nomenclature in common (e.g., Preacher & Hayes; Baron & Kenny, 1986). 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 ($a_i b_i$) to the total indirect effect of X on Y. The total indirect effect is therefore quantified as $\sum(a_i b_i)$. 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_i and b_i, 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 and Hayes (2008b)] are indicated with an asterisk (*). The bootstrap confidence interval (CI) is acquired by ranking the k values of a_ib_i* from low to high. The values which define the upper and lower 100(α/2)% of the distribution of a_ib_i* set the limits of the CI. With k = 5000, as recommended by Preacher and Hayes, and the conventional α = .05, the lower and upper limits of the CI would be the 125th and 4876th values of a_ib_i*. 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).

4.3 Results

4.3.1 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 4.2). 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. 4.2.

Table 4.2. 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	.46**	1					
Restoration likelihood [a]	3.86	0.59	2.33	5.23	.72**	.54**	1				
Entropy [b]	--	--	--	--	.24**	.31**	.24**	1			
Building height [b]	--	--	--	--	-.17*	.04	-.37**	-.02	1		
Perceived complexity [c]	4.61	0.77	2.37	6.24	.28**	.59**	.28**	.52**	.02	1	
Perceived enclosure [d]	7.48	1.54	4.43	9.93	-.18*	-.08	-.41**	.49**	.96**	.38**	1
Preference [a]	3.11	0.71	1.50	4.67	.54**	.62**	.72**	.05	-.23*	.30**	-.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).

Fig. 4.2. 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).

In the regression analysis, the two environmental variables explained 65.78% of the variance in restoration likelihood (see Fig. 4.3). With adjustment for building height, the total effect (*c*) of entropy on restoration likelihood was positive and significant, in keeping with Hypothesis 4.1. With the mediating variables in the 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 4.2a and 4.2b (see Table 4.3). 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 4.3). 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 4.3 (see Fig. 4.3). With

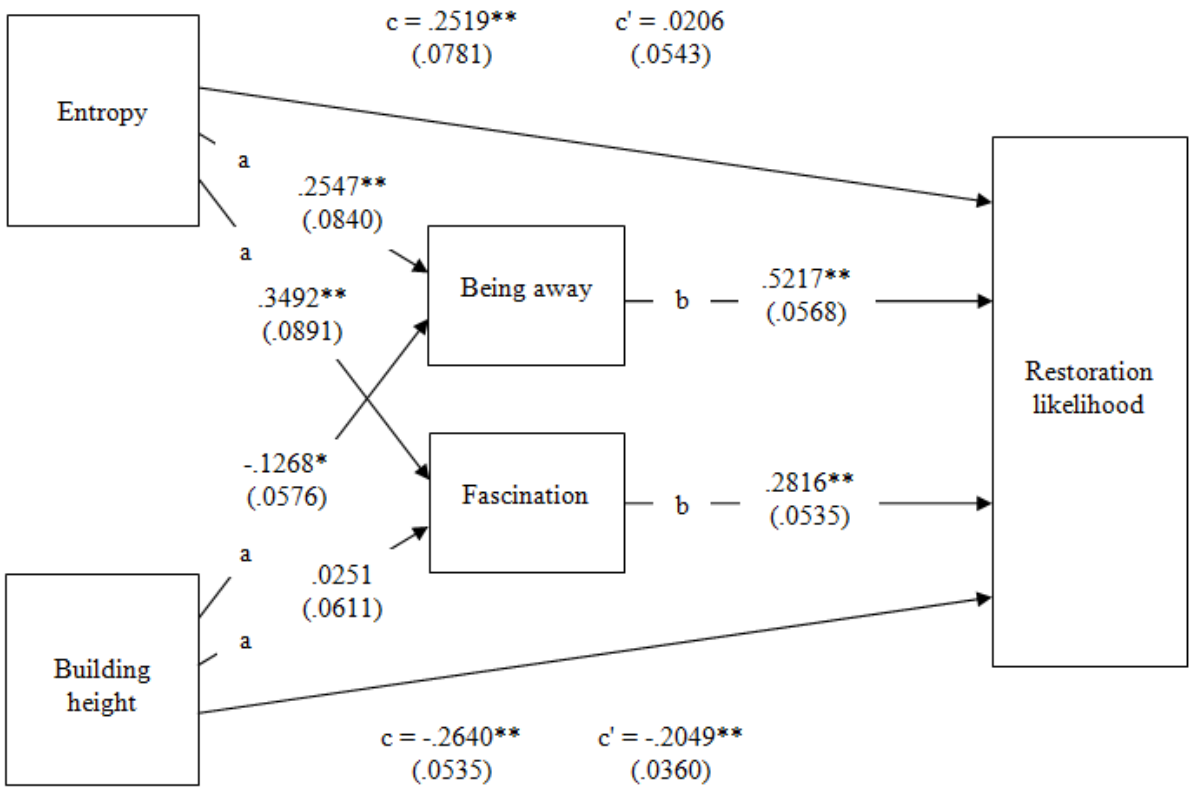

*Fig. 4.3. Mediation model with being away and fascination as mediators of the effects of physical environmental components of urban streetscapes on judgments of restoration likelihood. Unstandardized multivariate regression coefficients are shown with the corresponding standard errors in the parentheses. 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. *p< .05; **p< .005.*

the two mediators in the model, being away mediated the association between building height and likelihood of restoration, in keeping with Hypothesis 4.4a. As shown in Fig. 4.3, the higher buildings decreased the sense of being away, which in turn diminished the estimates of restoration likelihood. Contrary to expectations (Hypothesis 4.4b), 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 4.3). 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 4.3. Indirect effects of the association between the environmental components and restoration likelihood, through being away and fascination.

	Point estimate	BC[a] 95% confidence interval	
Entropy		Lower	Higher
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.

4.3.2 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 4.2). 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 4.2). 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.

4.4 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 4.1). Further, in line with Hypotheses 4.2a and 4.2b, 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 4.3). 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 4.4a). Higher buildings reduced the sense of being away, which in turn reduced the expectation that restoration would take place. Contrary to our expectations (Hypothesis 4.4b), 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 et al., 1997a, b). 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 colour 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 = .86) between environmental evaluations obtained on-site and those obtained with photographs (see also Hartig et al., 1997a; Stamps, 2010c). 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 colour 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, & Ellard, 2010; Valtchanov et al., 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. Rohrmann & 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 et al., 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 & Ellard, 2010; Valtchanov et al., 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 et al., 2003; Staats & Hartig, 2004). 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, Hartig, & Staats, 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.

Chapter 5 - Paper III: Effects of urban street vegetation on judgments of restoration likelihood and preference.

Lindal, P. J. & Hartig, T. (2013). Effects of urban street vegetation on judgments of restoration likelihood. (Under review)

5.1 Introduction

Streets take up some 25-35% of all developed urban land (Jacobs, 1997). This is a substantially higher proportion of urban area than that dedicated to parks and other public spaces. Due to their role in the urban infrastructure and their proximity to residences, streets are among the places where residents spend most of their time outdoors (Getz et al., 1982). Streetscapes also occupy the views that many people have from inside their homes and workplaces. Given the normal, recurring needs for psychological restoration experienced by people in cities, knowledge of how to increase the restorative quality of urban streetscapes should be beneficial, both for those living and working beside them and also for those who are moving along them as they travel to some destination. To address the need for such knowledge, in the present study we use a large number of computer-generated images to estimate the effect of different types and amounts of vegetation on judgments of the likelihood of restoration in urban streetscapes.

5.1.1 Restorative quality in environments

The concern for restorative quality here follows from recognition that restoration is a key pathway through which urban nature may promote public health (e.g., Health Council of the Netherlands, 2004). Attention restoration theory (ART) (Kaplan & Kaplan, 1989; Kaplan, 1995) provides an approach to understanding how natural elements on the streetscape level might serve psychological restoration. The theory is concerned with a capacity to direct attention, a cognitive resource assumed to be necessary for effective functioning in contemporary urban societies. People commonly rely on this resource in daily life, as when performing paid work, finding their way around town, and monitoring the behaviour of other people as they go along. Directing attention involves inhibiting other, more appealing or interesting stimuli, and this is assumed to

require effort. Because it requires effort, ART further assumes that this inhibitory mechanism can become fatigued. Attentional fatigue can become apparent in ineffective work performance, failure to pick up important cues on appropriate action, and increased irritability, among other behaviours.

To mitigate attentional fatigue, ART postulates that environments characterized by four qualities can be beneficial. *Being away* refers to psychological distancing from the routines and mental contents that ordinarily take up directed attention. *Fascination* refers to an effortless form of attention evoked by the environment. *Extent* refers to the degree of order and coherence in the environment as well as to the scope for involvement; one must have enough to perceive, think about and experience to remain engaged in the environment, and enough order to do so without becoming lost or disoriented. *Compatibility* refers to the degree to which the environment supports one's purposes and inclinations. The four restorative qualities may thus work as mediators between the physical environment and restoration; that is, features of the physical environment may affect the level of each quality as experienced by a person, which in turn can affect the degree of restoration realized by the person.

In the present study, only being away and fascination are under consideration, as the study materials and procedures limit the range of variation in extent and compatibility. We expect ratings of being away and fascination to be affected by the physical attributes of the streetscape images and in turn to influence ratings of the likelihood of restoration in the settings.

5.1.2 Selection of natural elements

Little research has considered the restorative benefits of vegetation along urban streets (van Dillen et al., 2012; Mitchell, Astell-Burt, & Richardson, 2011). However, numerous studies

have shown that trees and other vegetation affect preferences for urban environments (e.g., Stamps, 1997; Wolf, 2009), and several empirical studies have found that the effects of environmental variations on preferences were mediated by psychological restoration or expectations of restoration (Hartig & Staats, 2006; Staats et al., 2003; van den Berg et al., 2003). It follows that, where evidence concerning restorative benefits is lacking, one can turn to the literature on environmental preferences for help in identifying promising approaches to restorative urban design that make use of vegetation.

In the following, we consider three kinds of vegetation - trees, grass and flowers – that research has found to be related with preferences and/or with expectations about restoration with regard to urban streets.

5.1.2.1 Trees

Trees in the urban environment are seen as bringing nature closer to urban residents (Schroeder, Flannigan, & Coles, 2006), and it appears that many people think that trees in urban areas contribute significantly to their quality of life (Lohr, Pearson-Mims, Tarnai, & Dillman, 2004). Regarding possibilities for restoration, Lohr et al. (2004) report that the potential to help people to feel calmer is ranked second highest among the benefits of trees in urban settings in the USA. Studies have found that streetscapes with trees are ordinarily more preferred than streetscapes without trees (Gorman, 2004; Sommer et al., 1990; Stamps, 1997; Wolf, 2009), and having trees along streets may be just as important for residents as having them in parks (Getz et al., 1982). In a streetscape, trees may be the strongest single factor influencing preference when compared to other natural elements such as hedges, flowers, grass and soil (Todorova et al., 2004).

Several attributes of street trees may play a role in evaluations of streetscapes and at the same time have significant practical implications. Some attributes depend on the tree species. Particular species of street trees can be more or less preferred depending on their shape and other visual attributes, with deciduous trees generally preferred over coniferous trees (e.g., Summit & Sommer, 1999). Different species are also more or less demanding in terms of nuisances and maintenance requirements (Tomalak, Rossi, Ferrini, & Moro, 2011).

Species aside, the size and number of trees along a street will together affect the amount of apparent greenery in a streetscape. In light of the large body of evidence concerning the positive relationship between naturalness and both perceived restorativeness (e.g., Hartig et al., 1997a; Laumann et al., 2001) and preferences (e.g., Hartig, 1993; Kaplan & Kaplan, 1989; Stamps, 1999c), more apparent greenery could be expected to positively affect evaluations of streetscapes. Also, Kalmbach and Kielbaso (1979) found that a majority of residents in their sample wanted more trees in their own residential streets. Furthermore, the desire for more trees was stronger among those who presently had relatively few trees.

Additional trees may however not improve evaluations after a point because some trees will obscure others when viewed from a given vantage point (cf. Schroeder & Orland, 1994). It follows that the amount of apparent greenery that a given number of trees contributes to a streetscape also depends on their arrangement. For example, for a person looking down a street, a given number of trees evenly distributed along both sides could present an objectively larger amount of visible greenery than if the same number of trees were all aligned along one side, with trees in the foreground largely obscuring those behind them. Moreover, the amount of greenery aside, people may appreciate the greater symmetry that would obtain with trees aligned along

both sides of a street. Enquist and Arak (1994) claim that symmetrical patterns hold an almost universal appeal for humans. In line with this claim, Weber et al. (2008) assert that preference ratings can be increased if vegetation along streetscapes is symmetrical, with similar height and type along both sides.

In light of the foregoing discussion, we expect the size and number of trees to correlate positively with both rated restoration likelihood and preference. Furthermore, we expect that streetscapes with trees arranged symmetrically along both sides will be considered as more restorative and will be preferred more than streetscapes with trees along only one side.

5.1.2.2 Understory vegetation: flowers and grass

Little research has addressed the impact of understory vegetation in streetscapes on either restoration likelihood or preference. There is however some evidence concerning flowers and grass. Todorova et al. (2004) found that flowers were more preferred as elements for street-side plots than bare soil, grass or hedges. They even found greater preference for streets lacking trees but with flowers arranged in long plots along the curb than for streets with trees and bare soil, grass or hedges arranged beneath them along the curb. Preference was highest for plantings with bright, low flowers orderly arranged in the space beneath the trees. Todorova et al. furthermore found that streets with flowers were rated as relatively restful.

With regard to grass, Todorova et al (2004) found that streets with grass plots were more preferred than streets without grass plots, but they did not report results concerning whether grass also made the streets appear more restful or otherwise psychologically beneficial. In light of their preference findings and previous findings concerning the relationship between preference and restorative potential, we can nonetheless expect the presence of flowers and the

presence of grass to each increase judged restoration likelihood as well as preference. They may do so, moreover, without increasing the amount of apparent greenery to the same extent as would the addition of more street trees.

5.1.3 A potential interaction between vegetation and architectural characteristics

The amounts of trees, grass and flowers are not the only physical attributes of an urban streetscape that may affect ratings of restoration likelihood and preference. The buildings along the street may also have a significant effect. In a forerunner to this study, Lindal and Hartig (2013) analysed mean ratings of restoration likelihood for images of 145 urban streetscapes that did not include any trees or other street-side vegetation, but which were lined by buildings that had varying architectural characteristics. They found that the roofline silhouette, façade details, and the height of the buildings all affected judgments of restorative potential. The streetscapes judged to have low restorative potential were lined by three-story buildings with little visual complexity, whereas the streetscapes with the highest mean ratings of restoration likelihood were lined by one-story buildings with relatively high levels of visual complexity. Note however that the mean restoration likelihood ratings for the latter streetscapes were not high in some absolute sense; they fell close to the mid-point of the scale used.

The question arises whether the impact of vegetation on the restorative potential of a street depends on the architectural attributes of the buildings along the street. For example, street vegetation may increase or decrease evaluations of complexity of the built urban environment, as they can break up a monotonous environment or mask a chaotic one (Smardon, 1988; Thayer & Atwood, 1978). Trees and other vegetation may also modify the sense of enclosure otherwise provided by buildings through the ways in which they define spaces both vertically and

horizontally (cf. Bell, Blom, Rautamäki, Castel-Branco, Simson, & Olsen, 2005; Ewing, Handy, Brownson, Clemente, & Winston, 2006).

Building on the results from Lindal and Hartig (2013), we chose for use in the present study those of their streetscapes images that had the most divergent ratings of restorative potential on the basis of their architectural attributes alone. It was of interest whether any of the street vegetation variables as well as the overall amount of street vegetation would increase ratings of restoration likelihood to a greater degree in the streetscapes with architectural attributes that had previously elicited low ratings of restorative potential.

5.1.4 The present study

This study focuses on the influence of vegetation in streetscape settings on judgments of the likelihood of restoration. Five vegetation variables were systematically manipulated in a large set of computer-generated streetscape images: the number of trees, the size of the trees, the arrangement of the trees along the street, the presence versus absence of grass, and the presence versus absence of flowers. The vegetation was introduced into streetscapes that previously had received low versus moderate ratings of restorative potential on the basis of the architectural characteristics of the buildings lining the street (Lindal & Hartig, 2013). Independent groups of participants rated each in a set of images on one of several variables, including being away, fascination, restoration likelihood and preference. Participants' group mean ratings were calculated for each image, and each streetscape image was then treated as a unit of analysis in the subsequent statistical work. Our analyses addressed expectations that judgments of restoration likelihood would increase with a) increases in the number of street trees; b) increases in the size

of street trees; c) the presence of street trees on both versus only one side of the street; d) the presence of grass; and e) the presence of flowers.

In addition to assessing the independent effects of the different vegetation variables on ratings of restoration likelihood, we also assessed the extent to which those effects were mediated by ratings of being away and fascination. Further, we considered whether any of the street vegetation variables or the overall amount of vegetation had a greater positive impact on ratings of restoration likelihood for streetscapes that had previously elicited low ratings of restorative potential because of their architectural attributes (Lindal & Hartig, 2013).

Finally, as a check on our assumption that preference judgments offer insights on restorative quality, we assessed the correlations that ratings of preference had with the different vegetation variables and with ratings of restoration likelihood. We also repeated the regression analyses that treated being away and fascination as mediators of the effects of street vegetation, but with preference as the dependent variable.

5.2 Method

5.2.1 Visual stimuli

5.2.1.1 The architectural backdrop in the streetscapes

This study involved computer-generated images of urban residential streetscapes that were based on images used by Lindal and Hartig (2013). The streetscapes in the previous study varied in architectural characteristics alone and did not include any greenery. The streetscapes from that study with the two lowest and the two highest mean values for judgments of restoration likelihood were used as platforms for the further manipulations of the environment in terms of

greenery. The two images with the lowest values both had a mean of 2.35, and the two images with the highest values both had a mean of 5.14 on the 0-10 scale used for ratings of restoration likelihood. Note again that the streetscapes previously rated low in restorative potential had a mean that was low on the scale in an absolute sense, whereas the streetscapes with the highest ratings were only around the mid-point of the scale used, and so were not considered high in restorative potential in some absolute sense.

All of the streetscapes had a uniform set of spatial criteria, with a total length of 104.4 m between the proximal and distal curb corners, a 96 m long block of buildings on each side of the street, and buildings along the far side of the distal cross street to close off the space. The blocks of buildings were separated by 14.4 m, a distance taken up by a street (6 m wide), sidewalks (each 2 m wide from the foot of the doorstep to the curb of the sidewalk) and intermediate space (2.2 m wide) defined by the doorsteps, the sidewalk and the wall of the given building.[15] In contrast to the images used by Lindal and Hartig (2013), the images used in the present study had the intermediate spaces elevated 15 cm to distinguish them from the sidewalk and make them more like semi-private space belonging to the buildings.

In the two streetscapes previously judged to have low restorative potential, the blocks consisted of buildings three stories high on sunken cellars, with no surface details (i.e., no ornaments or trims) and relatively simple and uniform skyline silhouettes (i.e., flat roofs on the majority of the buildings). In the streetscapes previously judged to have relatively high restorative potential, the blocks had one-story buildings on sunken cellars, nearly all of which

[5] The street and sidewalk widths conform to published standards for residential blocks (e.g., Ewing, 1994).

had façade details (i.e., ornaments, cornices, window and door trims) as well as diversity in the skyline silhouettes, with a roughly 3:2 ratio of peaked to flat roofs. Street lamps and traffic signs were included in all streetscapes, but cars, people and animals were excluded. Further description of the streetscapes can be found in Lindal and Hartig (2013).

5.2.1.2 The street vegetation

Although we recognize that the choice of street tree species is an important practical consideration for arborists and urban foresters, in this study we decided to hold constant the type of tree. A three-dimensional unspecified deciduous tree was downloaded from the Google 3D Warehouse website. The density of the canopy was increased and other minor adjustments were made using Google Sketchup 7 (free version) before adding the trees to the streetscapes. The trees were introduced according to an arrangement in which their number, position and size were systematically manipulated. The number of trees had four levels: 0, 2, 4 or 6 trees. The intended number of trees in a streetscape was reached by copying the initial tree and then rotating it to prevent an identical appearance. The tree arrangement was on two levels: either all trees were on one side of the street, or half of them were on each side. In all cases, the trees were positioned at 30.5 cm from the pavement curb. The location of the trees along the street varied with the number of trees. When two trees were placed on one side, the pavement length was divided into tertiles (34.8 m per tertile) and the trees were their positioned at the tertile junctions. This was done to avoid the appearance of a large tree at the proximal end and one very small tree on the distal end with no vegetation in the middle. When two trees were divided across the two sides, the one tree on each side was positioned halfway down the street. When there were more than two trees on each side (i.e., when six trees were distributed on both sides, and when four and six

trees were positioned on one side), none of the trees was placed closer than 10.7 m to the curb of the cross-street at an intersection [cf. recommendations in the planning literature which specify distances from 7.6 m to 10.7 m; e.g. Portland Parks & Recreation City Nature Urban Forestry (no date); Texas Chapter of the International Society of Aboriculture (no date)]. Within the space remaining along the street [i.e., 104.4 – (10.7 x 2) = 83 m], the trees were evenly distributed depending on the number of trees; with three trees, the distance between trees was 41.5 m; with four trees, the intervening distance was 27.7 m; with six trees, the intervening distance was 16.6 m.

Tree size had two levels: small and medium. Urban trees from 6.1 to 9.0 m in height can be considered small, and trees from 9.1 to 12.2 m can be considered medium high (Grey & Deneke, 1978). In the study, small trees were 6.1 m and medium trees were 9.1 m. All of the trees in a given streetscape had the same size. A focus on small and medium size trees is consistent with the feasibility of introducing them into a streetscape.

In addition to varying numbers, sizes and locations of trees, the streetscapes were presented with grass or pavement covering the intermediate space framed by the buildings, the sidewalks and the door steps. Again, to give a sense of a semi-private space belonging to the residents, the intermediate space was elevated 15 cm above the public sidewalks. Both pavement and grass were created in Google Sketchup 7 by applying real life images of turf grass or pavement as a texture to the intermediate spaces.

Furthermore, the streetscapes were presented with or without beds of flowers. A model of unspecified flowers was downloaded from the Google 3D Warehouse website. All of the flowers had identical form and were low-lying, but they varied in bright colour (yellow, orange,

red, blue and purple). Colours were added to the basic form using Google SketchUp 7. Beds of flowers were then created by multiplying the initial flower model and, to prevent a uniform appearance, rotating some of them. Due to technical restrictions, creating flowerbeds beneath the trees as in Todorova et al. (2004) did not succeed and therefore they were arranged in relatively narrow plots in the intermediate spaces beside the doorsteps and near the wall of each building. In streetscapes without flowerbeds, the same area was occupied by grass or pavement.

5.2.1.3 Creation of the image pool

The manipulations of the street vegetation and other image features resulted in an image pool of 104 virtual streetscapes. The pool included one image with each possible combination of architecturally determined restorative quality (either one of the two low restorative quality streetscapes or one of the two higher restorative quality streetscapes), number of trees when trees were present (2, 4 or 6), arrangement of those trees (one or both sides), size of those trees (small or large), and the presence of grass or pavement with/without flowers. In addition to these 96 images, the pool included eight images that had no trees but which had pavement or grass with/without flowers against one or the other architectural background.

All of the images had the same cloudless, blue sky which Google SketchUp 7 offers as a default, and the same lighting features. The date and time of day for the images were set for June 21 at 12:00 AM (i.e., the summer solstice in the northern hemisphere) to minimize shadow-projection from buildings and trees.

After generating a streetscape, a virtual camera was positioned in the center of the near end of the street at a height of 1.75 m, which is about eye-level for an adult male of average height. Subsequently, a screenshot was captured and rendered in V-Ray v1.5.1 for SketchUp

(demo version) for photorealistic simulation of colour and light. More specific details of the image capture, camera settings and rendering process are provided by Lindal and Hartig (2013).

5.2.2 Amount of vegetation

A quantification of the vegetation was done to support the test of the interactive effect of street vegetation and architectural characteristics. Following an approach described by Nordh et al. (2009), a grid of 588 cells was laid over any image that included vegetation. Each cell more than 50% covered by vegetation was marked, and then all marked cells were counted. The percentage of vegetation ranged from 0 to 25.9% of the cells across images.

5.2.3 Psychological variables

Independent groups of participants rated each of the streetscapes on either preference (*I like this environment*), judged likelihood of restoration (*I would be able to rest and recover my ability to focus in this environment*), being away (two statements combined into one item, *Spending time here gives me a break from my day-to-day routine; It is a place to get away from the things that usually demand my attention*), or fascination (two statements combined into one item, *This place is fascinating; My attention is drawn to many interesting things*). Ratings on these items were given with the same 11-point scale (0 = *not at all*, 10 = *completely*). The items for being away and fascination were taken from the Perceived Restorativeness Scale (PRS) (Hartig et al., 1997a, 1997b).

5.2.4 Procedure

Data collection was carried out via the internet. The Social Science Research Institute of the University of Iceland recruited participants for the study by sending email and Facebook

messages to available lists. The messages provided a link to a website where the participants could access the study. 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 one of two different sets of streetscape images, each of which included half of the images. Each participant was asked to rate all of the images on only one of the psychological variables. The order of the images in the given set had previously been randomly generated using an online randomization program. The order was then fixed, and the participants went through the images from either first to last or vice versa. The participant was also asked to provide background information (age, gender, nationality and familiarity with the kind of environments shown in the images).

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, and they were asked to keep it in mind when rating the images: "*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 et al., 1997; Lindal & Hartig, 2013; Nordh et al., 2009, 2011; Staats et al., 2003). No scenario was presented prior to the ratings of preference.

5.2.5 Participants

In total, 188 Icelanders (57% women), ranging in age from 20 to 70 years (M = 44.6, SD = 13.1), voluntarily participated in the study. As in the forerunner of this study (Lindal & Hartig,

2013), in which the participants were also Icelandic, the level of familiarity with streetscapes like those presented was generally low among the participants (M = 3.97 out of 11, SD = 2.58). Urban environments in Iceland are generally different from those presented in this study. Participants would therefore have little opportunity to regularly experience streetscapes like those shown in the study. Some participants would however have experienced similar environments when travelling or through different types of media presentations. Despite the generally low level of familiarity, we collected data only from Icelanders in this study to better relate the results to the results from the previous study, and because densification of urban areas in Iceland could in the future involve streetscapes like those shown here.

5.2.6 Statistical analysis

Each participant rated only half of the images and then only on one of the four psychological variables. Thus, each participant was only asked to make ca. 52 ratings in total. The number of participants rating a given variable ranged from 41 to 52. The number varied because the variable to be rated was assigned at random by the data collection program. Based on the ratings from a given group, a mean value was calculated for each image and then the mean values for the images were used for further analysis. Thus, our analyses did not treat the individual participants as cases or units of analysis, but instead treated the images as units of analysis. A mistake made during the online survey creation forced us to drop one streetscape, leaving 103 images for further analyses.

Our main analyses assessed the strength of the independent direct effects of number, location and size of trees and the presence of flowers and grass on the judged likelihood of restoration. We also estimated mediation of the relationship between environmental features and

restoration likelihood by being away and fascination. For these analyses, we used Preacher and Hayes' (2008) regression-based approach, in which the total and the direct effect of the independent variables on the dependent variable (*c* and *c'*) and the indirect effect though mediators (*ab*) can be tested simultaneously using confidence intervals obtained with bootstrap methods. Further details of this approach and the rationale for using it in this kind of research are provided in Lindal and Hartig (2013). The mean ratings of being away (provided by one group) correlated strongly ($r = .90$) with the mean ratings of fascination (provided by another group); we therefore tested separate regression models with either being away or fascination as the sole mediator to avoid collinearity. We repeated these analyses with preference as the dependent variable. We did not include the variable representing the architectural characteristics of the buildings in the streetscapes, but we did include that variable in the final set of analyses.

The final set of analyses assessed the interactive effect of architectural characteristics and street-side vegetation. We first performed a multiple regression analysis which included three variables: the overall amount of vegetation in the image, the composite architectural characteristics of the buildings lining the street (i.e., one-story buildings with moderate surface and silhouette complexity versus three-story buildings with low surface and silhouette complexity), and the interaction term. The vegetation variable was centered prior to creating the interaction term to avoid collinearity (Tabachnick & Fidell, 2007). Following up on this analysis, we performed five two-way analyses of variance (ANOVA). Each ANOVA crossed the composite architectural characteristics with one of the five vegetation variables (i.e., number of trees, arrangement of trees, size of trees, presence of flowers, presence of grass).

5.3 Results

5.3.1 Effects of the physical variables on restoration likelihood ratings

The mean values for restoration likelihood ranged from low-to-moderate across the streetscapes (see Table 5.1). Those streetscapes that received the lowest, closest-to-average and highest ratings on restoration likelihood are shown in Fig. 5.1. Bivariate correlations show that, in keeping with expectations, restoration likelihood tended to be rated higher for streetscapes with more trees and with flowers present (see Table 5.1). Tree size, tree arrangement and the presence of grass also correlated positively with restoration likelihood; however, these correlations were not statistically significant.

Table 5.1. Descriptive statistics and correlation matrix for the variables under study, calculated looking across the streetscape images.

	M	SD	Min	Max	1	2	3	4
Being away [a]	4.02	0.83	1.70	5.48	1			
Fascination [a]	3.75	0.85	1.64	5.63	.90**	1		
Restoration likelihood [a]	4.29	0.86	2.43	6.74	.66**	.79**	1	
Preference	3.95	0.76	2.04	5.75	.87**	.88**	.83**	
Architectural properties [b]	--	--	--	--	.49**	.65**	.75**	.63**
Number of trees	--	--	--	--	.51**	.36**	.32**	.42**
Tree size [c]	--	--	--	--	.24*	.18	.08	.18
Tree arrangement [d]	--	--	--	--	.33**	.34**	.19	.27**
Grass [e]	--	--	--	--	.15	.12	.10	.17
Flowers [e]	--	--	--	--	.42**	.39**	.32**	.44**

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] Three stories and low complexity (= 0) versus one story and moderate complexity(= 1); a higher value indicates higher restorative potential as determined in a previous study
[c] 0 = small trees, 1 = large trees
[d] 0 = trees on one side, 1 = trees on both sides
[e] 0 = not present, 1 = present

Fig. 5.1. 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 = 2.43, SD = 2.19); The streetscape image with the closest-to-average mean rating for restoration likelihood (M = 4.24, SD = 1.74); The streetscape image with highest mean rating for restoration likelihood (M = 6.74, SD = 2.51).

5.3.2 Fascination and being away as mediators

The rated mean values for being away and fascination were relatively low (see Table 5.1). Both being away and fascination showed strong, positive bivariate correlations with multiple physical attributes as well as with restoration likelihood (see Table 5.1), in keeping with the expectation that they would mediate relationships between physical attributes and judgments of restoration likelihood.

In the regression analysis with being away as a mediator, the environmental components accounted for 44.9% of the variance in restoration likelihood. When adjusting for the influences of the other environmental components, the total effects (*c*) of number of trees and presence of flowers were statistically significant (see Fig. 5.2 and Table 5.2). When being away was added to the model, the indirect effects of number of trees, presence of grass and presence of flowers were significant. No direct effects (*c'*) of the environmental components remained significant with

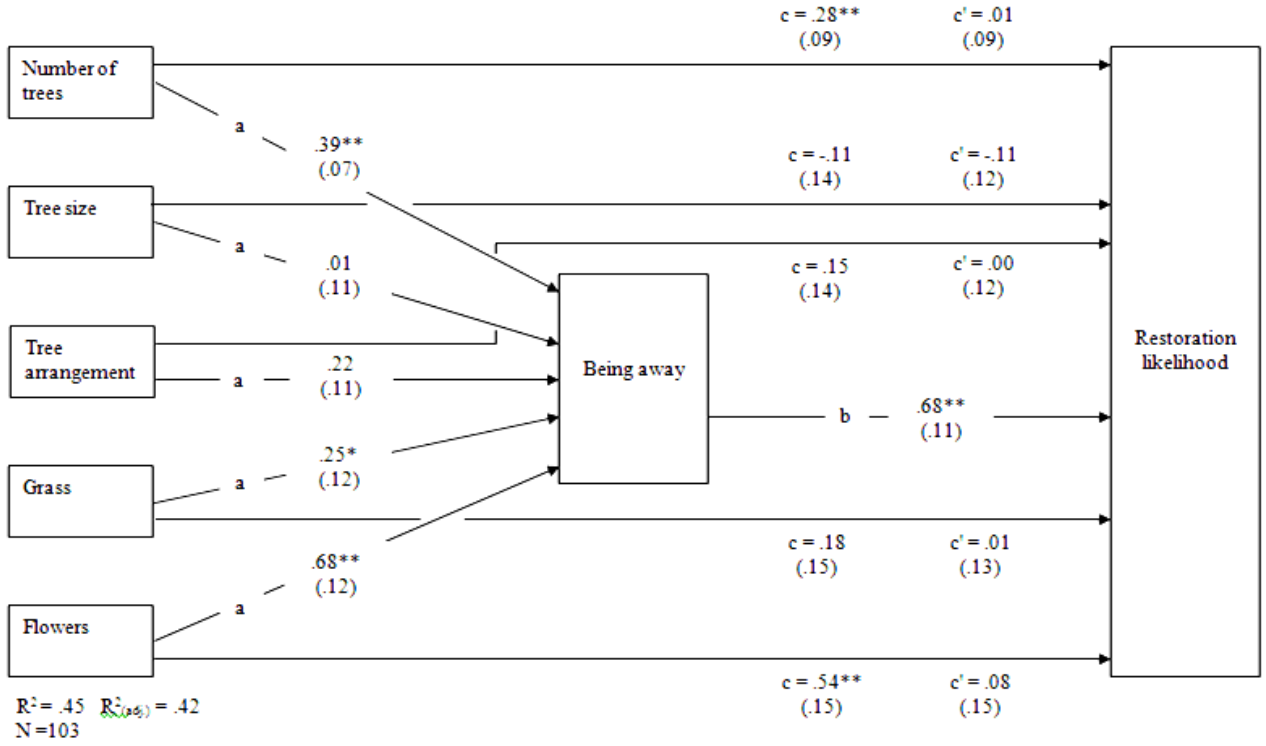

*Fig. 5.2. Mediation model with being away as the mediator of the effects of physical environmental components of urban streetscapes on judgments of restoration likelihood. Unstandardized coefficients are shown with the corresponding standard errors in the parentheses. The paths marked "a" represent the effect of the physical components on the mediator. The path marked "b" represents the effect of the mediator on restoration likelihood. The paths marked "c" represent the effects of the physical components on restoration likelihood before adjustment for the mediator, though with adjustment for the other physical environmental component. The paths marked "c'" (c prime) represent the effects of the physical components on restoration likelihood after adjustment for the mediator. The difference between the values for c and c' represents the sum of the indirect effects transmitted through the mediator. *p < .05; **p < .0001.*

being away as the mediator. Neither tree size nor tree arrangement significantly affected ratings of being away. With fascination as a mediator, the environmental components accounted for 63.1% of the variance in restoration likelihood. When adjusting for the other environmental components, the total effects (*c*) of number of trees and presence of flowers were significant (see

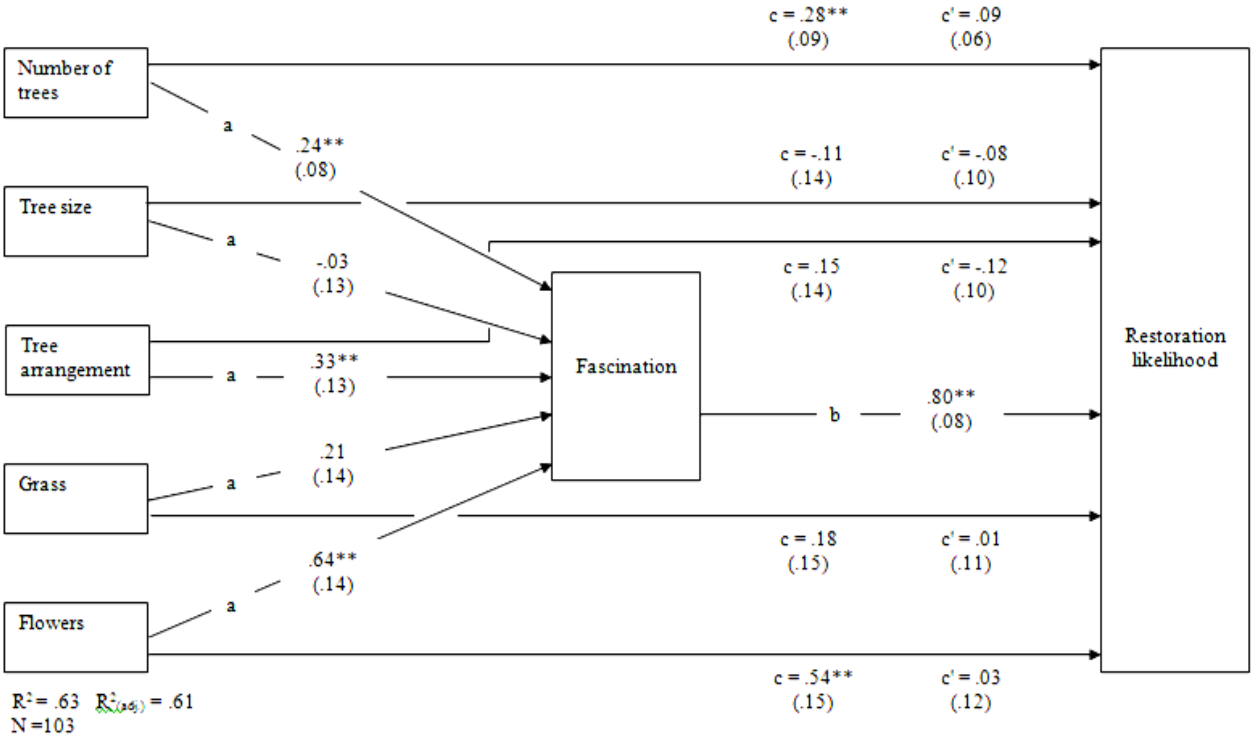

*Fig. 5.3. Mediation model with fascination as the mediator of the effects of physical environmental components of urban streetscapes on judgments of restoration likelihood. Unstandardized coefficients are shown with the corresponding standard errors in the parentheses. The paths marked "a" represent the effect of the physical components on the mediator. The path marked "b" represents the effect of the mediator on restoration likelihood. The paths marked "c" represent the effects of the physical components on restoration likelihood before adjustment for the mediator, though with adjustment for the other physical environmental component. The paths marked "c'" (c prime) represent the effects of the physical components on restoration likelihood after adjustment for the mediator. The difference between the values for c and c' represents the sum of the indirect effects transmitted through the mediator. *p < .05; **p < .0001.*

Fig. 5.3 and Table 5.3). When added to the model, fascination mediated the effects of number of trees, tree arrangement, and presence of flowers on restoration likelihood. As with being away, no direct effects (*c'*) of the vegetation variables remained significant with fascination as the mediator in the model. Neither tree size nor the presence of grass affected fascination.

5.3.3 Interaction between the built environment and street vegetation

As indicated by the correlations in Table 5.1, the composite architectural characteristics of the buildings along the streets had strong effects on the environmental evaluations. The one-story buildings with moderate surface and silhouette complexity engendered higher ratings of restorative quality and restoration likelihood than the three-story buildings with low surface and silhouette complexity. These correlations affirm that the manipulation of architectural characteristics in the streetscapes had the effects expected on the basis of the previous findings of Lindal and Hartig (2013).

Table 5.2. Indirect effects of the association between the environmental components and restoration likelihood, through being away.

	Point estimate	BC[a] 95% confidence interval	
		Lower	Higher
Number of trees	0.27	0.15	0.40
Tree size	0.01	-0.14	0.17
Tree arrangement	0.15	-0.01	0.31
Presence of grass	0.17	0.01	0.33
Presence of flowers	0.47	0.28	0.70

[a] BC (bias corrected confidence interval; see Efron, 1987) based on bootstrapped estimates. When the confidence interval does not include zero, the indirect effect can be regarded as statistically significant.

Table 5.3. Indirect effects of the association between the environmental components and restoration likelihood, through fascination.

	Point estimate	BC[a] 95% confidence interval	
		Lower	Higher
Number of trees	0.20	0.06	0.34
Tree size	-0.02	-0.21	0.18
Tree arrangement	0.27	0.07	0.47
Presence of grass	0.17	-0.05	0.40
Presence of flowers	0.51	0.27	0.79

[a] BC (bias corrected confidence interval; see Efron, 1987) based on bootstrapped estimates. When the confidence interval does not include zero, the indirect effect can be regarded as statistically significant.

Looking to the possibility that the effect of streetside greenery would depend on the architectural characteristics of the buildings along the street, our multiple regression analysis

revealed independent effects of the overall amount of vegetation (b = 0.05, $SE\ b$ = 0.01, β = 0.36, $p < .001$) and the composite architectural characteristics (b = 1.32, $SE\ b$ = 0.09, β = 0.77, $p <$ .001), with the two variables explaining 72% of the variance in restoration likelihood ratings. The interaction between composite architectural characteristics and amount of vegetation on judged restoration likelihood was however not significant (p = .17). We also did not find any significant interaction in the series of five ANOVA which crossed the composite architectural characteristics with one of the five vegetation variables (all ps > .45); however, the variance explained was substantial in each analysis (R^2 number of trees = 0.68; R^2 tree size = .60; R^2 tree arrangement = .61; R^2 grass = .59; R^2 flowers = .69).

5.3.4 Effects of the physical attributes on preference

The values for preference ranged from low to moderate across the images, and they correlated strongly and positively with the values for restoration likelihood (see Table 5.1). Preference also correlated positively with the number of trees, their size and arrangement, and the presence of grass and flowers; however, the correlations for tree size and presence of grass were not significant.

When we substituted preference for restoration likelihood in the multivariate assessments of mediation, the results showed the same basic patterns seen in Fig.s 5.2 and 5.3 for restoration likelihood, but with differences in the magnitude of some coefficients and somewhat greater amounts of explained variance (R^2 = .76 with being away as the mediator and R^2 = .73 with fascination as the mediator).

5.4 Discussion

This study sheds light on the significance of vegetation for restorative experience in urban streetscapes. A larger number of trees and the presence of flower beds beside buildings positively affected judgments of restoration likelihood. These effects were apparently mediated by two restorative qualities, being away and fascination. On the other hand, judgments of restoration likelihood did not increase with increasing size of trees, contrary to our expectation. Conceivably, the difference between the size of the canopies of the small and the large trees was too small.

Tree arrangement on both versus one side of the street also did not affect judgments of restoration likelihood, at least initially. When fascination was added as a mediator to a multivariate model which also adjusted for the effects of the other physical attributes, we did find that having trees on both sides of the street contributed positively to restoration likelihood. Similarly, the bivariate relationship between the presence of grass and restoration likelihood was not significant, but when being away was added to the model, we found the presence of grass to significantly increase restoration likelihood through the mediator.

We found no interaction between the composite of architectural properties and street vegetation. However, it should be noted that the streetscapes shown to have higher restorative potential on the basis of composite architectural characteristics (i.e., one story buildings with more façade details and peaked roofs) were not rated as highly restorative in some absolute sense, neither in this study nor in the study by Lindal and Hartig (2013). The difference in the restorative potential between the two streetscapes might have been too small to detect an interaction. Conceivably, some form of interaction could emerge if a broader register of

restorative quality, including high restorative quality, had been covered by the architectural manipulations. For example, Bell et al. (2006) have noted that the addition of trees might sometimes reduce the aesthetic quality of the environment by blocking beautiful facades or particularly appealing vistas. On the basis of the present results, however, the clearest conclusion that we can draw is that architecture and street greenery of different kinds had independent effects. More research on this issue is needed, given the practical implications. In this regard, we note that Smardon (1988) has pointed out that street trees may improve street appearance more effectively than facade improvements.

Regarding preference, the study replicates previous findings showing a strong relationship between preference and restoration likelihood ratings (e.g., Nordh et al., 2009; Lindal and Hartig, 2013). The bivariate and multivariate results thus lend support to our assumption that findings regarding environmental preference can be used as a source of guidance for predictors of restoration likelihood, given gaps in the literature on specific physical attributes that predict restorative potential. This said, the results of the tests involving preference were not exactly alike those for restoration likelihood. For example, the amount of variance explained in the respective multivariate analyses was substantially lower for restoration likelihood. This may reflect on the fact that in rating restoration likelihood the participants were asked to bear in mind a scenario of attentional fatigue. No such scenario was provided for the ratings of preference. In any case, the results indicate that although the two dependent measures correlate strongly, they are indicators of different underlying constructs. Preference is a broader construct than restoration likelihood; people may strongly like an environment because it supports restoration, but they may also like environments to differ degrees for reasons unrelated to restoration.

5.4.1. Limitations of the study

Critics might fault this study for using two-dimensional images to present the streetscapes. This is a common validity concern, and one addressed in comprehensive meta-analyses by Stamps (1990, 2010c). Both of his studies found strong correlations ($r = .86$) between ratings obtained with simulations versus on-site.

The sample that rated the streetscape images might also be considered a limitation of the study. Given the low familiarity that Icelanders have with the kind of environment presented, the relevance of our data could be questioned. We want to emphasize, however, that urban residential environments like those in our images could be built in Iceland as elsewhere, and having evaluations of those environments in advance could of great relevance when it comes time to decide how the development should proceed. It would nonetheless be interesting to see whether different results would be obtained from people who have more familiarity with such environments.

Another feature of the research that can reasonably be considered a limitation has to do with the vantage point of the viewer. The participants in this study viewed the streetscape from the far end, looking down the entire streetscape. We can only acknowledge that the results might be quite different if the vantage point were mid-street, where a person standing on one or the other sidewalk could have quite a different sense of the streetscape. This said, we think it is nonetheless important to represent in research the vantage point we chose, as it is that of a pedestrian or vehicle operator who could start down the street, at which point an impression of the streetscape would begin to develop.

5.4.2 Closing comments

Our results agree with previous studies showing that the presence of natural elements can promote perceptions of restorative quality in urban environments (e.g., Todorova et al., 2004). They also affirm a proposal by Thwaites, Helleur, and Simkins (2005), which see streets together with a dense network of small, well-designed public spaces as serving the restoration needs of people in dense urban environments.

This study also contributes to the literature on restorative environments. It replicates the findings by Lindal and Hartig (2013), showing the different impact of different street block architectural properties on restoration likelihood ratings. It also provides additional evidence that perceptions of being away and fascination mediate relationships between physical attributes of the environment and judgments of restoration likelihood.

The techniques used to create the environmental stimuli in this study also add value to the research on restorative environments. High-performance graphical and display technology (cf . de Kort & IJsselsteijn, 2006; Valtchanov, Barton & Ellard, 2010), offer an easily approachable and low cost opportunity to create highly realistic, three-dimensional virtual urban environment in which design variables of interest can be systematically manipulated and confounding variables can be controlled (Rohrmann & Bishop, 2002). Although the potential utility of virtual environments in this area of research has been recognized (cf . de Kort & IJsselsteijn, 2006; Valtchanov et al., 2010), the environments so far used do not to our knowledge make use of the kind of systematic manipulation of environmental attributes that we have demonstrated here. This study and its forerunner (Lindal & Hartig, 2013) have provided a platform for the creation of interactive three dimensional virtual urban environments that can be used to carry out studies

on actual restoration in virtual “field settings”. This seems a promising approach to us, particularly in a time when urban densification calls for public input regarding ways to increase residential densities while also providing contact with nature and other opportunities for restorative experiences.

Chapter 6 - Paper IV: Correspondence between measured restoration and restoration likelihood judgments for virtual urban environments

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Lindal, P. J. & Hartig, T. (2013). Correspondence between measured restoration and restoration likelihood judgments for virtual urban environments. (Submitted)

6.1 Introduction

People normally must restore depleted physical and psychological resources on a regular basis. The degree to which they can realize needed restoration at a given time depends on numerous factors, including the characteristics of the socio-physical environment then available for restoration. Given the practical significance of restoration for performance and health, the restorative quality of environments has attracted substantial attention from researchers.

Various approaches have been developed to measure restorative quality (Hartig, 2011). One approach involves asking people to report on the likelihood that they would experience restoration when visiting a given environment. In studies using this approach, participants are given a scenario that describes some need for restoration, and they are asked to imagine being in this condition while rating one or more environments, typically presented with photographs or digital images. This approach has important advantages. The scenarios describe common restoration needs, and participants consider them to be familiar and plausible (e.g., Herzog et al., 1997; Staats et al., 2003). The restoration likelihood rating can be obtained with a single item formulated in straightforward language. When the rating task uses a single item, it can be administered easily and quickly, so that participants can evaluate many different environments without becoming exhausted (e.g., Nordh et al., 2009). The rating task can thus work well in studies that involve large sets of photographic or digital images that capture practically relevant ranges of variation in focal environmental variables. In this way the approach can provide information useful for guiding the design of future environments.

Despite these advantages, the utility of the approach remains in question because of the uncertain correspondence between the perceived likelihood of experiencing restoration and

restoration that might actually occur. Building on their previous experience with restoration in different environments, people might perceive a high likelihood of restoration in a given environment. It is uncertain, however, whether the same or other people would, on future occasions, actually experience changes in attention, affect, or physiology characteristic of restoration. The validity of the approach would therefore be strengthened by experimental evidence that restoration likelihood ratings do predict future restoration.

The present study addresses this issue. It compares the restorative effects of environments that previously had received different ratings of restoration likelihood. At the same time, drawing inspiration from de Kort and IJsselsteijn (2006; de Kort, Meijnders, Sponselee, & IJsselsteijn, 2006), the present study explores the utility of interactive virtual display technology for applied research concerned with restorative quality. In comparison to traditional approaches to implementing environmental comparisons in this research area, virtual technology may enable more accurate estimates of the restorative impacts of specific architectural and natural features in future environments.

Traditionally, researchers have studied the restorative effects of different environments by showing their participants images or videos of the environments while seated in a laboratory setting (e.g., Berto, 2005; Ulrich et al., 1991), or by having their subjects walk or otherwise spend time outdoors in field settings (e.g., Hartig et al., 2003; Johansson et al., 2011). These comparisons typically have involved locally available exemplars of two broad environmental categories, natural and urban, and they have frequently (though not uniformly) found more beneficial change in affect, physiological parameters, and/or performance on cognitive tests in the natural environment (Bowler et al., 2010). Such results have been used to support broad

policy and design initiatives regarding access to natural environments for people living in cities (e.g., Länsstyrelsen i Stockholms län, 2003); however, they provide little specific guidance regarding configurations of physical variables that designers might manipulate when trying to promote restorative quality in future environments (Velarde et al., 2007).

In comparison to this traditional approach, virtual technology enables researchers to estimate the restorative impact of possible future environments in which architectural and natural features have been manipulated in very specific ways. This technology thus lends itself to studies that hold the promise of providing specific design guidance. Moving beyond the basic natural versus urban comparison is particularly important in light of the demand for residential densification in many cities worldwide, which is prompting calls for urban design that promotes restorative quality in urban areas through better integration of natural and built features (Beatley, 2009; Nordh et al., 2009; van den Berg et al., 2007; White and Gatersleben, 2011).

To date, few studies have used virtual technology to assess restoration with realistic three-dimensional virtual representations of different kinds of everyday environments. Like traditional studies in the field, they have focused on a small number of exemplars from broad environmental categories, and they have produced findings generally congruent with those from traditional studies in that they have shown a restorative advantage of natural environments (e.g., Valtchanov and Ellard, 2010; Valtchanov et al., 2010). Building on this kind of research, the present study also compares the restorative effects of a small number of virtual environments. Unlike the earlier studies, however, the two virtual environments that we compare are not exemplars of broad environmental categories. Rather, they were created from sets of digital images in which natural and architectural characteristics had been systematically manipulated.

The images used in the creation of virtual environments for the present study were selected on the basis of restoration likelihood ratings obtained in two previous studies. Both of the previous studies concerned the restorative quality of urban residential streetscapes as they might be experienced by a person walking home from work.

For the first of the previous studies (Lindal & Hartig, 2013a), we generated 145 three dimensional streetscape images by digitally manipulating three architectural properties in streetside buildings: roofline silhouette (flat versus peaked roof) , the amount of facade ornamentation, and the height of the building (one- versus three-story).[6] The roofline silhouette and façade ornamentation variables were integrated for each streetscape (i.e., across all buildings) into a measure of entropy, or aggregate visual complexity. For the rating task, the participants were provided with a scenario describing a need for restoration ("*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*"). Keeping this scenario in mind, they were asked to rate the likelihood of experiencing restoration if they were to walk through the streetscape presented (i.e., a single item, "*I would be able to rest and recover my ability to focus in this environment*"; 0 = not at all, 10 = completely). The ratings for each image were averaged across the participants, providing a score that was used in an analysis that treated the images as cases. The streetscapes lined by one-story high buildings with relatively high visual complexity had the highest scores

[6] The rationale for the selection of these variables as potential determinants of restorative quality is provided in the original article.

for restoration likelihood; however, scores generally were distributed at the low end of the scale, ranging between 2.33 and 5.23 on the 0-10 scale. The streetscapes with three-story buildings and little visual complexity got the lowest ratings.

A similar methodology and procedure were used in the second of the previous studies (Lindal & Hartig, 2013b). Starting from the two images with the lowest restoration likelihood ratings and the two with the highest restoration likelihood ratings in the previous study, we systematically introduced different amounts and configurations of trees, grass and flowers to the streetscapes (see Note 6). In total, 103 images were presented to participants. The rating task was preceded by the same scenario describing a need for restoration, and ratings were given with the same restoration likelihood item. The results showed that, as in the previous study, the architectural characteristics of the buildings along the street had a strong effect on restoration likelihood ratings. Additionally, street trees and the presence of flowers each boosted restoration likelihood, over and above the contribution of the architectural variation. In comparison to the results from the previous study, the distribution of restoration likelihood scores shifted upward, ranging between 2.43 and 6.74 on the 0-10 scale. Thus, the two previous studies provided sets of images for which divergent restoration likelihood ratings could be attributed to specific manipulations of architectural and natural features. The most divergent images across the two sets were used to create the virtual environments compared in the present study.

In the present study, as in the two previous studies, our understanding of restorative quality is informed by attention restoration theory (ART) (Kaplan & Kaplan, 1989; Kaplan, 1995). ART postulates that directed attention is a cognitive resource that is necessary for effective functioning in everyday life, and that the capacity to direct attention can become

depleted in efforts to meet everyday demands. According to ART, restoration of this depleted capacity is supported in person-environment exchanges characterized by four qualities. Being away refers to psychological distance from mentally demanding daily projects and routines. Fascination refers to effortless attention that is captured and held by objects in the environment and by processes such as exploration of the environment. Extent refers to the degree of coherence and order perceived in the environment and the scope for becoming involved in the environment. Finally, compatibility refers to how effectively the environment supports a person's inclinations and intentions.

In the previous two studies, ratings of being away and fascination were obtained for all of the images.[7] These ratings were not provided by those who completed the restoration likelihood ratings, but were instead provided by different groups of people. As with the restoration likelihood ratings, a mean score was obtained for each image and used as data in analyses that treated images as cases. In both of the previous studies, being way and fascination appeared to mediate the effects of physical variations on restoration likelihood. For example, in the first study, greater differentiation in the roofline and more ornamentation of buildings entailed greater fascination which in turn boosted restoration likelihood, while greater building height reduced the sense of being away and so reduced restoration likelihood. Following from the earlier studies, the present study considers whether experiences of being away and fascination mediate eventual

[7] Extent and compatibility were not measured in the previous studies due to expectations of range restriction imposed by features of the study set-up, visual stimuli, and instructions to participants.

effects of the different virtual environments on the ability to direct attention and on affective states.

6.1.1 Study objectives and hypotheses

In sum, the present study was designed to serve three objectives: (1) to provide a test of correspondence between restoration likelihood ratings and actual restoration in different virtual environments; (2) to demonstrate the use of virtual technology in implementing environmental comparisons that enable estimates of the restorative quality impacts of specific environmental design measures; and (3) to assess the role of being away and fascination as mediators of the restorative effects of different virtual urban environments. To serve these objectives, we created two virtual urban neighbourhoods using sets of streetscape images that in two previous studies had received divergent ratings of restoration likelihood. After completing tasks intended to induce a need for restoration, participants spent time "walking" through one of the neighbourhoods. Measures of directed attention and affective states were obtained before and after the "walk" so we could assess the restorative effects of the virtual neighbourhoods. Measures of being away and fascination were also obtained to assess their mediating role. We tested two sets of hypotheses. First, we hypothesized that participants who walked through a virtual neighbourhood comprising streetscapes previously rated relatively high on restoration likelihood would experience more restoration than those who walked through a virtual neighbourhood comprising streetscapes that previously had gotten low ratings on restoration likelihood. More specifically, we expected that participants experiencing the neighbourhood previously rated as more restorative would show more improvement in their performance on a test of attention, as well as greater improvement in affective states. Second, we hypothesized that

these differential effects of the virtual neighbourhoods on attention and affect would be mediated by being away and fascination.

6.2 Method

6.2.1 Virtual environments

Two interactive three-dimensional virtual urban residential neighbourhoods were created based on the results from the first of our previous studies (Lindal & Hartig, 2013a), which concerned restoration likelihood judgments in relation to variations in the architectural characteristics and height of buildings in urban residential streetscape. The five streetscape images that got the lowest mean ratings on restoration likelihood in Paper II (values from 2.33 to 2.74) and the five streetscapes images that got the highest mean ratings (values from 4.81 to 5.23) were adapted and combined to form two virtual neighbourhoods. For both neighbourhoods, the street plan was identical and consisted of an area of 3x3 square city blocks in a grid. Each neighbourhood comprised 36 sections of

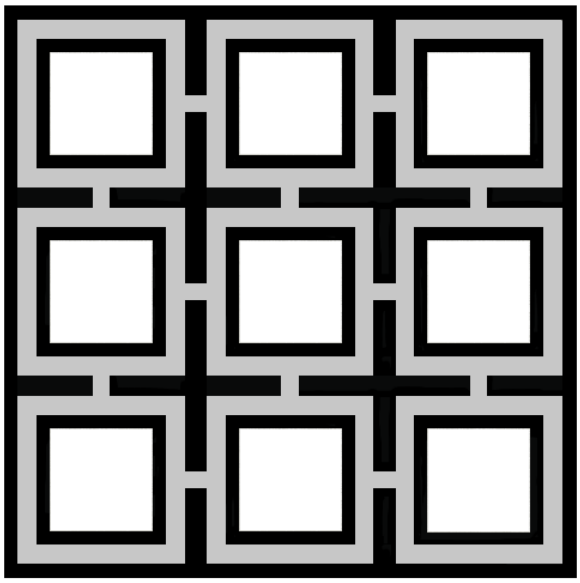

Fig. 6.1. The street plan used for the two virtual neighbourhoods. Grey lines represent streets and black lines represent blocks of buildings.

main streets (each 125 m long) and 12 sections of connecting streets (each 45 m long) (see Fig. 6.1).[8]

Blocks of buildings were arranged along the streets. Depending on their location within the neighbourhood, the blocks consisted of 7-15 individual buildings. The buildings were generally eight meters wide, but a few were widened to 10.5 meters to fill gaps. The distance between the blocks of buildings on the opposing sides of each street was 14.4 m, wall-to-wall. This distance included a 6 m wide street, a 2 m wide sidewalk on each side of the street, and a 2.2 m wide "intermediate" space beside each block of buildings bounded by the building walls, doorsteps and the sidewalk.

For the neighbourhood assumed to have a low restoration likelihood, the streets were lined with three-story buildings that had low levels of silhouette complexity (i.e., most of the buildings had flat roofs) and surface complexity (i.e., most of the building façades had few details) (see Fig. 6.2 (left panel)). For the neighbourhood assumed to have higher restoration likelihood, the buildings were one story high and had higher levels of silhouette complexity (i.e.,

Fig. 6.2. Screenshots from the two virtual neighbourhoods: (left panel) the neighbourhood assumed to have a low restoration likelihood; (right panel) the neighbourhood assumed to have a higher restoration likelihood.

most of the buildings had peaked roofs) and surface complexity (i.e., most of the buildings had ornamentation and other details). In line with the second of our previous studies (Lindal & Hartig, 2013b), trees were placed along streets in this neighbourhood to further increase the difference in restorative quality between the two neighbourhoods (see Fig. 6.2 (right panel)). Due to technical restrictions, we were not able to add the same amount of street vegetation shown in the streetscape images that got the highest restoration likelihood ratings in the previous study. Both neighbourhoods included street lamps and traffic signs, but no cars or people were included.

The three dimensional software Google SketchUp 7® (free version) was used to develop the virtual neighbourhoods. As a texture to increase the realism of the environment, overlay photos were pasted to all visible surfaces in the model. To further increase realism and provide interactivity to the virtual environments, the video game engine Unity 3D® was used for rendering.

The virtual neighbourhoods were presented on a 21" LCD monitor in 1024x768 resolution using a computer with either an ATi x1900xt or a nVidia GTX285 1024MB graphics card running on the "fantastic" settings in the Unity engine. In each neighbourhood, the participants were able to navigate freely along the streets, to start and stop, and to look in any direction by using a mouse and the arrow-keys. An ambient urban background sound was played through Philips SHP2500 headphones which the participant was asked to put on just before the VE started running.

For the sake of convenience, we will in the following refer to the comparison conditions as the low and the high restoration likelihood neighbourhoods or environments; however, the

designations are relative. We assume that the low restoration likelihood neighbourhood really does have little restorative potential, but the high restoration likelihood neighbourhood should not be considered as highly restorative in some absolute sense.

6.2.2 Experimental design and participants

A mixed two (environment; low versus high restoration likelihood) x two (time; pretest versus posttest) repeated measures design was implemented. The sample consisted of 58 students (76% women) at a large Swedish university. The participants ranged in age from 19 to 36 years old (M = 24.2, SD = 4.04) and were recruited with flyers placed around the university campus. Substantially more women than men registered for the study, so the sample was stratified by gender before random assignment to the two environment conditions. Six men and 22 women were assigned to the low restoration likelihood condition and seven men and 23 women were assigned to the high restoration likelihood condition. A movie ticket or course credit was given in exchange for participation.

The study was approved by the Human Research Ethics Committee at the University of Sydney, Australia.

6.2.3 Measures

6.2.3.1 Directed attention capacity

The Sustained Attention to Response Task (SART) (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Manly, Robertson, Galloway, & Hawkins, 1999) was used to induce attentional fatigue prior to the virtual "walk" and also to obtain pretest and posttest measures of directed attention capacity. The SART appears to have been a sensitive measure of attentional

performance in several studies on restorative experience (Berto 2005; Berto, Baroni, Zainaghi, & Bettella, 2010). The version of the SART used for this study involves pressing the same response key (e.g., the space bar) as quickly as possible as a digit (from 1 – 9) appears on a computer screen, except when the digit "3" appears, when the key press must be inhibited. The digit "3" appears infrequently, so key presses can quickly become routinized, and this makes it difficult to inhibit the key press when the "3" does appear unless one is paying close attention. Both inhibition errors (i.e., hitting the response key when the digit "3" appears on the screen) and reaction time have been linked to sustained attention capacity (Robertsson et al., 1997; Manly et al., 1999). A lower error rate together with a faster average reaction time indicates better sustained attention and vice versa.

The SART version used in the present study consisted of 267 digits presented over a 6-minute interval. The digits were black on a white background and presented with a font size of 40 points. Each digit appeared for 425 msec. The time taken to make a response was registered unless the response was made after the 425 msec period during which digit was presented, in which case the reaction time was recorded as 425 msec. The digit presentation was followed by a 975 msec mask (i.e., a blank screen). With these parameters, the SART version used in the present study differed slightly from the version used previously in this area (e.g., Berto 2005). The difference is due to technical restrictions imposed by the software used to run the experiment.

6.2.3.2 Affective states

A Swedish translation of Zuckerman's (1977) Inventory of Personal Reactions (ZIPERS) was used to measure current affective states before and after the environmental treatment. The

ZIPERS has been used previously in studies of restorative environments (e.g., Ulrich et al., 1991; Hartig et al., 2003; Valtchanov & Ellard, 2010) and includes 12 items which measure five factors: positive affect, anger/aggression, fear arousal, sadness and attentiveness. Responses to items (e.g., "*My heart is beating fast*", "*I feel carefree and playful*") were given with 5-point scales (1 = not at all, 5 = very much). For the ZIPERS scales with multiple items, internal consistencies (Cronbach's alphas) for the pretest measures were as follows: for positive affect, .74; for fear arousal, .70; and for anger/aggression, .66. Internal consistencies for the posttest measures were as follows: for positive affect, .84; for fear arousal, .66; and for anger/aggression, .84.

To address skew in some subscales, and to improve measurement reliability and simplify data analysis, we calculated an affective balance score applying the logic used with the Affective Balance Scale (see Schiaffino, 2003). To compute the balance score, the ZIPERS items that represent negative feelings and reactions (anger/aggression, fear arousal and sadness) were combined into a broad "negative affect" measure at the two time points. The internal consistencies between the negative affect items were acceptable for both time points (pretest .77; posttest .85). To compute the affective balance score, the mean of the negative affect measure was subtracted from the mean of the positive affect measure. Thus a positive affective balance score indicates that positive feelings are experienced to a higher degree than negative feelings, and vice versa.

Attentiveness, the fifth factor of the ZIPERS, was not included in the affective balance measure as it does not clearly tap into positively or negatively valenced affect. It is treated separately as a self-report measure of attentional engagement.

6.2.3.3 Perceived restorative quality

Subjects completed 10 items from the being away and fascination subscales of the Perceived Restorativeness Scale (PRS) (Hartig et al., 1997a; Hartig et al., 1997b). Items from these subscales were used in the two earlier studies (Lindal & Hartig, 2013a, b) to test whether being away and fascination mediated relationships between physical attributes in streetscape images and ratings of restoration likelihood. As used in the present study, the being away scale consisted of five items adapted to the environments in focus (e.g., "*Spending time in the virtual neighbourhood gave me a break from my day-to-day routine*") with acceptable internal consistency (alpha = .74). The fascination scale consisted of five items (e.g., "*There was much to explore and discover in the virtual neighbourhood*") with acceptable internal consistency (alpha = .78). For simplicity in programming, the ten items were rated on a 5-point scale similar to the one used for the ZIPERS items (1 = *not at all*, 5 = *completely*).

6.2.3.4 Preference and familiarity

Subjects were asked to indicate how much they liked the architecture and design shown in the given virtual neighbourhood (1 = *disliked very much*, 5 = *liked very much*). They were also asked to indicate how familiar they were with places like the one represented in the virtual neighbourhood (1 = *completely unfamiliar*, 5 = *completely familiar*). The preference measure provided a check on the aesthetic evaluation of the environments, while the familiarity variable was included as a potential statistical control measure (cf. Hartig & Staats, 2006).

6.2.4 Procedure

Upon arrival, participants provided informed consent and then were seated in either one of two similarly furnished laboratory rooms. The procedure began with background questions, followed by a short SART practice test. Then the SART was administered three times to induce attentional fatigue and provide a pretest measure of directed attention capacity. Previous studies have used a single SART session as a fatigue manipulation (Berto, 2005); however, this approach does not enable confirmation of performance decay consistent with attentional fatigue. We asked the participants to repeat the SART three times so that we could assess decay in performance and so have a better sense of their restoration needs before the virtual walk. During 30 sec breaks between the SART sessions, participants received encouragement regarding their performance. On completion of the third six-minute SART session, the participants rated their affective state with the ZIPERS. Before entering the environmental treatment, participants were asked to read the following scenario and keep it in mind during the navigation: "*Imagine you are walking home after a long day at school. You are exhausted after having spent the entire day concentrating on school work and you now have a chance to stroll before you get home.*" After "walking" through the assigned environment for 15 minutes, they again completed the ZIPERS and SART. Finally, they completed the items regarding preference, being away, fascination and familiarity for the assigned environment. In total, it took the participants about 60 min to complete the procedure.

6.2.5 Preparations for statistical analysis

Five participants (four women and one man) fell from analyses because of incomplete data (mainly due to computer crashes with the virtual environments). This left data for analysis

from seven men and 20 women in the low restoration likelihood condition and from five men and 21 women in the higher restoration likelihood condition.

A preliminary test found greater familiarity with the high versus low restoration likelihood neighbourhood (M = 3.00, SD = 1.13 versus M = 2.33, SD = 1.14, respectively), $t(51) = 2.13$, $p = .038$. In our multivariate analyses we therefore considered whether any environmental effect on change in outcomes was moderated by familiarity, dichotomized as low (scores less than 3) versus moderate to high (scores 3-5). Aside from familiarity, we considered whether gender moderated the effect of environment on change in outcomes.

6.3 Results

6.3.1 Check on the attentional fatigue induction

Before the hypothesis tests, we checked whether the SART had induced attentional fatigue prior to the environmental treatment. Two repeated-measures analyses of variance (RM-ANOVA) were used to separately test change in mean reaction time and lack of inhibition (i.e., number of uninhibited key presses with presentation of the target digit). For these analyses, the three SART pre-treatment sessions were used as levels of a within-subjects factor (time). Reaction time appeared to become slightly faster across the SART sessions, rather than the anticipated increase which would have signaled declining performance (see Table 6.1). The

Table 6.1. Descriptive statistics for Sustained Attention to Response Test reaction time (msec) and lack of inhibition (errors of commission) in the three fatigue-induction sessions completed before the environmental treatment.

		1st session	2nd session	3rd session
Reaction time	M	331.85	325.75	328.23
	SD	25.40	29.24	30.47
Lack of inhibition	M	18.91	18.55	17.74
	SD	6.65	8.00	8.18

RM-ANOVA confirmed the apparent absence of performance decline; for the within-subjects main effect of time, $F(1.48, 76.84) = 2.70$, $p = .089$, partial $\eta^2 = .049$ (Greenhouse-Geisser corrected degrees of freedom). For lack of inhibition the results also indicate a slight improvement in performance rather than a decline, but the amount of change is again not statistically significant; for the main effect of time, $F(2, 104) = 1.44$, $p = .242$, partial $\eta^2 = .028$. In sum, performance of three consecutive six-minute SART sessions did not induce substantial attentional fatigue as expected on the basis of previous research (Berto, 2005). Supplementary analyses indicated that the overall patterns of results did not vary significantly with either gender or assignment to the environmental condition.

6.3.2 Effects of the virtual environments on change in SART performance

Participants in the high versus low restorativeness condition were expected to realize greater attentional restoration as reflected in a decrease in reaction times and a decrease in errors of commission from pretest to posttest. Mean reaction time did decrease slightly from the pretest to the posttest, suggesting a slight improvement in performance (see Table 6.2); however, the RM-ANOVA did not indicate a significant main effect of time, $F(1, 51) = 2.96$, $p = .092$, partial $\eta^2 = .055$. The amount of change in reaction time that did occur was not affected by the environmental manipulation, $F(1, 51) < 0.00$, $p = .987$, partial $\eta^2 < .000$.

Table 6.2. Descriptive statistics for Sustained Attention to Response Test reaction time (msec) and lack of inhibition (errors of commission) for the two virtual environment conditions at the pretest and posttest.

		Low restoration likelihood		High restoration likelihood	
		Pre	Post	Pre	Post
Reaction time	M	329.70	325.78	326.69	322.69
	SD	29.70	28.12	31.76	41.62
Lack of inhibition	M	17.44	18.70	18.04	18.73
	SD	8.47	7.87	8.01	9.44

Results for lack of inhibition (i.e., errors of commission) are similar to those for reaction time. The participants showed little pretest-posttest change (see Table 6.2), and this is reflected in the non-significant main effect of time in the RM-ANOVA, $F(1, 51) = 1.71$, $p = .196$, partial $\eta^2 = .033$. Moreover, the lack of substantial improvement in inhibition could be seen in both the high and low restorativeness conditions. Accordingly, the interaction of time and environmental condition was not significant, $F(1, 51) = 0.15$, $p = .705$, partial $\eta^2 = .003$.

The absence of substantial effects of environment on change in reaction time and errors of commission did not depend on either gender or familiarity; neither of them interacted with environment in affecting change in SART performance.

6.3.3 Effects of the virtual environments on affective states

At the pretest, just after completing the three initial rounds of the SART, the participants reported low to moderate levels of positive affects and attentiveness as well as low levels of anger/aggression, fear arousal, and sadness (see Table 6.3). The picture of change is complicated by the fact that, at the pretest, the participants in the low restoration likelihood neighbourhood reported greater positive affect ($p < .05$) and lower anger/aggression than their counterparts in the high restoration likelihood neighbourhood. The subsequent change in each measure thus appears to have closed a gap between the conditions in affective experience, rather than to have opened one. For each of these two measures, the environment x time interaction was not statistically significant; for positive affects, $F(1, 51) = 2.31$, $p = .135$, partial $\eta^2 = .043$, and for anger/aggression, $F(1, 51) = 1.29$, $p = .262$, partial $\eta^2 = .025$. In contrast, fear arousal and sadness did not show similar pretest differences between the two conditions, and change in each was more consistent with expectations. Also, the environment x time interaction was somewhat

stronger for each one, though still not significant; for fear arousal, $F(1, 51) = 2.88$, $p = .096$, partial $\eta^2 = .053$, and for sadness, $F(1, 51) = 2.46$, $p = .123$, partial $\eta^2 = .046$. On the whole, looking across these measures, the low restoration likelihood neighbourhood engendered a shift toward more negative affect while the high restoration likelihood neighbourhood engendered a shift toward more positive affect; for the environment x time interaction in affective balance, $F(1, 51) = 3.70$, $p = .060$, partial $\eta^2 = .068$.

Table 6.3. Descriptive statistics for affect measures obtained with the Zuckerman Inventory of Personal Reactions for the two virtual environment conditions at the pretest and posttest.

		Low restoration likelihood		High restoration likelihood	
		Pre	Post	Pre	Post
Positive affects	M	2.49	2.10	2.05	2.07
	SD	0.80	0.79	0.78	1.06
Anger/ aggression	M	1.79	2.10	2.06	2.08
	SD	0.75	1.05	0.99	1.20
Fear arousal	M	1.69	1.58	1.73	1.31
	SD	0.76	0.80	0.72	0.52
Sadness	M	1.70	2.11	1.81	1.73
	SD	0.78	1.34	0.80	0.83
Attentiveness	M	2.89	1.96	3.00	2.04
	SD	1.15	0.94	1.23	1.18
Affective balance	M	0.76	0.17	0.18	0.37
	SD	1.09	1.35	1.24	1.55

Note. With the exception of affective balance, scores fall on a scale from 1 to 5, where higher values indicate more of the given affect. For affective balance, positive values indicate that the mean for positive affects exceeds the mean for negative affects (anger/aggression, fear arousal, sadness).

Attentiveness was at similarly moderate levels in both groups at the pretest and then declined similarly during the environmental treatment; for the environment x time interaction, $F(1, 51) < 0.01$, $p = .928$, partial $\eta 2 < .001$.

The modest effects of environment on pretest-posttest change in affect were not further modified by either gender or familiarity, with the exception of positive affect. The observed means suggest that among the participants not familiar with the given environment, positive

affect declined from pretest to posttest in both environments. Among the participants familiar with the given environment, positive affect declined in the less restorative neighbourhood but increased in the more restorative neighbourhood. This pattern echoed in the test of change in affective balance and was statistically significant; for the environment x time x familiarity interaction, $F(1, 51) = 5.55$, $p = .023$, partial $\eta^2 = .102$. This outcome had implications for our further analyses.

6.3.4 Assessment of mediation by restorative quality

In the absence of clear environmental effects on change in SART performance and self-reported attentiveness, assessment of mediation by restorative quality was beside the point for those outcomes (cf. Baron & Kenny, 1986). It remained of interest however whether being away and fascination mediated the marginal effect of environment on affective balance.

Toward assessing mediation, we compared the ratings of being away and fascination for the two virtual neighbourhoods. The means of both restorative quality variables were low and fell within a narrow range in both environments; for being away, $M_{LR} = 2.40$ ($SD = 0.87$) and $M_{HR} = 2.53$ ($SD = 0.86$); for fascination, $M_{LR} = 1.64$ ($SD = 0.67$) and $M_{HR} = 1.55$ ($SD = 0.56$). Tests of the mean differences found that neither approached statistical significance: for being away, $t(51) = 0.55$, $p = .58$, and for fascination, $t(51) = -0.49$, $p = .62$. The participants' differential perceptions of restorative quality therefore could not have mediated the effect of environment on change in affective balance.

6.3.5 Did perceptions of restorative quality have any explanatory power?

The question remained, however, whether perceptions of restorative quality within each environment accounted for any change in affect that took place there (cf. Gonzalez, Hartig, Patil,

Martinsen, & Kirkevold, 2009). We therefore conducted an analysis of covariance with pretest-posttest change in affective balance as the dependent variable, environment and familiarity as fixed factors, and a restorative quality variable as a covariate. The being away and fascination scores correlated strongly (r = .63, p < .001), so we took the product of the two as the restorative quality covariate. The results indicate that perceived restorative quality was strongly and positively associated with improvement in affective balance, $F(1,48) = 21.43$, $p < .001$, partial $\eta^2 = .309$. Interestingly, with adjustment for perceived restorative quality, the effect of environment on change in affective balance became stronger, $F(1,48) = 5.55$, $p = .023$, partial $\eta^2 = .104$, as did the interaction of environment and familiarity, $F(1,48) = 6.99$, $p = .011$, partial $\eta^2 = .127$. Thus, the restoration likelihood judgments made by the participants in the previous studies proved to more reliably predict change in affective balance among the present participants after adjustment for the current participants' perceptions of restorative quality and their familiarity with the kind of environment presented.

6.3.5 Remaining issues

Remaining analyses addressed two issues. First, we checked to see whether the two virtual environments received different aesthetic evaluations as reflected in the preference ratings. The means for both were quite low: $M_{LR} = 2.11$ ($SD = 1.15$) and $M_{HR} = 2.27$ ($SD = 1.12$), and they did not differ significantly, $t(51) = 0.51$, $p = .615$. Supplementary analyses indicated that neither gender nor familiarity significantly moderated the preference ratings.

Second, and finally, we checked on the appropriateness of characterizing the change in affective balance as indicative of restoration. We did so by assessing the correspondence between the pretest scores and the amount of change that subsequently took place. To the extent

that the participants reported a lower level of positive affect and a higher level of negative affect (anger/aggression, fear arousal and sadness combined) after completing the initial three SART sessions, they also showed greater increases in affective balance, independent of the environment to which they were assigned, partial $r = -.42$, $p = .002$.

6.4 Discussion

The first objective of the present study was to test for correspondence between restoration likelihood ratings and measured restoration in different virtual environments. The results provide qualified evidence of such correspondence. Participants who "walked" through a virtual neighbourhood constructed from digital streetscape images that in our previous work were rated relatively high on restoration likelihood showed a positive shift in affective balance, while participants who walked through a virtual neighbourhood constructed of streetscape images that previously had gotten low ratings on restoration likelihood showed a negative shift in affective balance. At least with regard to affective states, then, ratings on restoration likelihood would seem to have predictive validity with regard to actual restoration. Moreover, they appear to have predictive validity independently of the participants' own perceptions of restorative quality. Familiarity with the given environment also appeared to play a role, driving down affect in the low restoration likelihood neighbourhood and enhancing affect in the high restoration likelihood neighbourhood.

On the one hand, the affect results seem remarkable. Restoration likelihood ratings provided for digital images of distinctly different urban residential neighbourhoods by two independent samples of adults in one geographic location predict change in affective states by a

third, geographically distant sample of adults with a "walk" through virtual neighbourhoods constructed from the previously used digital images. On the other hand, the result must be regarded with some caution. Repeated performance of the SART prior to the virtual walk did not clearly create a need for attentional restoration (cf. Valtchanov & Ellard, 2010), as we did not find a performance decline to indicate a diminished capacity to direct attention. The participants did however report rather low levels of positive affect after completing the pre-treatment rounds of the SART, and some also evidenced negative affects such as sadness, fear arousal, and anger/aggression; their pretest levels might be taken as an indication of a potential for restoration. Also, the amount of improvement in affect that occurred with the virtual walk was inversely related to the affect reported just after the initial SART sessions. Thus, the SART may have induced some potential for restoration in affective terms.

The present results suggest that the restoration likelihood measure used in our two earlier studies (Lindal & Hartig, 2013a, b) was more sensitive to environmental variations than the attentional and affective measures used in the present study. Whereas the two previous studies uncovered strong associations between the architectural characteristics and natural elements of streetscapes, the present study found less clear discrimination between two virtual neighbourhoods in terms of restorative effects. The relatively weak effects may reflect the fact that the streetscape images used to create the virtual environments for this study were drawn from a relatively narrow range of restoration likelihood ratings. The present comparison is thus appropriately considered a conservative one. Unfortunately, technical and resource limitations disallowed us from capturing the full range of restoration likelihood represented in the earlier

studies. In particular, we could not introduce all of the natural elements that in the second of our earlier studies worked to boost ratings of restoration likelihood.

Another objective of the present study was to assess the role of being away and fascination as mediators of the restorative effects of different virtual urban environments. It appeared, however, that our participants did not see much difference between the two virtual neighbourhoods in terms of restorative quality, as they gave them quite similar – and quite low – ratings of being away and fascination. A logical prerequisite of mediation thus was lacking. Further analysis revealed however that perceptions of restorative quality were nonetheless relevant to understanding change in affective balance during the virtual walk. Irrespective of which neighbourhood they "walked" in, those participants who found that it afforded a sense of being away and engaged their interest also showed more positive change in affective balance.

One further objective of the present study was to demonstrate the use of virtual technology in estimating the restorative quality impacts of specific environmental design measures. Virtual technology offers important methodological and procedural advantages, especially in light of the complexity and financial demands of studies of restoration in field settings. There are, however, some critical research issues that need further consideration. A virtual environment only approximates some "real" setting, so the behaviour produced in the virtual environment can only approximate "real" behaviour. The more real that participants experience the virtual environment to be, however, the better their behaviour in the simulation can approximate what it would be like if they were in a similar environment in reality. Also, a person might in real-life settings experience uncontrollable circumstances that outweigh any restorative effects that otherwise might have been attributed to the environmental characteristics

under study. Such factors can be strictly controlled within the virtual environment, leading to a "cleaner" outcome. On the other hand, if some uncontrollable circumstance is an essential aspect of a real-life environment, one could ask whether there is any point in estimating restorative effects with a virtual environment that "controls" for that circumstance.

Implementation of virtual technology also presents its own challenges. For example, allowing participants to navigate freely through the virtual environment as we did can make it difficult to know where participants went and what they did within the given limits of action. We attempted to use tracking software to collect information on the path chosen through the given environment, but again technical restrictions denied us this possibility. Analysis of such data would however also present difficulties. Taking lessons from the design of video-games, a better approach might be to constrict the user's control by creating a predetermined path where environmental cues encourage participants to move forward and leave them wondering what is around "the next corner". This approach would make it easier for a researcher to know what the user experienced during the virtual navigation.

Aside from how the encounter unfolds, the quality of the virtual environment is an issue. The virtual environments used in the present study were created with very limited financial means and generous volunteer inputs. On the one hand we thus demonstrate the feasibility of carrying through such research with few resources. On the other hand, the study leaves substantial room for improvement in the quality of the virtual environments. Bugs, missing texture, blinking edges, and other small details may have distracted the participants and hindered restorative effects.

The present study offers initial experimental evidence of correspondence between restoration likelihood ratings and measured restoration in terms of positive affective change. It also adds to previous work (e.g., de Kort & IJsselsteijn, 2006; Valtchanov & Ellard, 2010) that has demonstrated the potential and relevance of rapidly developing computer imaging technologies for research on restorative environments. Finally, the present results contribute to the discussion of relations among psychological restoration, sustainability and urban densification. Building on the results from its two forerunners, this study affirms that even densely built residential settings can promote restoration, depending on how they are designed. Such knowledge will be important for creating psychologically and socially sustainable urban environments.

Chapter 7 - General discussion

Over recent decades, authorities around the world have realized the necessity of densifying the urban environment to serve sustainability goals. Despite good intentions and ambitious projects, the success seems to have been limited, at least when considering the relationship between urban compactness and sustainability, according to authors such as Neuman (2005). A prominent explanation for the seeming lack of association refers to the inability of dense urban environments to fulfil social and psychological needs of the residents.

The present work contributes to understanding how densely built urban environments can affect people psychologically. More specifically, utilizing different methodological approaches and environmental representation technologies, this dissertation has considered how urban residential streetscape design can promote restorative experience. The findings from this work offer insights on how the built urban environment can be densified without compromising the restorative potential.

This chapter starts with an overview of those findings, followed by discussion of the ork, its implications, limitations of the studies conducted, and possible directions for future studies. The chapter ends with the overall conclusions of the dissertation.

7.1 Main findings

In the present section the main findings from the studies are presented, starting with the initial identification of research needs in Paper I (Chapter 3) and continuing through the three empirical studies reported in Papers II-IV (Chapters 4-6).

7.1.1 Paper I

Paper I introduced the restorative perspective as a way of understanding individual adaptation to environmental change. It also covered environmental design and management measures that are aligned with the restorative perspective. The paper then reviewed the empirical literature on the relationship between the natural environment and restoration, as an increasing number of studies indicate restoration as a key pathway linking natural environment and health (de Vries, 2010; Health Council of the Netherlands, 2004; Hartig et al., 2011).

Due to the importance of natural environment and natural elements in everyday life for people living in cities, the paper discussed the need for research on ways to combine natural and architectural features in urban settings to better serve the restoration needs of residents and so promote sustainability. It also discussed the need for research on how the different architectural characteristics of buildings themselves might positively affect restoration and assessments of restorative quality. With increasing populations in cities around the world, and attendant increases in the demands faced in everyday life, the paper argued that it is likely that environmental design and planning solutions that emphasize opportunities for restorative experience will grow in importance as a means to promote urban sustainability.

7.1.2 Paper II

In the first of the empirical studies, entropy was used as an indicator of complexity due to variation in architectural elements aggregated across buildings in urban residential streetscapes, and the height of those buildings was used to elicit different degrees of a sense of enclosure. Through systematic manipulation of these features of residential buildings, 145 computer-generated streetscape images were created. The results of multiple-mediator regression analysis

demonstrated a positive effect of entropy on the judged likelihood of restoration, whereas the effect of building height on restoration likelihood was negative. It appears that lower buildings with more architectural complexity were perceived as more conducive to restoration. Furthermore, the results revealed the role of being away and fascination as mediators between the physical environment and judgments of restoration likelihood. Together, the two perceived restorative qualities fully mediated the effects of entropy on judgments of restoration likelihood. In contrast, the effect of building height was only mediated by being away.

In sum, the results harmonize with other studies that have demonstrated that different urban residential environments have different restorative potential (e.g., Herzog et al., 2003; Hidalgo et al., 2006; Staats et al., 2010), and they affirm that densely built urban residential settings can provide opportunities for restorative experience, depending on their particular architectural characteristics. In practice, the results provide guidance for the use of architecture in the design of more urban residential environments that are both psychologically and ecologically more sustainable.

7.1.3 Paper III

The streetscapes that got the lowest and the highest ratings on restoration likelihood in the first empirical study were used as platforms for the environmental manipulations in the second empirical study. 103 computer-generated images were created by systematically adding different kinds and amounts of street vegetation to the streetscapes. The results indicated positive relationships between ratings of restoration likelihood and the number of street trees and the presence of flower beds, which were mediated by being away and fascination. Additionally, the positive relationship between the presence of grass and restoration likelihood was mediated by

being away, and fascination mediated the relationship between the arrangement of trees along the street and restoration likelihood. The architectural characteristics of the buildings did not interact with street vegetation in affecting restoration likelihood ratings.

In sum, the results indicated that the presence of natural elements can promote perceptions of restorative quality in urban residential streetscapes over and above the effects of the architectural attributes of the built environment. The study also replicated the main findings from the first empirical study, showing that streetscapes lined by lower buildings with more architectural complexity were rated higher in terms of restoration likelihood than streetscapes with higher buildings and less complexity. The study also affirmed the role of being away and fascination as mediators between the objective environmental variations and restoration likelihood ratings.

7.1.4 Paper IV

Based on the results from the two previous studies, two interactive, virtual, three-dimensional neighbourhoods were constructed from the five streetscapes rated highest on restoration likelihood and from the five that got the lowest ratings on restoration likelihood. The results indicated a correspondence between restoration likelihood ratings and actual restoration in the two environments. Those who navigated through the neighbourhood with low restorative potential based on the ratings from the previous studies showed a negative shift in affective balance, while those who "walked" through the more restorative neighbourhood showed a positive affective balance. When adjusted for the participants' own ratings on the restorative quality variable (a combination of being away and fascination), the effect of the a priori restorative potential became stronger. In addition to providing initial evidence of the predictive

validity of restoration likelihood ratings from independent samples, the results demonstrate the utility of virtual technology for studies of how specific characteristics of the urban environment can influence restoration.

7.2 Discussion and implications

The empirical work presented in this dissertation adds value to the restorative environments literature by providing results on the effects of visual entropy, building height, and street vegetation on judgements of restoration likelihood, and by shedding light on the underlying psychological mechanisms that mediated the effects of those specific features of the physical environment. Furthermore, the present work provides initial results concerning the correspondence between two commonly used measurements in the field, ratings of restoration likelihood and actual restoration. The value of the present work is further enhanced by the use of a variety of digitally created urban residential streetscapes and design components, and by addressing diverse psychological responses with guidance from an integrative theoretical framework.

As discussed in Paper I, work in various areas has acknowledged the importance of restorative experience for physical and mental health. While many studies have demonstrated the high restorative potential of natural environments, less attention has been paid to the urban environment. But, in a rapidly urbanized world, where the link between people and nature has been substantially transformed and is less apparent in everyday life, it is important to pay more attention to the types of settings where members of the growing urban population will spend

most of their time outdoors in the future. According to Getz et al. (1982), those places could include streets.

Limited work has been done that focuses on how streetscape design, such as architectural characteristics of buildings along streets and streetside vegetation, might affect restoration and assessments of restorative quality. To get around this gap in the literature, the studies reported in Papers II and III relied on the preference literature when identifying relevant design properties that could enhance restoration likelihood, given that previous studies (e.g., Hartig & Staats, 2004; Nordh et al., 2009) have found strong correlations between restoration likelihood ratings and preferences. Both studies lend support to this approach by replicating previous findings, as well as with statistical tests that indicate that preference and restoration likelihood share important similarities in results. Given that the environmental preference literature is much more extensive than the literature on psychological restoration, the results have important practical value for future studies on restorative environments.

By indicating that increasing architectural variation in buildings along a street positively affects ratings of restoration likelihood while the height of the buildings negatively affects restoration likelihood, the study reported in Paper II cast light on how different specific properties of the built environment affect ratings of perceived restoration likelihood differently. Following up and partly using the same set of streetscapes, the study reported in Paper III, which obtained data from an independent sample of people, replicated the findings and at the same time demonstrated that role that the arrangement, types and amounts of street vegetation can play for the restorative experience in an urban residential context. Using a different mode of presentation, different research design, a different set of measures, and a geographically distinct sample of

people, the study reported in Paper IV offers support to its forerunners by indicating similar trends in neighbourhoods developed from streetscapes shown to differ in their perceived restorative potential affect participants differently.

Considering the mixed correspondence between sustainability and urban densification (Neuman, 2005) and the potential role of psychological factors in strengthening this connection (cf. van den Berg et al., 2007), these results are important. Generally speaking, they support the notion that the restorative potential of the urban environments, which can help to improve their psychological sustainability, is partly evaluated in terms of the specific design and architectural properties. In that sense, the results validate the relevance of the RED as approach when it comes to densifying the built urban environment without further compromising its social and psychological sustainability. The results can, therefore, provide guidance for those authorities, designers and planners responsible for making decisions about future projects, as well as for the development of design controls and urban design processes meant to promote health and well-being. Instead of being merely based on individual expressions by an individual or a group of people that do not necessarily have the relevant knowledge or experience, decisions, policies and regulations would have an important empirical foundation.

All three empirical studies presented in this dissertation underline the role of being way and fascination for the restorative experience. The studies reported in Papers II and III provide empirical support for the two theoretical constructs as they indicate that they both mediate influences of physical environmental variations on ratings on restoration likelihood. The studies reported in Papers II and III also demonstrate a strong correlation between being away and fascination, but, importantly, they also provide further theoretical support for the constructs, in

that the results show how each construct mediates the effects of different environmental manipulations in different ways (cf. Nordh et al., 2009). This is especially notable if it is kept in mind that in each study, the data for each construct were collected from independent groups of people, an approach that avoids the risk of single source bias (Hartig, 2011). Finally, the experiment reported in Paper IV indicates that a greater sense of being away and fascination helped to explain the change in affective balance that occurred when navigating through a virtual environment.

In the first two empirical studies, Papers II and III, participants were asked to provide judgments of likelihood of experiencing restoration if visiting a given environment. Despite important advantages of this approach, it is open for criticism regarding the correspondence between the perceived likelihood of experiencing restoration and actual restoration experienced. The results for all three studies show consistent trends, and together they indicate that ratings on restoration likelihood seem to be a valid indicator of actual restoration, at least with regard to affective responses. The results demonstrate that virtual navigation through streetscapes that previously were rated low on restoration likelihood caused a negative shift in affective balance while navigation through streetscapes previously rated as relatively high on restorative caused a positive shift. Despite showing similar trends, it should be mentioned that the restoration likelihood measures used in the first two studies proved to be more sensitive to the design manipulations than the affective measures used in Paper IV. Considering the limited range in entropy and the relatively limited range in ratings on restoration likelihood in those studies, the fact that associations were nonetheless fairly strong seems to indicate a relatively high level of sensitivity of the restoration likelihood measure. These results have both methodological and

practical values, as asking people to rate the likelihood of experiencing restoration in a given (possible future) environment is a much more accessible and affordable approach than collecting data on actual restoration in the given alternative environments.

A distinctive feature of the present work compared to other work done within the field of restorative environments is that it involves a consequent series of studies for which all environments have been created using 3D modelling software. While the studies reported in Papers II and III used static images of the three-dimensional virtual environment and thereby followed long running tradition within the field, the final experiment utilized the rapidly growing development in the video game technology to implement interactive, three-dimensional virtual environments. As traditional studies of actual restoration in field settings involve methodological and procedural challenges (cf. Hartig et al., 2003), the interactive virtual technology offers opportunities to assess actual restoration in laboratory settings but while still allowing participants be actively involved. The novelty here with more specific regard to the use of virtual technology is the generation of environments through a process is systematic process in which each step is empirically tested in successive studies which provide guidance regarding the tests in the subsequent work. This contrasts with the re-generation of existing urban built environment, an approach which also has values but which offers relatively limited insight on the restorative impact of specific physical properties (cf. Valtchanov & Ellard, 2010). The present series of empirical studies demonstrates that available computer technology has the potential to greatly enhance and extend research opportunities, even for those with rather limited resources, and so to support a widely applicable approach for studies of restorative environments.

Computer technology can support RED not only by facilitating the study of the restorative value of existing urban environments, but also by creating opportunities to present future projects and plans to the people who will occupy the environments to be created. In a time when urban design and planning call for public input regarding how a dense urban environment can be created without compromising the needs for restorative experience, allowing people to interact with proposed built urban environments and evaluate them in terms of restorative experience should provide valuable guidance for RED in dense urban environments.

7.3 Limitations and directions for future research

One might argue that the selection of attributes of interest based on the preference literature is problematic. However, as Velarde et al. (2007) concluded, few studies on restorative environments have focused on the role of specific environmental features for the restorative experience. With such limited guidance, looking into the preference literature can provide insights, as 1) many studies have assessed preferences for different built urban environments and these provide information on specific physical attributes that might affect preferences, and 2) a number of studies have found strong correlations between preferences for different environments and judgments regarding their restorative quality and the likelihood of restoration in them.

The results of the studies reported in Papers II and III illustrate that the preference literature is a relevant source for identifying components and design characteristics to study with regard to restorative experience and in guiding the manipulation of those elements. In most cases, the results of the empirical work harmonized well with the expectations formulated on the basis of the previous preference research. One exception is the weak relationship between

preference and entropy found in the first empirical study (Paper II). This may be due to the limited range of variation in entropy (from 0 to 2), which contrasts with the broader range (0-12) covered in research by Stamps (2003), who found a positive relationship between preference and entropy.

This discussion taps into speculation regarding what level of entropy is the most preferred, a question that Stamps (2003) claims still remains unanswered although design policies commonly assume an inverted U-shaped correlation between visual diversity and preference. Stamps (2003) encourages further empirical work where the range of entropy is extended, but claims that puzzling methods to create stimuli with known degrees of entropy might have been a drawback for many (see in more details Stamps, 2010a). The mixed results between entropy and preference should also encourage further research work to relationship between the two constructs (Stamps, 2010a).

Although this work strengthens the basis for RED for dense urban environments, it should be stressed that the body of empirical knowledge in this regard is still sparse. RED would benefit if more researchers followed the calls by, for example, Stamps (e.g., 1994, 2003), Alkhresheh (2007), and Velarde et al. (2007) for studies that provide information on how specific attributes of the physical environment come to be affect outcomes that are informative with regard to restorative experience.

Some methodological and procedural aspects of the present work can raise concerns. For example, some might argue that the use of single-item measures for psychological variables in the studies reported in Papers II and III is problematic, following the classic psychometric argument that including more items in self-report measures will provide a more stable, reliable

and precise outcomes (e.g., Bowling, 2005). This notion has however been questioned. For example, at least one comparison of these two types of measures did not find a significant difference in terms of their validity and reliability (Gardner, Cummings, Dunham, & Pierce, 1998; see also Bergkvist & Rossiter, 2007). Furthermore, it is quite conventional to use single-item measures for basic environmental assessments and evaluations like complexity, enclosure and preference (e.g., Herzog, 1992; Imamoglu, 2000; Kaplan et al., 1972; Stamps, 2002b, 2010b). Furthermore, several previous studies have used a single-item restoration likelihood measure which has turned out be responsive to different environments as expected (e.g., Hartig & Staats, 2006; Nordh et al., 2009; Staats & Hartig, 2004; Staats et al., 2003). For their part, the measures of being away and fascination used in the first two empirical studies were taken from widely used multi-item measures that typically demonstrate high internal consistency (e.g., Hartig et al., 1997a, b).

Similarly, the use of static colour images of digital three dimensional streetscapes in the first two empirical studies (Papers II and III) might also raise concerns about validity. Unlike experiencing the environment on-site, static images prevent the viewer from getting a sense of the wider surroundings, and this might cause a difference in judgments of the restorative value of environment. Interactive, three-dimensional virtual reality technology might raise similar concerns about validity. It should be stressed here that regardless of the mode of presentations and measures, the three empirical studies demonstrate a consistent trend when it comes to the evaluations of the restorative potential and the actual restorative experience, which was mainly in line with hypotheses put forward on the basis of theory and previous empirical research concerning restorative environments and environmental preferences. Furthermore, we note that

other researchers have previously addressed this kind of validity concern. For example, Stamps (1990) tested the validity of using still pictures as simulations with a meta-analysis of 11 different studies with a total of 2400 participants. He found a strong correlation (r = .86) between preferences for photographs of an environment and preferences for the environments rated on-site. A later meta-analysis with 84 studies and 6323 participants (Stamps, 2010c) showed similar results. The meta-analysis also indicated a strong correlation (r = .83) between environmental ratings obtained by viewing dynamic simulation and on-site (Stamps, 2010c).

Although the ability to create virtual three-dimensional interactive environments that affect people in the same way as the real world would seem to be useful for studies of restorative environments, this approach confronts some critical issues that need further research consideration. The main issue has to do with the fact that the virtual environment is only an approximation of the real world and therefore, the behaviour shown in the virtual environment is only an approximation of real-life behaviour. It can be assumed that the more "real" participants experience the virtual environment to be, the more likely it is that there will be a correspondence in their behaviour in the virtual environment and if they were in a similar real-life environment. From this perspective, one might consider it remarkable that differential restorative effects were measured in the final experiment, given the quite simple and limited virtual environments used.

To be better able to utilize an approach involving interactive virtual environments, an assessment and understanding of how people respond to it is needed. One construct becoming vital in this context is *presence* (Banos, Botella, Alcaniz, Liano, Guerrero, & Rey, 2004), or the feeling of being in a different world (IJsselsteijn & Riva, 2003). Commonly acknowledged as a complex multidimensional perception formed through the interplay of raw multi-sensory data

and various cognitive processes (IJsselsteijn & Riva, 2003), presence has been shown to mediate between the virtual environment and emotional and behavioural outcomes (Fox, Arena, & Bailenson, 2009). However, the lack of a generally accepted definition of presence and of consensus regarding its measurement (Banos et al., 2004; Slater, Spanlang, & Corominas, 2009; Schifter, Ketelhut, & Nelson, 2012) means that discussions of the validity of virtual environments will continue. These issues notwithstanding, those who come to this work from research on restorative environments cannot help but notice the correspondence between notions of presence and constructs used to describe restorative quality, in particular extent (Kaplan & Kaplan, 1989).

Other aspects of the use of virtual environment might raise other concerns about the approach. One of them is cybersickness, which is characterized by dizziness, light-headedness, and nausea after spending time in a virtual environment (Fox et al., 2009). The level of familiarity can also be confound with the psychological or physiological variables of interest through different skills of controlling the path through the environment or different expectations regarding the scope of possible movement in the virtual environment (Frey et al., 2007). Furthermore, the computer simulation equipment, such as the weight of the instruments or interruptions in data rendering can present problems for data collection and the interpretation of results (e.g., Frey et al., 2007; IJsselsteijn, de Ridder, Freeman, & Avons, 2000; Jones, Kennedy, & Stanney, 2004).

Another problem faced in the present research has to do with the measurement of restoration in the third empirical study. As explained in Paper IV, the participants did not show a significant increase in mental fatigue after repeated performance of the SART prior to the virtual

navigation. This raises questions about the characterization of the effects in that study as indicative of restoration. These results should be regarded with reservation; however, considering the low level of positive affect as well as the indication of negative affect prior to the environmental treatment, along with the particular pattern of change in affective balance observed with the virtual navigation, it seems plausible that some need for affective restoration was induced by the SART.

These results also raise questions about the utility of the SART to induce mental fatigue in studies on restorative environments. Due to technical restrictions, in the final experiment, some parameters of the SART differed from those of the SART version used in previous studies (e.g., Berto, 2005; Berto et al., 2010). These modifications might have been important for fatigue induction (cf. Jahncke et al., 2011). This said, Valtchanov and Ellard (2010) also were unable to induce mental fatigue with the SART prior to the environmental treatment, and their version seems to not have been modified. In line with their suggestion to extend the mental fatigue induction process from 5 minutes to 20 or 30 minutes, the SART was administered three times, for total 18 minutes, prior to the virtual walk. Given this, more research on the utility of SART for mental fatigue induction seems important.

7.4 Conclusions

When considering the future, mankind confronts many challenges. One of the largest is how global sustainability can be increased. According to the Global Footprint Network (2013), humanity needs 1.5 planets to support current lifestyles. In recent decades, urban densification has been considered a vital component for the pursuit of sustainability. Despite efforts to densify

cities, empirical studies have revealed mixed results when it comes to demonstrating a positive link between urban density and sustainability. A possible explanation might be the neglect of psychological factors within the compact city model. Restorative environmental design, or RED, has been proposed as a useful approach to address basic human psychological needs while working toward more ecologically sustainable design solutions. Partly based on the theoretical background and empirical work concerned with the restorative effects of nature experience for people living in urbanized societies, RED simultaneously emphasizes environmentally friendly urban development and promotion of the restorative potential of urban designs. As research on the restorative benefits of the built urban environment is still at an early stage, the present work makes a novel contribution to a literature on restorative environments that in other respects is growing rapidly.

The results presented in this dissertation demonstrate how different residential urban environments can provide for restorative experience, depending on the specific physical components and characteristics manipulated through design. Streetscapes with lower buildings and more architectural façade variation appear to promote restorative experience more efficiently than streetscapes with higher, monotonous buildings. Moreover, streetscapes with trees, flowers and grass also appear to promote restorative experience more effectively than those without the vegetation components, regardless of the building architecture. These results indicate the relevance of RED for the pursuit of sustainability, as densely built urban residential environments need not lack restorative potential. The compact city practice must consider the quality of residential design and not only the number of people to be fitted into the given space. RED can enhance psychological sustainability, which in turn promotes sustainability more

generally. Thus, this work encourages more attention to RED from governments, local authorities, architects and planners as they work to create a more psychologically sustainable built urban environment. Also, the present dissertation calls for more empirical work to strengthen the foundation of RED and to find the forms and properties of built urban settings that effectively support and enhance restorative experience. The research presented in this dissertation has provided methodological support for the needed research with regard to measures and a systematic approach to development of test environments. The results offer initial evidence that restoration likelihood ratings can be used to predict actual restoration in members of a different sample, at least with regard to change in affective states. This result is especially valuable in light of the methodological and practical advantages of measuring restoration likelihood versus actual restoration as a means to evaluate different environmental alternatives. Finally, this work demonstrates the utility of the rapidly developing virtual technology for investigating how specific urban design features can affect restorative experience.

References

Akalin, A., Yildirim, K., Wilson, C., & Kilicoglu, O. (2009). Architecture and engineering students' evaluations of house façades: Preference, complexity and impressiveness. *Journal of Environmental Psychology*, *29*, 124-132.

Alkhresheh, M.M. (2007). *Enclosure as a function of height-to-width ratio and scale: Its influence on user's sense of comfort and safety in urban street space* (doctoral dissertation). Gainesville, FL: Department of Urban and Regional Planning, University of Florida. Retrieved July 29, 2009 from http://etd.fcla.edu/UF/UFE0019676/alkhresheh_m.pdf

Antonovsky, A. (1979). *Health, stress, and coping*. San Francisco: Jossey-Bass.

Appleton, J. (1996). *The experience of landscape.* NewYork: JohnWiley. (Original work published 1975).

Arbury, J. (2005). *From urban sprawl to compact city: An analysis of urban growth management in Auckland*, (Doctoral dissertation). Received on June 26, 2012 from www.portal.jarbury.net/thesis.pdf.

Attneave, F. (1957). Physical determinants of the judged complexity of shapes. *Journal of Experimental Psychology*, *53*, 221-227.

Banos, R. M., Botella, B., Alcaniz, M., Liano, V., Guerrero, B., & Rey, B. (2004). Immersion and emotion: Their impact on the sense of presence. *Cyberpsychology & Behavior*, *7*, 734-741.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*, 1173-1182.

Beatley, T. (1999). *Green urbanism: Learning from European cities*. Washington: Island Press.

Beatley, T. (2009). Biophilic urbanism: Inviting nature back to our communities and into our lives. *William & Mary Environmental Law and Policy Review*, *34*, 209-238.

Bell, S., Blom, D., Rautamäki, M., Castel-Branco, C., Simson, A., & Olsen, I. A. (2006). Design of urban forests. In C. C. Konijnendijk, K. Nilsson, T. B. Randrup, & J. Schipperijn (Eds.), *Urban forests and trees* (pp.149-186). New York: Springer.

Bergkvist, L., & Rossiter, J. R. (2007). The predictive validity of multi-item versus single-item measures of the same constructs. *Journal of Marketing Research*, *44*, 175-184.

Berlyne, D. E. (1960). *Conflict, arousal and curiosity*. New York: Mc-Graw-Hill.

Berlyne, D. E. (1970). Novelty, complexity and hedonic value. *Perception and Psychophysics*, *8*, 279-286.

Berlyne, D. E. (1974). *Studies in the new experimental aesthetics*. New York: Wiley.

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science*, *19*, 1207-1212.

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology, 25*, 249-259.

Berto, R., Baroni, M. R., Zainaghi, A., & Bettella, S. (2010). An exploratory study of the effect of high and low fascination environments on attentional fatigue. *Journal of Environmental Psychology*, *30*, 494-500.

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health*, *10*, 456.

Bowling, A. (2005). Just one question: if one question works, why ask several? *Journal of Epidemiology and Community Health*, *59*, 342-345.

Bringslimark, T., Hartig, T., & Patil, G. G. (2007). Psychological benefits of indoor plants in workplaces: Putting experimental results into context. *HortScience*, *42*, 581-587.

Bringslimark, T., Hartig, T., & Patil, G. G. (2009). The psychological benefits of indoor plants: A critical review of the experimental literature. *Journal of Environmental Psychology*, *29*, 422-433.

Bringslimark, T., Hartig, T., & Patil, G. G. (2011). Adaptation to windowlessness: Do office workers compensate for a lack of visual access to the outdoors? *Environment & Behavior*, *43*, 469-487.

Carmona, M., Heath, T., Oc, T., & Tiesdell, S. (2003). *Public places, urban spaces*. Burlington: Architectural Press.

Chiang, C. F., Alomar, D., & Barrero, J. (2008). *V-Ray for SketchUp*. ASGVIS. Retrieved September 24, 2010 from http://www.filestube.com/6fa35c41a1a33c2903e9,g/VRay-for-Sketchup-Manual.html.

Congress for the New Urbanism (2001). *Charter of the New Urbanism*. Retrieved February 21, 2012 from http://www.cnu.org/charter.

Corral-Verdugo, V. (2012). The positive psychology of sustainability. *Environment, Development, and Sustainability, 14*, 651–666.

Daniel, T. C. (2001). Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning, 54*, 267-281.

de Kort, Y. A. W. & IJsselsteijn, W. A. (2006). Reality check: The role of realism in stress reduction using media technology. *CyberPsychology and Behavior, 9*, 230-233.

de Kort, Y. A. W., IJsselsteijn, W. A., Kooijman, J., & Schuurmans, Y. (2003). Virtual laboratories: Comparability of real and virtual environments for environmental psychology. *Presence: Teleoperators and Virtual Environments, 12*, 360-373.

de Kort, Y. A. W., Meijnders, A. L., Sponselee, A. A. G., & IJsselsteijn, W. A. (2006). What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology, 26*, 309-320.

de Vries, S. (2010). Nearby nature and human health: Looking at mechanisms and their implications. In C. Ward Thompson, P. Aspinall, & S. Bell (Eds.), *Innovative Approaches to Researching Landscape and Health: Open Space: People Space 2* (pp. 77-96). New York: Routledge.

de Vries, S., Verheij, R. A., Groenewegen, P. P., & Spreeuwenberg, P. (2003). Natural environments - healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A, 35*, 1717-1731.

Depledge, M. H., Stone, R. J., & Bird, W. J. (2011). Can natural and virtual environments be used to promote improved human health and wellbeing. *Environmental Science & Technology, 45*, 4660-4665.

Devlin, K., & Nasar, J. K. (1989). The beauty and the beast: Some preliminary comparisons of "high" versus "popular" residential architecture and public versus architect judgments. *Journal of Environmental Psychology, 9*, 333-344.

Efron, B. (1987). Better bootstrap confidence intervals. *Journal of the American Statistical Association, 82*, 171-185.

Efron, B., & Tibshirani, R. J. (1993). *An introduction to the bootstrap*. Boca Raton, FL: Chapman & Hall.

Enquist, M., & Arak, A. (1994). Symmetry, beauty and evolution. *Nature, 372*, 169-172.

Epstein, R., & Kanwisher, N. (1998). A cortical representation of the local visual environment. *Nature, 392*, 598-601.

Epstein, R. A., & Ward, E. J. (2010). How reliable are visual context effects in the parahippocampal place area? *Cerebral Cortex, 20*, 294-303.

Evans, G. W. (2003). The built environment and mental health. *Journal of Urban Health: Bulletin of the New York Academy of Medicine, 80,* 536-555.

Evans, G. W., & Cohen, S. (1987). Environmental stress. In D. Stokols og I. Altman (Eds.), *Handbook of Environmental Psychology* (Vol. 1, pp. 571-610). New York: Wiley.

Evans, G. W., Wells, N. M., & Moch, A. (2003). Housing and mental health: A review of the evidence and a methodological and conceptual critique. *Journal of Social Issues, 59,* 475-500.

Ewing, R. (1994). Residential street design: Do the British and Australians know something Americans do not? *Transportation Research Record, 1455,* 42-49.

Ewing, R., & Hardy, S. (2009). Measuring the unmeasurable: Urban design qualities related to walkability. *Journal of Urban Design, 14,* 65-84.

Ewing, R., Handy, S., Brownson, R. C., Clemente, O., & Winston, E. (2006). Identifying and measuring urban design qualities related to walkability. *Journal of Physical Activity and Health, 3,* Suppl 1, S223-S240.

Fox, J., Arena, D., & Bailenson, J. N. (2009). Virtual reality. A survival guide for the social scientist. *Journal of Media Psychology, 21*, 95-113.

Fransson, U., & Hartig, T. (2010). Leisure home ownership and early death: A longitudinal study in Sweden. *Health & Place, 16,* 71-78.

Frey, A., Hartig, J., Ketzelb, A., Zinkernagel, A., & Moosbrugger, H. (2007). The use of virtual environments based on a modification of the computer game Quake III Arena® in psychological experimenting. *Computers in Human Behavior, 23,* 2026-2039.

Frumkin, H. (2001). Beyond toxicity: Human health and the natural environment. *American Journal of Preventive Medicine, 20,* 234-240.

Frumkin, H., Frank, L., & Jackson, R. (2004). *Urban sprawl and public health: Designing, planning, and building for healthy communities*. Washington: Island Press.

Galindo, M. P. & Hidalgo, M. C. (2005). Aesthetic preferences and the attribution of meaning: Environmental categorization processes in the evaluation of urban scenes. *International Journal of Psychology, 40,* 19-26.

Gardner, D. G., Cummings, L. L., Dunham, R. B., & Pierce, J. L. (1998). Single-item versus multiple-item measurement scales: An empirical comparison. *Education and Psychological Measurement, 58,* 898-915.

Gehl, J. (1987). *Life between buildings*. New York: VNR Company.

Gehl, J. (2010). *Cities for People*. Washington DC: Island Press.

Getz, D. A., Karow, A., & Kielbaso, J. J. (1982). Inner city preferences for trees and urban forestry programs. *Journal of Arboriculture, 8,* 258-263.

Glass, J. C., & Singer, J. E. (1972). *Urban stress: Experiments on noise and social stressors.* New York: Academic Press.

Global Footprint Network (2013). World footprint: Do we fit on the planet? Retrieved March 20, 2013 from http://www.footprintnetwork.org/en/index.php/GFN/page/world_footprint/

Gonzalez, M. T., Hartig, T., Patil, G. G., Martinsen, E. W., & Kirkevold, M. (2009). Therapeutic horticulture in clinical depression: A prospective study. *Research and Theory for Nursing Practice, 23,* 312-328.

Gorman, J. (2004). Residents' opinions on the value of street trees depending on tree location. *Journal of Arboriculture, 30,* 36-44.

Grahn, P., & Stigsdotter, U. (2003). Landscape planning and stress. *Urban Forestry and Urban Greening*, *2*, 1-18.

Grey, G. W., & Deneke, F. (1978). *Urban forestry*. New York: John Wiley.

Groenewegen, P. P., van den Berg, A. E., Maas, J., Verheij, R. A., & de Vries, S. (2012). Is a green residential environment better for health? If so, why? *Annals of the Association of American Geographers*, *102*, 996-1003.

Handy, S. L., Boarnet, M. G., Ewing, R., & Killingsworth, R. E. (2002). How the built environment affects physical activity: Views from urban planning. *American Journal of Preventive Medicine*, *23*, 64-73.

Hartig, T. (1993). Nature experience in transactional perspective. *Landscape and Urban Planning*, *25*, 17-36.

Hartig, T. (2001). Guest editor's introduction [special issue on restorative environments]. *Environment and Behavior*, *33*, 475-479.

Hartig, T. (2004). Restorative environments. In C. Spielberger (Ed.), *Encyclopedia of applied psychology* (Vol. 3, pp. 273-279). San Diego: Academic Press.

Hartig, T. (2007). Three steps to understanding restorative environments as health resources. In C. Ward Thompson & P.Travlou (Eds.), *Open space: People space* (pp. 163-179). London: Taylor & Francis.

Hartig, T. (2008). Green space, psychological restoration, and health inequality. *Lancet, 372*, 1614-1615. [invited comment]

Hartig, T. (2011). Issues in restorative environments research: Matters of measurement. In B. Fernández-Ramírez, C. Hidalgo-Villodres, C.M. Salvador-Ferrer, & M.J. Martos, Méndez, (Eds.), *Psicología ambiental 2011: Entre los estudios urbanos y el análisis de la sostenibilidad* [Environmental Psychology 2011: Between urban studies and the analysis of sustainability]. Proceedings of the 11th Conference on Environmental Psychology in Spain) (pp. 41-66). Almería, Spain: University of Almería & the Spanish Association of Environmental Psychology.

Hartig, T., Bringslimark, T., & Patil, G. G. (2008). Restorative environmental design: What, when, where, and for whom? In S. R. Kellert, J. Heerwagen, & M. Mador (Eds.), *Bringing*

buildings to life: The theory and practice of biophilic building design (pp. 133-151). New York: Wiley.

Hartig, T., Böök, A., Garvill, J., Olsson, T., & Gärling, T. (1996). Environmental influences on psychological restoration. *Scandinavian Journal of Psychology, 37*, 378-393.

Hartig, T., & Evans, G. W. (1993). Psychological foundations of nature experience. In T. Gärling & R. G. Golledge (Eds.), *Advances in psychology: Vol. 96: Behavior and environment: Psychological and geographical approaches* (pp. 427-457). Amsterdam: Elsevier.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology, 23*, 109-123.

Hartig, T., & Fransson, U. (2009). Leisure home ownership, access to nature, and health: A longitudinal study of urban residents in Sweden. *Environment & Planning A, 41*, 82-96.

Hartig, T., Kaiser, F. G., & Bowler, P. A. (1997b). Further development of a measure of perceived environmental restorativeness (Working Paper No. 5), Gävle, Sweden: Institute for Housing and Urban Research, Uppsala University.

Hartig, T., Kaiser, F. G., & Bowler, P. A. (2001). Psychological restoration in nature as a positive motivation for ecological behavior. *Environment and Behavior, 33*, 590-607.

Hartig, T., Kaiser, F. G., & Strumse, E. (2007). Psychological restoration in nature as a source of motivation for ecological behavior. *Environmental Conservation, 34*, 291-299.

Hartig, T., Korpela, K., Evans, G. W., & Gärling, T. (1997a). A measure of restorative quality in environments. *Scandinavian Housing & Planning Research, 14*, 175-194.

Hartig, T., Mang, M., & Evans, G. W. (1991). Restorative effects of natural environment experiences. *Environment and Behavior, 23*, 3-26.

Hartig, T., & Staats, H. (2006). The need for physiological restoration as a determinant of environmental preferences. *Journal of Environmental Psychology, 26*, 215-226.

Hartig, T., van den Berg, A., Hägerhäll, C., Tomalak, M., Bauer, N., Hansmann, R., Ojala, A., Syngollitou, E., Carrus, G., van Herzele, A., Bell, S., Camilleri Podesta, M. T., Waaseth, G. (2011). Health benefits of nature experience: Psychological, social and cultural processes. In Nilsson, K., Sangster, M., Gallis, C., Hartig, T., De Vries, S., Seeland, K., & Schipperijn, J. (Eds.), *Forests, trees, and human health* (pp. 127-168). Dordrecht: Springer.

Health Council of the Netherlands (2004). *Nature and Health: The influence of nature on social, psychological and physical well-being*. Den Hague: Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning.

Heath, T., Smith, S. G., & Lim, B. (2000). Tall buildings and the urban skyline: The effect of visual complexity on preferences. *Environment and Behavior*, *32*, 541-556.

Heimlich, J., Sydnor, T. D., Bumgardner, M., & O'Brien, P. (2008). Attitudes of residents toward street trees on four streets in Toledo, Ohio, U.S. before removal of ash trees (Fraxinus spp.) from Emerald Ash Borer (Agrilus planipennis). *Arboriculture & Urban Forestry*, *34*, 47-53.

Herzog, T. (1989). A cognitive analysis of preference for urban nature. *Journal of Environmental Psychology*, *9*, 27-43.

Herzog, T. R. (1992). A cognitive analysis of preference for urban spaces. *Journal of Environmental Psychology*, *12*, 237-248.

Herzog, T. R., Black, A. M., Fountaine, K. A., & Knotts, D. J. (1997). Reflection and attentional recovery as two distinctive benefits of restorative environments. *Journal of Environmental Psychology*, *17*, 165-170.

Herzog , T., Kaplan, S., & Kaplan, R. (1982). The prediction of preference for unfamiliar urban places. *Population and Environment*, *5*, 43-59.

Herzog, T. R., Maguire, C. P., & Nebel, M. B. (2003). Assessing the restorative components of environments. *Journal of Environmental Psychology*, *23*, 159-170.

Hidalgo, M. C., Berto, R., Galindo, M. P., & Getrevi, A. (2006). Identifying attractive and unattractive urban places: categories, restorativeness and aesthetic attributes. *MedioAmbiente y ComportamientoHumano*, *7*, 115-133.

Hitchmough, J. D., & Bonugli, A. M. (1997). Attitudes of residents of a medium sized town in South West Scotland to street trees. *Landscape Research*, *22*, 327-337.

Holden, C. (2000). The brain's special places. *Science*, *287*, 1587.

Howard, E. (1902). *Garden cities of to-morrow*. London: Swan Sonnenschein & Co (republished by Faber & Faber, London, in 1946).

IJsselsteijn, W. A., & Riva, G. (2003). Being There: The experience of presence in mediated environments. In G. Riva, F. Davide, & W. A. IJsselsteijn (Eds.), *Being there: Concepts. effects and measurement of user presence in synthetic environments.* Amsterdam: Ios Press.

IJsselsteijn, W. A., de Ridder, H., Freeman, J., & Avons, S. E. (2000). Presence: Concept, determinants and measurement. In B.E. Rogowitz & T.N. Pappas (Eds.), *Proceedings of the SPIE: Volume 3959: Human Vision and Electronic Imaging V* (pp. 520-529) (June 2, 2000); doi:10.1117/12.387188.

Imanoglu, Ç. (2000). Complexity, liking and familiarity: Architecture and non-architecture Turkish student's assessments of traditional and modern house facades. *Journal of Environmental Psychology, 20*, 5-16.

International Code Council (2006). *International residential code for one- and two-family dwellings 2006*. Washington DC: International Code Council.

Jacobs, A. (1993). *Great Streets.* Cambridge: MIT Press.

Jacobs, A.B. (1997). Keynote: Looking, learning, making. *Places, 1*, 4-7.

Jahncke, H., Hygge, S., Halin, N., Green, A., & Dimberg, K. (2011). Open-plan office noise: Cognitive performance and restoration. *Journal of Environmental Psychology*, *31*, 373-382.

James III, R. N. (2010). The origin of spaces: Understanding residential satisfaction from ape nests, human cultures, and the hierarchy of natural housing functions. *Housing, Theory and Society, 27*, 279-295.

Jenks, M., Burton, E., & Williams, K. (1996). *The compact city: A sustainable urban form?* London: E., & F. N. Spon.

Jensen, J. O., Christensen, T. H., & Gram-Hanssen, K. (2011). Sustainable urban development - Compact cities or consumer practices? *Danish Journal of Geoinformatics and Land Management, 46*, 50-64.

Johansson, M., Hartig, T., & Staats, H. (2011). Psychological benefits of walking: Moderation by company and outdoor environment. *Applied Psychology: Health and Well-being, 3,* 261-280.

Jones, M. B., Kennedy, R. S., & Stanney, K. M. (2004). Toward systematic control of cybersickness. *Presence: Teleoperators and Virtual Environments, 13*, 589-600.

Kalmbach, K. L., & Kielbaso, J. J. (1979). Resident attitudes toward selected characteristics of street tree plantings. *Journal of Arboriculture, 5,* 124-129.

Kaplan, R. (1993). The role of nature in the context of the workplace. *Landscape and Urban Planning, 26,* 193-201.

Kaplan, R. (2001). The nature of the view from home: Psychological benefits. *Environment and Behavior, 33,* 507-542.

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective.* New York: Cambridge University Press.

Kaplan, R., Kaplan, S., & Ryan, R. L. (1998). *With people in mind. Design and management of everyday nature.* Washington DC: Island Press.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15,* 169-182.

Kaplan, S., Bardwell, L. V., & Slakter, D. B. (1993). The museum as a restorative environment. *Environment and Behavior, 25,* 725-742.

Kaplan, S., & Berman, M. G. (2010). Directed attention as a common resource for executive functioning and self-regulation. *Perspectives on Psychological Science, 5,* 143-157.

Kaplan, S., & Kaplan, R. (1982). *Cognition and environment - Functioning in an uncertain world*. New York: Praeger.

Kaplan, S., Kaplan, R., & Wendt, J. S. (1972). Rated preference and complexity for natural and urban visual material. *Perception and Pscyhophysics, 12,* 334-356.

Karmanov, D., & Hamel, R. (2008). Assessing the restorative potential of contemporary urban environment(s): Beyond the nature versus urban dichotomy. *Landscape and Urban Planning, 86,* 115-125.

Kellert, S. R. (2005). *Building for life: Designing and understanding the human-nature connection*. Washington DC: Island Press.

Kellert, S. R., Heerwagen, J., & Mador, M. (2008). *Bringing buildings to life: The theory and practice of biophilic building design*. New York: Wiley.

Knopf, R. C. (1987). Human behavior, cognition and affect in the natural environment. In D. Stokols & I. Altman (Eds.), *Handbook of environmental psychology* (Vol. 1, pp. 783-825). New York: Wiley.

Korpela, K., & Hartig, T. (1996). Restorative qualities of favorite places. *Journal of Environmental Psychology, 16*, 221-233.

Korpela, K. M., Ylén, M., Tyrväinen, L., & Silvennoinen, H. (2010). Favorite green, waterside and urban environments, restorative experiences and perceived health in Finland. *Health Promotion International, 25*, 200-209.

Kuo, F. E. (2001). Coping with poverty: Impacts of environment and attention in the inner city. *Environment and Behavior, 33*, 5-34.

Kuo, F. E., & Sullivan, W. C. (2001). Aggression and violence in the inner city: Effects of environment via mental fatigue. *Environment and Behavior, 33*, 543-571.

Länsstyrelsen i Stockholms län och Regionplane- och Trafikkontoret (2003). *Aldrig långt till naturen: Skydd av tätortsnära natur i Stockholmsregionen* [Never far to nature: Protection of nature close to towns in the Stockholm region] (Rapport 2003:20). Stockholm: Author.

Laumann, K., Gärling, T., & Stormark K. M. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology, 23*, 125-134.

Lin, J-J., & Yang, A-T. (2006). Does the compact-city paradigm foster sustainability? An empirical study in Taiwan. *Environment and Planning B: Planning and Design, 33*, 365-380.

Lindal, P. J., & Hartig, T. (2013a). Architectural variation, building height, and the restorative quality of urban residential streetscapes. *Journal of Environmental Psychology*, *33*, 26–36.

Lindal, P. J., & Hartig, T. (2013b). Effects of urban street vegetation on judgments of restoration likelihood and preference. (Revised manuscript under review.)

Lohr, V.I., Pearson-Mims, C. H., Tarnai, J., & Dillman, D. A. (2004). How urban residents rate and rank the benefits and problems associated with trees in cities. *Journal of Arboriculture, 30*, 28-35.

Maas, J., Verheij, R. A., Groenewegen, P. P., de Vries S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: How strong is the relation? *Journal of Epidemiology and Community Health, 60,* 587-592.

Manly, T., Robertson, I. H., Galloway, M., & Hawkins, K. (1999). The absent mind: Further investigations of sustained attention to response. *Neuropsychologia, 37,* 661-670.

Martens, D., Gutscher, H., & Bauer, N. (2011). Walking in "wild" and "tended" urban forests: The impact on psychological well-being. *Journal of Environmental Psychology, 31,* 36-44.

McIntyre, N. E., Knowles-Yánez, K., & Hope, D. (2000). Urban ecology as an interdisciplinary field: differences in the use of "urban" between the social and natural sciences. *Urban Ecosystems, 4,* 5-24.

Milgram, S. (1970). The experience of living in cities. *Science, 13,* 1461-1464.

Mitchell, R., Astell-Burt, T., & Richardson, E. A. (2011). A comparison of greenspace indicators for epidemiological research. *Journal of Epidemiology & Community Health, 65,* 853-858.

Mitchell, R., & Popham, F. (2008). Effect of exposure to natural environment on health inequalities: An observational population study. *The Lancet, 372,* 1655-1660.

Morita, E., Fukuda, S., Nagano, J., Hamajima, N., Yamamoto, H., Iwai, Y., Nakashima, T., Ohira, H., & Shirakawa, T. (2007). Psychological effects of forest environments on healthy adults: Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction. *Public Health, 121,* 54-63.

Moser, G., & Robin, M. (2006). Environmental annoyances: An urban-specific threat to quality of life? *Revue Européenne de Psychologie Appliquée/European Review of Applied Psychology, 56,* 35-41.

Müller, D. K. (2004). Second homes in Sweden: patterns and issues. In C. M. Hall & D. K. Müller (Eds.), *Tourism, mobility and second homes: Between elite landscape and common ground* (pp. 244-258). Clevedon: Channel View Publications.

Nasar, J. (1984). Visual preferences in urban street scenes: A cross-cultural comparison between Japan and the United States. *Journal of Cross-Cultural Psychology, 15,* 79-93

Nasar, J. L., & Terzano, K. (2010). The desirability of views of city skylines after dark. *Journal of Environmental Psychology, 30,* 215-225.

Neuman, M. (2005). The compact city fallacy. *Journal of Planning Education and Research*, *25*, 11-26.

Nordh, H., Alalouch, C., & Hartig, T. (2011). Assessing restorative components of small urban parks using conjoint methodology. *Urban Forestry and Urban Greening*, *10*, 95-103.

Nordh, H., Hartig, T., Hagerhall, C. M., & Fry, G. (2009). Components of small urban parks that predict the possibility for restoration. *Urban Forestry & Urban Greening*, *8*, 225-235.

Olmsted, F. L. (1870). *Public parks and the enlargement of towns*. Cambridge: Riverside Press (reissued by Arno Press, New York, 1970).

Ouellette, P., Kaplan, R., & Kaplan, S. (2005). The monastery as a restorative environment. *Journal of Environmental Psychology*, *25*, 175-188.

Park, B. J., Tsunetsugu, Y., Kasetani, T., Hirano, H., Kagawa, T., Sato, M., & Miyazaki, Y. (2007). Physiological effects of shinrin-yoku (taking in the atmosphere of the forest) – using salivary cortisol and cerebral activity as indicators. *Journal of Physiological Anthropology*, *26*, 123-128.

Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2009). The physiological effects of *Shinrin-yoku* (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine*, *15*, 18-26.

Pitt, D. G., & Zube, E.H. (1987). Management of natural environments. In D. Stokols & I. Altman (Eds.), *Handbook of environmental psychology* (Vol. 2, pp. 1009-1042). New York: Wiley.

Population Reference Bureau (2012). Human Population: Urbanization. Retrieved May 11, 2012 from http://www.prb.org/educators/teachersguides/humanpopulation/urbanization.aspx

Portland Parks & Recreation City Nature Urban Forestry (no date). Street tree planting and establishment guidelines. City of Portland, Oregon, USA. Retrieved May 13, 2010 from http://www.portlandonline.com/parks/index.cfm?a=164329&c=39712

Preacher, K. J., & Hayes, A. F. (2008a). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods*, *40*, 879-891.

Preacher, K. J., & Hayes, A. F. (2008b). Contemporary approaches to assessing mediation in communication research. In A. F. Hayes, M. D. Slater, & L. B. Snyder (Eds.), *The Sage sourcebook of advanced data analysis methods for communication research* (pp. 13-54). Thousand Oaks, CA: Sage.

Purcell, A. T., Peron, E., & Berto, R. (2001). Why do preferences different between scene types? *Environment and Behavior*, *33*, 93-106.

Raanaas, R. K., Evensen, K. H., Rich, D., Sjöström, G., Patil, G. (2011). Benefits of indoor plants on attention capacity in an office setting. *Journal of Environmental Psychology*, *31*, 99-105.

Raanaas, R. K., Patil, G. G., & Hartig, T. (2012). Health benefits of a view of nature through the window: A quasi-experimental study of patients in a residential rehabilitation center. *Clinical Rehabilitation*, *26,* 21-32.

Rapoport, A., & Hawkes, R. (1970).The perception of urban complexity. *Journal of the American Planning Association*, *36,* 106-111.

Richardson, E. A., Mitchell, R., Hartig, T., de Vries, S., Astell-Burt, T., & Frumkin, H. (2012). Green cities and health: A question of scale? *Journal of Epidemiology and Community Health*, *66*, 160-165.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!' Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*, 747-758.

Roe, J., & Aspinall, P. (2011). The restorative benefits of walking in urban and rural settings in adults with good and poor mental health. *Health & Place*, *17,* 103-113.

Rohrmann, B., & Bishop, I. (2002). Subjective responses to computer simulation of urban environments. *Journal of Environmental Psychology*, *22*, 319-331.

Rose, G. (1985). Sick individuals and sick populations. *International Journal of Epidemiology*, *14*, 32-38.

Saegert, S., & Winkel, G. (1990). Environmental psychology. *Annual Review of Psychology*, *41*, 441-477.

Schiaffino, K. M. (2003). Other measures of psychological well-being. *Arthritis & Rheumatism, 49*, S165-S174.

Schifter, C. C., Ketelhut, D. J., & Nelson, B. C. (2012) Presence and middle school students' participation in a virtual game environment to assess science inquiry. *Educational Technology & Society*, *15*, 53-63.

Schroeder, H. W., & Orland, B. (1994). Viewer preference for spatial arrangement of park trees: An application of video-imaging technology. *Environmental Management, 18*, 119-128

Schroeder, H. W., Flannigan, J., & Coles, R. (2006). Residents' attitudes toward street trees in the UK and U.S. Communities. *Arboriculture & Urban Forestry*, *32*, 236-246.

Shin, S. W. (2010). Sustainable compact cities and high-rise buildings. In E. Ng (Ed.), *Designing high-density cities for social and environmental sustainability*, (pp. 293-308). London: Sterling Earthscan.

SketchUp. (2012). Retrieved September 22, 2012, from http://www.sketchup.com/

Slater M., Spanlang B., & Corominas D. (2010). Simulating virtual environments within virtual environments as the basis for a psychophysics of presence. *ACM Transactions on Graphics, 29*, 92:1-9.

Smardon, R. C. (1988). Perception and aesthetics of the urban environment: Review of the role of vegetation. *Landscape and Urban Planning*, *15*, 85-106.

Sommer, R., Guenther, H., & Barker, P. A. (1990). Surveying householder response to street trees. *Landscape Journal*, *9*, 79-85.

Staats, H., & Hartig, T. (2004). Alone or with a friend: A social context for psychological restoration and environmental preferences. *Journal of Environmental Psychology, 24*, 199-211.

Staats, H., Kieviet, A., & Hartig, T. (2003). Where to recover from attentional fatigue: An expectancy-value analysis of environmental preference. *Journal of Environmental Psychology*, *23*, 147-157.

Staats, H., van Gemerden, E., & Hartig, T. (2010). Preference for restorative situations: Interactive effects of attentional state, activity-in-environment and social context. *Leisure Sciences, 32*, 401-417.

Ståhle, A. (2008). *Compact sprawl: Exploring public open space and contradictions in urban density* (doctoral dissertation). Stockholm: Department of Architecture and the Built Environment, Swedish Royal Institute of Technology.

Stamps, A. E. (1990). Use of photographs to simulate environments: A meta-analysis. *Perceptual and Motor Skills*, *71*, 907-913.

Stamps, A. E. (1994). A study in scale and character: Contextual effects on environmental preferences. *Journal of Environmental Management*, *42*, 223-245.

Stamps, A. E. (1997). Some streets of San Francisco: Preference effects of trees, cars, wires, and buildings. *Environment and Planning B: Planning and Design*, *24*, 81-93.

Stamps, A. E. (1999a). Physical determinants of preferences for residential façades. *Environment and Behavior*, *31*, 723-751.

Stamps, A. E. (1999b). Architectural detail, van der Laan septaves and pixel counts. *Design Studies*, *20*, 83–97.

Stamps, A. E. (1999c). Demographic effects in environmental aesthetics: A meta-analysis. *Journal of Planning Literature*, *14*, 155-175.

Stamps, A. E. (2000). *Psychology and the aesthetics of the built environment*. Boston: Kluwer Academic Publishers.

Stamps, A. E. (2002a). Entropy, visual diversity, and preference. *The Journal of General Psychology*, *129*, 300-320.

Stamps, A. E. (2002b). Environmental enclosure in urban settings. *Environment and Behavior*, *34*, 781-794.

Stamps, A. E. (2003). Advances in visual diversity and entropy. *Environment and Planning B: Planning and Design*, *30*, 449-463.

Stamps, A. E. (2004a). Mystery, complexity, legibility and coherence: A meta-analysis. *Journal of Environmental Psychology*, *24*, 1-16.

Stamps, A. E. (2004b). Entropy and visual diversity in the environment. *Journal of Architectural and Planning Research*, *21*, 239-256.

Stamps, A. E. (2005a). Visual permeability, locomotive permeability, safety and enclosure. *Environment and Behavior*, *37*, 587-619.

Stamps, A. E. (2005b). Enclosure and safety in urbanscapes. *Environment and Behavior*, *37*, 102-133.

Stamps, A. E. (2010a). Creating stimuli with designed amounts of discrete Shannon information entropy. Retrieved August 24, 2012 from http://home.comcast.net/~InstituteOfEnvironmentalQuality/Construction_of_blocks8.pdf

Stamps, A. E. (2010b). Effects of permeability on perceived enclosure and spaciousness. *Environment and Behavior*, *42*, 864-886.

Stamps, A. E. (2010c). Use of static and dynamic media to simulate environments: A meta-analysis. *Perceptual and Motor Skills*, *111*, 355-364.

Stamps, A. E. (2011). Effects of boundary height and horizontal size within boundary on perceived enclosure. *Perceptual and Motor Skills*, *113*, 995-998.

Stigsdotter, U. K., Ekholm, O., Schipperijn, J., Toftager, M., Kamper-Jørgensen, F., & Randrup, T. B. (2010). Health promoting outdoor environments: Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scandinavian Journal of Public Health*, *38*, 411-417.

Summit, J., & Sommer, R. (1999). Further studies of preferred tree shapes. *Environment & Behavior*, *31*, 550-576.

Syme, S. L. (1996). Rethinking disease: Where do we go from here? *Annals of Epidemiology*, *6*, 463-468.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using Multivariate Statistics* (5th ed.). New York: Allyn and Bacon.

Taylor, A., Kuo, F. E., & Sullivan, W. C. (2002). Views of nature and self-discipline: Evidence from inner-city children. *Journal of Environmental Psychology*, *22*, 49-63.

Texas Chapter of the International Society of Arboriculture (no date). Sec. 9-11-11. Tree ordinance. Retrieved May 14, 2010 from http://www.isatexas.com/members/Ordinances/2012_Ordinances/Public_Tree_Care_Ordinances/Coppell%20-%20Public%20Tree%20Care.pdf

Thayer, R. L., & Atwood, B. G. (1978). Plants, complexity, and pleasure in urban and suburban environments. *Environmental Psychology and Nonverbal Behavior*, *3*, 67-76.

Thwaites, K., Helleur, E., & Simkins, I. M. (2005). Restorative urban open space: Exploring the spatial configuration of human emotional fulfilment in urban open space. *Landscape Research*, *30*, 525-547.

Todorova, A., Asakawa, S., & Aikoh, T. (2004). Preferences for and attitudes towards street flowers and trees in Sapporo, Japan. *Landscape and Urban Planning*, *69*, 403-416.

Tomalak, M., Rossi, E., Ferrini, F., & Moro. P. (2011). Negative aspects and hazardous effects of forest environment on human health. In K. Nilsson, M. Sangster, C. Gallis, T. Hartig, S. de Vries, K. Seeland, & J. Schipperijn (Eds.), *Forests, trees, and human health* (pp. 77-124). New York: Springer.

Tsunetsugu, Y., Park, B. J., Ishii, H., Hirano, H., Kagawa, T., & Miyazaki, Y. (2007). Physiological effects of *Shinrin-yoku* (taking in the atmosphere of the forest) in an old-growth broadleaf forest in Yamagata Prefecture. *Journal of Physiological Anthropology*, *26*, 135-142.

Ulrich, R. S. (1979). Visual landscapes and psychological well-being. *Landscape Research*, *4*, 17-23.

Ulrich, R. S. (1983). Aesthetic and affective responses to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Human Behavior and Environment: Advances in Theory and Research* (Vol. 6, pp. 85-125). New York: Plenum.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, *224*, 420-421.

Ulrich, R. S., Simons, R., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*, 201-230.

United Nations (2009). *World Urbanization Prospects: The 2009 Revision Population Database*. Retrieved January 18, 2012 from http://esa.un.org/unpd/wup/index.htm

United Nations (2011). World Urbanization Prospects, the 2011 Revision. Retrieved May 4, 2012 from http://esa.un.org/unpd/wup/index.htm

United Nations General Assembly (1987). Report of the World Commission on Environment and Development: Our Common Future. Transmitted to the General Assembly as an Annex to

document A/42/427 - Development and International Co-operation: Environment. Retrieved May 7, 2012 from http://www.un-documents.net/ocf-02.htm

United Nations Population Fund (2011). State of world population 2011. People and possibilities in a world of 7 billion. Retrieved May 3, 2012 from http://foweb.unfpa.org/SWP2011/reports/EN-SWOP2011-FINAL.pdf

Valtchanov, D., & Ellard, C. (2010). Physiological and affective responses to immersion in virtual reality: Effects of nature and urban settings. *Journal of CyberTherapy & Rehabilitation, 3,* 359-379.

Valtchanov, D., Barton, K. R., & Ellard, C. (2010). Restorative effects of virtual nature settings. *Cyberpsychology, Behavior, and Social Networking, 13,* 503-512.

van den Berg, A. E., Hartig, T., & Staats, H. (2007). Preference for nature in urbanized societies: Stress, restoration, and the pursuit of sustainability. *Journal of Social Issues, 63,* 79-96.

van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental preference and restoration: (How) are they related? *Journal of Environmental Psychology, 23,* 135-146.

van den Berg A. E., Maas, J., Verheij, R. A., & Groenewegen, P. P. (2010). Green space as a buffer between stressful life events and health. *Social Science and Medicine, 70,* 1203-1210.

van der Laan, H. (1983). *Architectonic space: fifteen lessons on the disposition of the human habitat*. Leiden: EJ Brill.

van Dillen, S. M. E., de Vries, S., Groenewegen, P. P., & Spreeuwenberg, P. (2012). Greenspace in urban neighborhoods and residents' health: Adding quality to quantity. *Journal of Epidemiology & Community Health, 66,* e8.

Velarde, M. D., Fry, G., & Tveit, M. (2007). Health effects of viewing landscapes: Landscape types in environmental psychology. *Urban Forestry and Urban Greening, 6,* 199-212.

Weber, R., Schnier, J., & Jacobsen, T. (2008). Aesthetics of streetscapes: Influence of fundamental properties on aesthetic judgments of urban space. *Perceptual and Motor Skills, 106,* 128-146.

Wells, N. M., & Evans, G. W. (2003). Nearby nature: A buffer of life stress among rural children. *Environment and Behavior, 35,* 311-330.

White, E.V, & Gatersleben, B. (2011). Greenery on residential buildings: Does it affect preferences and perceptions of beauty? *Journal of Environmental Psychology*, *31*, 89-98.

White, M., Smith, A., Humphryes, K., Pahl, S., Snelling, D., & Depledge, M. (2010). Blue space: The importance of water for preference, affect, and restorativeness ratings of natural and built scenes. *Journal of Environmental Psychology*, *30*, 482-493.

WHO (1948). Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948. Geneva: WHO.

Wohlwill, J. F. (1983). The concept of nature: A psychologist's view. In I. Altman & J.F. Wohlwill (Eds.), *Behavior and the Natural Environment* (pp. 5-37). New York: Plenum Press.

Wolf, K. L. (2009). Strip malls, city trees, and community values. *Arboriculture & Urban Forestry*, *35*, 33-40.

Zajonc, R. B. (1980). Feeling and thinking: preferences need no inferences. *American Psychologist*, *35*, 151-175.

Zuckerman, M. (1977). Development of a situation-specific trait-state test for prediction and measurement of affective responses. *Journal of Consulting & Clinical Psychology*, *45*, 513-523.