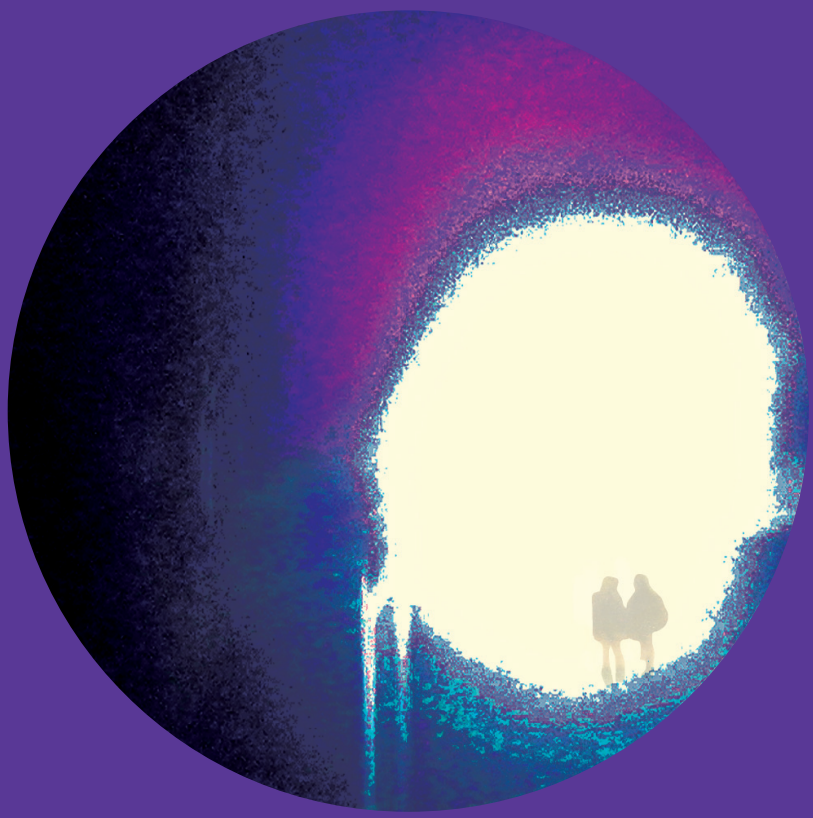
Department of Electronics

Perceptions of lighting, perceived restorativeness, preference and fear in outdoor spaces

Heli Nikunen



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Perceptions of lighting, perceived restorativeness, preference and fear in outdoor spaces

Heli Nikunen

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Abstract

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Abstract

This thesis considers outdoor lighting as a fundamental factor affecting environmental experiences after dark. It explores the restorative potential of outdoor lighting within the framework provided by attention restoration theory (ART). Also, perceived safety and preference variables are included in the research work. These factors may have a major effect on outdoor space use after dark and on the level of satisfaction with the neighbourhood in which a person lives.

The modern way of living calls for a capacity for long and intense periods of concentration, the ability to direct attention. However, this mental effort is susceptible to fatigue and a restorative period is needed before a person can be effective again. Thus, the need for restoration may be considerable during the evening, and public lighting environments should promote opportunities for restoration. This thesis explores how the perception of different lighting attributes is connected with the perception of restorative potential.

The research method was based on subjective assessments of simulated environments as well as field assessments. The results were obtained by applying quantitative analysis methods to the assessment data. In studies III and IV, the quantitative data was supplemented with qualitative data obtained from free responses. Both hypothesis testing with ANOVA and linear regression were used for quantitative data analysis.

The main finding is that the perceived quality of the lighting environment correlates with perceptions about the potential for restoration, thus providing a new framework for lighting research. The results indicate that perceived restorativeness is positively connected with the perception of such lighting attributes as the focus of light on natural scene contents and the perception of a pleasant colour quality, whereas the connection may be negative when the light is focused on urban scene contents. The results also indicate that perceptions of safe and a pleasant lighting environment are connected with the perception of a pleasant colour quality. Also, changes in the focus of the lighting affected preferences and feelings of safety, so that when the light was focused on natural scene contents, the preferences and perceptions of safety were higher, whereas they were lower when the light was focused on parking lots and roads. Thus, the results suggest putting more weight on the quality of lighting.

Keywords lighting, restoration, preference, fear

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Tekijä
Heli Nikunen

Väitöskirjan nimi
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Tiivistelmä

Tässä väitöskirjassa ulkovalaistus nähdään tekijänä, jolla voi olla merkittävä vaikutus pimeän ajan ulkotilojen laatuun. Väitöskirja tutkii ulkovalaistuksen elvyttävyyspotentiaalia tarkkaavuuden elpymisen teorian tarjoamassa viitekehyksessä sekä valaistuksen vaikutusta turvallisuuden tunteeseen ja preferenssiin. Näillä tekijöillä voi olla merkittävä vaikutus ulkotilojen käyttöön pimeän aikaan ja tyytyväisyyteen omaan asuinalueeseen.

Moderni elämäntapa vaatii usein kykyä keskittyä pitkään ja intensiivisesti. Tarkkaavuuden suuntaamiskyky on kuitenkin altis heikentymään ja toimintakyvyn palauttaminen vaatii elpymistä. Tarve elpymiselle voi olla huomattava iltaisin ja julkisten tilojen valaistuksen tulisi tukea elpymismahdollisuuksia. Väitöskirja tavoitteena on selvittää kuinka havainnot ulkovalaistuksen laadusta liittyvät havaintoon elvyttävyyspotentiaalista.

Väitöskirjan tutkimusmenetelmät perustuivat subjektiivisiin arviointeihin simuloiduista ympäristöistä ja todellisista ympäristöistä. Tulokset saatiin käyttämällä kvantitatiivisia analysointimenetelmiä. Tutkimuksissa III ja IV kvantitatiivista aineistoa täydennettiin kvalitatiivisella aineistolla. Sekä hypoteesitestausta (ANOVA) että lineaarista regressiota käytettiin aineiston analysointiin.

Väitöskirja antoi näyttöä siitä, että valaistuksella voi olla aiemmin tuntematonta elvyttävyyspotentiaalia ja siten se tarjoaa uuden viitekehyksen valaistuksen tarkasteluun. Tulokset antoivat viitteitä siitä, että havaittua elvyttävyyspotentiaalia voi lisätä valon kohdistuminen miellyttäviin näkymäsisältöihin ja valon väriominaisuuksien kokeminen miellyttävinä. Havaittua elvyttävyyspotentiaalia voi puolestaan heikentää valon kohdistaminen epämiellyttäviin, luontoa sisältämättömiin, kaupunkinäkymiin. Väitöskirjan tulosten mukaan turvallisuuden tunnetta ja preferenssiä voi edistää kohdistamalla valoa miellyttäviin näkymäsisältöihin, kuten viherympäristöön. Valon kohdistaminen parkkipaikkoihin ja teihin puolestaan heikensi turvallisuuden tunnetta ja preferenssiä. Miellyttäväksi koetut valon väriominaisuudet olivat yhteydessä miellyttävään ja turvallisen tuntuiseen valaistukseen. Tulokset antavat viitteitä valaistuksen laatuun perustuvasta tavasta vaikuttaa elvyttävyyspotentiaaliin, preferenssiin ja pelkoon.

Avainsanat valaistus, elvyttävyys, preferenssi ja pelko

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Preface

This thesis is about the environment, people and lighting. It has grown from an interest in the effect that the illuminated environment has on people. However, this effect, as with light itself, is often ignored. Although light makes things visible, light itself is invisible. It cannot be seen. This may happen also at a conceptual level when light is invisible in an environmental research or design. This thesis puts light itself on the stage. It focuses on the decisive impact of electric lights on our environmental experiences.

This thesis crosses the boundaries between environmental psychology, lighting design, urban planning and lighting technology. Writing for such a diverse audience is challenging. I have tried to accommodate differing expectations and offer understandable supporting information. I hope the result is readable for all and offers inspiring moments for those interested in lighting environments.

Major support for the environmental psychology and restoration aspects of the thesis as well as encouragement in getting the work started has been provided by Professor Kalevi Korpela from the University of Tampere. Professor Liisa Halonen from the Aalto University Lighting Unit and Dr Marjukka Puolakka have provided their invaluable expertise in the area of lighting technology. Furthermore, they have been very supportive in summarising this work. The comments of the reviewers, Associate Professor Yvonne de Kort and Professor Steve Fotios, significantly contributed to this thesis as well. M.Sc. Antti Rantakallio helped with the photometric measurements and the whole personnel of the Lighting Unit helped create a positive working atmosphere. Furthermore, the anonymous reviewers of the journal papers have helped to clarify the ideas during the publication processes. Finally, warm thanks to my whole family and especially to my husband Riku and my little ones, Iitu and Ohto.

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Espoo, August 2013, Heli Nikunen

Contents

List of publications

I NIKUNEN, H., & KORPELA, K.M. (2009). Restorative Lighting Environments - Does the Focus of Light Have an Effect on Restorative Experiences? *Journal of Light and Visual Environment, 33,* 37-45.

II NIKUNEN, H., & KORPELA, K.M. (2012). The effect of scene contents and focus of light on perceived restorativeness, fear, and preference in nightscapes. *Journal of Environmental Planning and Management, 55*, 453-468.

III NIKUNEN, H., PUOLAKKA, M., RANTAKALLIO, A., KORPELA, K., & HALONEN, L. Perceived restorativeness and walkway lighting in near home environments. *Lighting Research and Technology,* first published on February 20, 2013 as doi:10.1177/1477153512468745.

IV NIKUNEN, H., PUOLAKKA, M., RANTAKALLIO, A., KORPELA, K., & HALONEN, L. (2012). Lighting promoting safety and creating a sense of pleasantness in suburban environments after dark. *Journal of Lighting Engineering*, *14*, 7-21.

The Author has played a major role in all aspects of the work presented in this thesis. She planned the study designs and analysed the data and results for all the studies with the exception of the luminance and illuminance measurements and the photometric calculations in studies 3 (III) and 4 (IV) (they were conducted by Antti Rantakallio) and Table 15 in Appendix 1 (which was provided by Kalevi Korpela). Kalevi Korpela, Marjukka Puolakka, Liisa Halonen and Antti Rantakallio have provided support by commenting on the study designs and improving the manuscripts.

List of abbreviations and symbols

Abbreviations

AFI	Attentional Function Index
ANOVA	Analysis of variance
ART	Attention Restoration Theory
CCT	Correlated Colour Temperature
CIE	Commission Internationale de L'Eclairage (International commission on illumination)
CRI	Colour Rendering Index
DSB	Digit Span Backwards test
LED	Light Emitting Diode
NCPCT	Necker Cuba Pattern Control Test
NCSS	Number Cruncher Statistical System
POMS	abbreviated Profile of Mood State
PRS	Perceived Restorativeness Scale
ROS	Restoration Outcome Scale
SART	Sustained Attention to Response Test
SD	Standard Deviation
SMT	Search Memory Test
SPSS	Statistical Package for the Social Sciences
ZIPERS	Zuckerman Inventory of Personal Reactions

Symbols

cd	candela, luminous intensity
F	F-test value
L	luminance [cd/m^2]
L_{ave}	average surface luminance [cd/m^2]
lm	lumen, luminous flux
M	mean value
m	metre
p	probability value
r	correlation coefficient
Ra	colour rendering index

U_l	longitudinal luminance uniformity
U_o	overall luminance uniformity
TI	threshold increment [%]
W	Watt, power
α	Cronbach's alpha
η_p^2	Partial eta squared

Definitions

Being away – A component of the restorative experience referring to escape and distraction from everyday routines.

Brightness – Attribute of a visual perception, according to which an area appears to emit, or reflect, more or less light.

Compatibility – A component of the restorative experience referring to belongingness to the environment and being able to do things that one likes.

Concealment – Place offering concealment and control over a situation for an offender – offender's refuge.

Defensible space – Physical features of the environment that encourage territorial control, which in turn would reduce crime and fear.

Deflected vista – A view that is partially covered by, for example, foliage or a curving pathway.

Directed attention – Voluntary attention that is a resource for executive functioning and self-regulation.

Escape – Opportunities for escape when attacked

Extent – A component of the restorative experience referring to an environment that is coherent and gives a feeling of being in a 'whole other world'.

Fascination – A component of the restorative experience referring to things like interest and stimulation that draw effortless attention.

Likeability – The probability that the environment will receive a strong and favourable evaluative response.

Mental fatigue – A state of depleted directed attention capacity that occurs when the inhibitory attention system, which allows us to concentrate in the face of distractions, becomes burdened.

Mystery – A promise that more will be seen and enhanced/operationalised by features such as curving pathways and partial concealment (= deflected vista)

Perceived restorativeness – A perceived potential to be restored

Preference – Evaluative judgement in the sense of liking or disliking an object.

Prospect – Opportunities to control the environment visually.

Refuge – A place of concealment for him/herself.

Restoration – A rubric covering the multiple processes involved in renewing diminished functional resources and capabilities.

Restorative experience – An experience in which being away, coherence, compatibility and fascination are central.

Territorial functioning – Environment-related functioning that conveys a non-verbal message of control, separation from outsiders and a stake in the locale.

1 Introduction

1.1 Research background

Since its introduction, electric lighting has had a significant role in urban environments. 'Cities of light' have transformed our way of life and the visual image of our night-time environment. In the research field on lighting, the ability of light to, for example, attract attention and affect the performance of visual tasks, moods and a person's circadian system has been recognised (Boyce, 2003; IES Lighting Handbook, 1984). However, light may also have other effects. This thesis demonstrates that the way light augments a person's perceptions of the environment may be connected with the perception of restorative qualities.

Research on outdoor lighting has focused on the performance of different visual tasks, such as facial recognition or obstacle detection (e.g. Fotios & Cheal, 2007, 2009, 2012; Fotios & Goodman, 2012; Rea, 2012; Rea et al., 2009). This research field has led to the creation of normative lighting regulations for certain functions and numerical lighting standards to create appropriate visual conditions.

In the field of environmental psychology, nightscapes have been seen primarily as sources of fear and lighting as a matter of visual access (e.g. Brantingham & Brantingham, 1993; Haans & de Kort, 2012; Loewen et al., 1993; Marzbali et al., 2012; Nasar & Fisher, 1993). The possible positive experiences have received little attention when the focus has been on the negative side of the urban nightscape.

However, it is equally important to look for the favourable effects of nightscapes as a means of grasping the whole picture of environmental experiences during the hours of darkness. Outdoor lighting creates a scene for various actions, including romantic walks, jogging, a space for kids to play and relaxation. There is a need to widen the scope from the negative connotations of fearful passers-by performing visual tasks to seeing the full diversity of human needs and experiences during the hours of darkness.

Although few would argue about the importance of our environment on our well-being, the public is less familiar with the importance of the *visual encounter* with our environment. However, the idea of recovering from urban stress and job demands while viewing nature was suggested by landscape architect Fredrick Law Olmsted already in 1865. More recent research has given us a well-articulated body of findings that having a visual encounter with

certain environments helps restore attentional fatigue (Berto, 2005; Hartig et al., 2003), it has a positive effect on mood (Morita et al., 2007; Ulrich 1979, 1981) and physiological states (Parsons et al., 1998;), and may even affect health (Ulrich, 1984). These types of stress-recovering environments are called restorative environments and they appear to apply more to natural rather than urban scene contents. However, since natural areas are decreasing rapidly in the face of urbanisation and since feelings of overload, stress and insecurity are connected with modern urban life (Lederbogen et al., 2011; Milgram, 1970; Savage, 1993), it is crucial to find out about those particular environmental characteristics that promote well-being and foster a positive mood within the modern urbanised environment.

1.1.1 Restoration

Restoration is the counterpoint to stress and attentional fatigue. It covers various processes involving renewing or recovering diminished functional resources and capabilities (Hartig, 1993; Hartig & Staats, 2003). In the restoration research field, two processes have received much attention — one focuses on attention restoration and the other on psychophysiological stress recovery. Attention restoration theory provides the theoretical framework for this thesis. Attentional and stress recovery are considered conceptually distinct even though they both contribute to restorative experiences. (Kaplan, 1995.)

Attention restoration theory (ART) sees natural environments as helping to restore attentional capacity, foster a positive mood and thus promote well-being. Attentional capacity may weaken as a result of prolonged mental effort (Berto, 2005; Kaplan & Kaplan, 1989). This mentally fatigued condition is signalled by increased irritation and difficulties in concentrating. It may also be manifested through an increased propensity for outbursts of anger and even violence (Kuo & Sullivan, 2001). Ordinary natural settings have a high restorative potential and promote the recovery of a person's attentional capacity. Also, recovery from psychophysiological stress is more likely to occur when natural view is present (e.g. Ulrich, 1981). This recovery may be both faster and more complete when subjects are exposed to natural rather than urban environments (Ulrich et al., 1991). Ulrich (1979) has also noted that nature scenes have a positive effect on a specific cluster of emotions, including sadness, fear and arousal, in daytime environments.

Besides the cognitive, emotional and physiological changes, restoration is also an experience in which the environment supports our intended activities (compatibility), creates distances from our everyday routines (being away), offers a substantial scope and feeling of coherence (extent) and supports the use of effortless attention (fascination) (Kaplan &Kaplan, 1989). Nature seems to offer good possibilities for these key experiences to occur.

Although urban planning supports the provision of restorative experiences in the form of green spaces (e.g. Prow, 1999), the provision of such opportunities during the hours of darkness is rarely considered. Also, the research on restorative environments has focused on daytime environments. However, the time spent for recreational purposes is often limited to evenings. Furthermore, the need for restoration may be considerable after dark due to the mental effort needed during the work day (Kant et al., 2003). Researchers have also found that having access to green spaces acts as a moderator on health inequalities in general and especially on health inequalities related to circulatory diseases, in which chronic stress and physical inactivity have causal roles (Mitchell & Popham, 2008). Thus, there is a need to extend restoration research so that it covers nightscapes and provides information about how people may satisfy their restoration needs in urban environments.

1.1.2 Fear in nightscapes

Fear at night may occur for several reasons. Besides the reasons related to the social environment, or so-called 'social night' (Koskela & Pain, 2000), and individual factors, such as gender and environmental trust, (e.g. Johansson et al., 2011), an obstructed field of view has also been connected with feelings of discomfort and fear (Fisher & Nasar, 1992). The obstruction may be physical, but it may also be caused by insufficient visual performance. Visual performance is reduced by limited or scattered luminance distribution, low luminance levels, very high or low luminance contrasts and glare (Boyce, 2003). Also, weak colour contrast or a colour appearance that deviates from what is normal may harm the performance of visual tasks.

When pedestrian outdoor lighting provides an environment where photopic luminances vary between 0.01 and 3 cd/m^2, the human visual system relies on more peripheral mesopic vision than the photopic vision used during daytime lighting conditions (Boyce, 2003). Mesopic vision is less able to discriminate between colours. However, it detects movement more readily than photopic vision, but with less sharpness in terms of the images produced. This higher

degree of sensitivity to movement and lower quality images sets high demands for recognition processes. It could be further suggested that being more sensitive to moving stimuli but less able to identify the stimuli induces greater sensitivity to the experiences of fear than photopic vision.

Urban nightscapes are also environments where shadows have a strong role. Very often there is hardly any scattered light leading to high-luminance-contrast lighting environments with strong shadows. Thus, the visual image of three-dimensional objects, like faces, differs significantly at night from the daytime image, making the recognition process challenging. Furthermore, the multiplicity of light sources, and thereby the directions of light, generates an environment where even an observer's own shadow makes sudden movements when passing between the various light sources. Also, when branches are close to the light source, a small movement caused by the wind stirring the branches of trees is multiplied in the movement of shadows cast upon the ground. These shadow movements, together with the higher movement sensitivity of mesopic vision, may further induce experiences of fear. Therefore, an urban electric lighting environment may also be a source of disinformation and fear.

The lighting environments of early humans with a single dominant far off light source, sun or moon, provided a more stable light-shadow environment. Thus, at that time strong shadow movements during night may well have been produced by a predator and fear was a beneficial reaction supporting survival in such a situation.

For modern humans, fear at night is more likely a damaging rather than a beneficial reaction. Besides being an unpleasant feeling, fear is related to stress and harmful psychophysiological conditions (e.g. Inoue et al., 1993; Yoshioka et al., 1996). Furthermore, fear limits the use of outdoor spaces during night-time (Keane, 1998), which negatively affects human well-being. However, there is evidence indicating that making changes to environmental conditions can reduce the fear of crime (Perkins et al., 1992). For example, lighting may help combat a fear of crime (Atkins et al., 1991; Herbert & Davidson, 1994; Loewen et al., 1993). It is thus important to find those lighting characteristics that promote a perceived sense of safety and increase pleasurable stimuli, thereby helping to combat uncertainty and confusion in nightscapes. However, practical lighting interventions to diminish the fear of crime have often encompassed changes in various lighting attributes, e.g. in terms of photometric attributes, the spectral power distribution, mean surface luminance and luminance distribution may have been changed (e.g. Herbert & Davidson, 1994). Because of the large number of attributes, it is difficult to identify which lighting attributes may have caused the possible positive effects.

Traditionally, lighting has been seen as a matter of visual performance and visual access, providing reassurance for those who are fearful in public places. Lighting allows people to see what is around them so that they can easily recognise potential escape routes and notice that there are no places for offenders to hide (Appleton, 1975; Fisher & Nasar, 1991). Furthermore, lighting makes it possible to evaluate the expressions, gestures and appearances of other people, enabling a person to make risk evaluations and change their route if necessary (Boyce, 2003; Pain, 2000). Lighting also makes it possible for a person to be seen so that, in the case of an attack, others may perceive and react to the situation (Loewen et al., 1991).

Lighting is also related to the concepts of territorial functioning and physical incivility (Brantingham & Brantingham, 1993; Perkins et al., 1992). Fully operating and aesthetical lighting may lead to a reduced fear of crime, since it alerts a person that they are in a well-off environment that is taken care of, whereas dull lighting with broken luminaries sends a signal of indifference and disarray. There is also empirical evidence that perceiving the lighting environment as pleasant is more important for feelings of safety than merely perceiving the brightness of an environment (Johansson et al., 2011).

In conclusion, the experiences of fear have dominated experiential outdoor lighting research, whereas there is hardly any research concerning possible positive experiences. Furthermore, lighting interventions with local participants have characterised the lighting attributes of a familiar place only to a minor degree (Atkins et al., 1991; Herbert & Davidson, 1994; Nair et al., 1993), whereas many experimental studies have used unfamiliar settings (Johansson et al., 2011; Boyce et al., 2000) or settings that are dominated by a sense of fear (Nasar & Jones, 1997; Nasar et al., 1993), contexts in which people may be more sensitive to negative environmental cues (Zube et al., 1985). However, in everyday life people tend to use the routes and areas they know beforehand and that cause less of a sense of fear. Furthermore, in near-home environments the lighting needs may be more diverse and differ from the needs of a fearful passer-by. The lighting environment sets the scene for recreational outdoor activities after dark. It builds up a place identity and affects community pride. Thus, it is important to augment the research field with positive perceptions of lighting in near-home environments.

1.2 Aims

The main aim of this thesis is to explore whether lighting is connected with the perception of the restorative potential of night-time environments. The

secondary objectives are to explore how different lighting attributes are connected with the perception of pleasant and safe lighting environments and how the focus of light affects perceptions of safety and pleasantness and to provide practical suggestions for lighting implementations.

Study 1 (publication I) aims to examine how changes in the focus of light affect perceived restorativeness.

Study 2A (publication II) investigates how the content of the scene (urban-mixed-natural) affects perceived restorativeness, fears and preferences when controlling the perceived spatial configuration.

Study 2B (publication II) extends the research of study 1 by examining the effect of the focus of light on perceived restorativeness, fears and preferences. It will clarify the interplay between these variables during night-time.

Study 3 (publication III) aims to clarify whether perceptions of different lighting attributes (brightness, distribution, glare, colour quality, the sense of safety generated by light and the pleasantness of the lighting environment) in a near-home suburban environment is connected with the perception of the components of ART (being away, fascination, extent and compatibility).

Study 4 (publication IV) aims to reveal the most significant connections between the lighting attributes (colour quality, evenness, extensiveness, brightness, glare) and perceived safety (generated by light) and pleasantness (of the lighting environment) variables in near-home suburban environments.

1.3 Hypotheses

This chapter presents the hypotheses of studies 1, 2A and 2B. Studies 3 and 4 have more of an exploratory nature. Thus, no hypotheses were formulated for those studies. The hypotheses below are constructed based on previous research dealing with restoration, preferences, fears and lighting. The main hypotheses (1-3) examine the effects of the focus of light. However, it is expected that changes in the scene contents and focus of light will have similar kinds of effects. Therefore, hypotheses 1.1, 2.1 and 3.1 are analogous to the main hypotheses and concentrate on the effects that the scene contents may have on perceived restorativeness, fears and preferences. Hypotheses 4 and 5 present the expected correlations between these study variables. The hypotheses are as follows:

1 At night-time, the focus of light may affect perceived restorativeness so that perceived restorativeness is higher when the light is focused on natural elements than when it is focused on urban elements.

1.1 At night-time, the scene contents may affect perceived restorativeness so that perceived restorativeness is higher in natural environments than in urban environments.

During daytime, perceived restorativeness tends to be higher in natural environments than in urban ones (Berto, 2007; Herzog et al., 2003; Laumann et al., 2001). There is no previous research on restorative environments during the hours of darkness. However, as greenery also tends to increase preferences during night-time (Hanuy, 1997) and preference and restoration have both theoretical and empirical connection (Berto, 2007; Kaplan, 1987; Kaplan & Kaplan, 1989; Ulrich, 1986; Ulrich et al., 1991; Van den Berg et. al., 2003), it may well be expected that perceived restorativeness is also higher in natural environments than in urban ones during the hours of darkness (hypothesis 1.1). Thus, the response would follow the daytime pattern.

Lighting may have a considerable effect on perceived restorativeness. The daytime image of city space is reshaped by lighting during the dark periods. Artificial light constructs the space by revealing certain features and hiding others. Thus, lighting may promote certain features in the environment while diminishing others. Lighting may also serve as a guide to the eye since regions with high degrees of contrast attract attention (Koch & Ullman, 1985; Parkhurst et al., 2002). As a restorative experience, restoration and perceived restorativeness are based on the visual exposure of environments (e.g. Berto, 2007; Hartig et al., 1996; Hartig & Staats, 2006; Parsons et al., 1998, Ulrich 1981), thus lighting may play a considerable role in perceived restorativeness. Light can focus our attention on the positive (or negative) restorative features of the space, and in this way, enhance or weaken the perceived restorative potential.

It may thus be hypothesised that focusing light on natural elements results in higher ratings of perceived restorativeness than focusing light on urban elements (hypothesis 1).

2 During night-time, the focus of light may affect preference so that preference is higher when light is focused on natural elements than when it is focused on urban elements.
2.1 During night-time, the scene contents may affect preference so that preference is higher in natural environments than in urban environments.

The preference studies are in line with restoration research in general, indicating a higher preference for natural than urban environments during the daytime (e.g. Kaplan & Kaplan, 1989; Nasar, 1998; Verderber, 1986). Hanuy (1997) reported in his study on residential areas after dark that a positive relationship exists between an affective appraisal and the degree of openness and naturalness. The relationship was negative between an evaluative response and the prominence of vehicles. It may thus be hypothesised that natural scene contents are preferred over urban ones also during the hours of darkness (hypothesis 2.1). Since light is able to hide, reveal and focus our attention (Koch & Ullman, 1985; Parkhurst et al., 2002), it has a major effect on our environmental perceptions in urban nightscapes. It may thus be hypothesised that focusing light on natural scene contents also results in higher rates of preference than focusing light on urban scene contents during night-time (hypothesis 2).

3 During night-time, the focus of light may affect perceived safety so that fear is greater when light is focused on urban elements than when it is focused on natural elements.
3.1 During night-time, the scene contents may affect perceived safety so that fear is greater in urban environments than in natural environments.

With the same spatial configuration, urban scenes are generally less preferred and considered more frightening than natural ones during the day (Herzog & Miller, 1998). Also, Kuo et al. (1998) have noted that greenery is positively linked with perceived safety and preference during daytime. Ulrich (1979, 1981, 1991) received

similar results in his studies, indicating that nature exposure reduced fear arousal.

There are only a few studies concerning responses to different scene contents during the hours of darkness. However, Hanuy (1997) has found evidence that natural settings also increase perceived pleasantness and safety during night-time, whereas the prominence of vehicles is evaluated negatively. Herbert and Davidson (1994) noted that more intense lighting may increase fear if it makes the unpleasant things more visible. These results are also echoed by Boyce et al. (2000), who found that more lighting is needed in urban parking lots than in suburban ones to create the same degree of safety. It may thus be hypothesised that fear is also greater in urban environments than in natural environments during the hours of darkness (hypothesis 3.1). Furthermore, it is expected that when the focus of light enhances the green appearance of the environment, people experience less fear than when the focus of light promotes the presence of the urban scene contents (hypothesis 3).

4 Preference has a positive correlation with perceived restorativeness.

People tend to prefer natural environments over built environments (Ulrich, 1986; Kaplan & Kaplan, 1989) and to perceive them as being more restorative (Berto, 2007; Hartig et al., 1996; van den Berg, 2003). Theoretical rationales for such preferences at least partly reflect the functional and restorative effects and significance that the environment has for the perceiver (Ulrich, 1986, 1991; Kaplan, 1987; Kaplan & Kaplan, 1989). The mediation analysis used in a study by Van den Berg et al. (2003) indicated that affective restoration accounts for a substantial proportion of the preference for natural over built environments and thus provides support for these rationales. Also, Staats et al. (2003) found a correlation between preferences (attitude toward walking in) and the perceived likelihood for restoration. Therefore it is expected that preference and perceived restorativeness have a positive correlation.

Fear and preference have a negative correlation

The relationship between preferences and the perceived sense of danger is intricate. Mystery, as a promise that more can be seen and enhanced/operationalised by such features as curving pathways and partial concealment (= deflected vista), has been positively linked to both preference and fear in daytime environments (Herzog & Miller, 1998; Kaplan & Kaplan, 1989; Nasar et al., 1993; Ulrich, 1986).

It has also been suggested that visual and locomotor access are positive predictors of preference and negative predictors of fear (Herzog & Kutzli, 2002). In studies one (I) and two (II), the variation in the ability to see and move around well was rather modest, whereas the variation in scene contents was quite remarkable. Therefore, the role of mystery, as it is interpreted in this context, may be substantial. Urban night-time environments may connote a risk of social danger, and therefore mystery may turn into a feeling of fear, whereas the possibility for positive outcomes may be greater in natural environments.

As the previous research suggests, a negative but not necessarily very strong correlation between preference and fear (Herzog & Kropscott, 2004; Herzog & Kutzli, 2002) it is expected that fear and preference have a negative correlation.

1.4 Contributions

This thesis sees lighting as a key factor affecting environmental experiences. It explores how lighting perceptions are connected with perceived restorativeness, preferences, pleasantness and fears. These factors were chosen because it is believed that they significantly affect people's willingness to use urban spaces after dark (Alfonso, 2005; Larco et al., 2012). They may also affect the way in which these spaces are used and how frequent they are used. Increased amounts of walking and cycling rather than using motorised transport has environmental benefits, such as a decrease in energy consumption and lower levels of fine particles in the air. It also has a positive effect on mental and physiological health (e.g. Penedo & Dahn, 2005). An increased use of outdoor spaces by women, elderly people and families also affects the nature of social life at night. The existing research concentrates on

perceived restorativeness. However, the results are also indicative what comes to restoration as there is increasing evidence connecting the two (Hartig et al., 1991, 1996, 1997; Hietanen et al., 2007; Hietanen & Korpela, 2004; Korpela et al., 2002; Chang et al., 2008).

Restoration per se has been associated with better moods, better physiological states and better health (for an overview, see Velarde et al., 2007). Furthermore, there is evidence suggesting a connection between mental fatigue and the increased propensity for outbursts of anger and violence (Kuo & Sullivan, 2001). Thus, restoration may have the potential to improve a person's social environment through increasing their capacity for self-regulation.

The provision on the restorative possibilities offered by lighting is especially relevant in northern parts of the world, where free time is limited to the dark hours during winter time. Furthermore, people's restoration needs may be greatest in the dark evenings after the mental effort required during the work day (Kant et al., 2003). As mental fatigue has been connected with disturbed sleep (Åkerstedt et al., 2003), and disturbed sleep has been associated with negative health outcomes, including obesity, cardiovascular disease and cancer (Cappuccio et al., 2008; Gallichio & Kalesan, 2009), restoring mental fatigue during the evening is essential for well-being. In conclusion, the parallel benefits of perceived restorativeness, restoration, preference and safety have a great potential for enhancing the urban environment and making it a better place for human beings to live in.

In an overview of 31 studies on the health effects of viewing nature, Velarde et al. (2007) concluded that the absence of studies on mixed environments constitutes a fundamental knowledge gap in restorative environment research. This thesis presents one study (2) with urban-mixed-natural categories and two studies (1 and 2) where the perception of mixed environment is affected by lighting, thus providing insights into the way people perceive of mixed environments.

Study 1 (I) will give the first indication of the restorative potential of light by examining the effect of the focus of light. It will also extend the restoration research field to take into account night-time environments. Study 2 A (II) investigates how the content of the scene (urban-mixed-natural) affects perceived restorativeness, fears and preferences during the dark hours while controlling the spatial configuration. It will also give some indications of the restorative quality of mixed environments compared with urban and natural ones. Study 2 B (II) will proceed further. It will suggest that besides affecting perceived restorativeness, the focus of light may also affect the perceptions of

preferences and fears during night-time. The results of study 3 (III) will give insights on how the perception of different lighting attributes (brightness, distribution, glare, colour quality, feelings of safety produced by the light and the pleasantness of the lighting environment) is connected with the perceived restorative potential of familiar suburban environments. Since the components of ART are examined separately, the results will also give some indications of how night-time lighting perceptions are connected to the experiences of relaxation (being away) and the intrinsic appeal of the environment (fascination). The results will also suggest how lighting perceptions are connected to the creation of a coherent visual image of the urban nightscape that has scope (extent) and willingness to use outdoor spaces after dark (compatibility). Study 4 (IV) will examine how perceptions of different lighting attributes are connected with perceptions of a safe and pleasant lighting environment. In conclusion, the results extend the restoration research to urban nightscapes and offer insights into the perceived lighting qualities of attractive and potentially restorative lighting environments. They will also emphasize the importance of near-home environments. Perceiving near-home environments as potentially restorative, safe and attractive may be important for recreational engagements and the level of satisfaction with one's neighbourhood (Björk et al., 2008).

1.5 Scope

The research on restoration is concentrated on the perception of restorative potential. Restoration on a behavioural and/or physiological level has not been studied. Restoration on an experiential level is examined in publication I in using the Restoration Outcome Scale (ROS).

The focus of light was chosen to serve as an independent variable in studies 1 (I) and 2 (II), as it is one of the fundamental aspects of lighting when creating an illuminated environment. It determines what we are able to see in urban nightscapes and what scene contents are left in darkness. The focus of light is related to the term 'luminance distribution', which is often used in lighting technology. However, the term 'focus of light' better conveys the key idea — the places that have the highest luminance — whereas luminance distribution is a more generic concept. Furthermore, the idea behind focus of light connotes the presence of a significant luminance contrast.

Studies 3 (III) and 4 (IV) examine near-home suburban environments. Since lighting needs and expectations are context dependent, the results may not be generalized to other contexts.

All of the studies examine the perceptions of artificially illuminated environments after dark. Perceptions of restorativeness during daytime or in daylight conditions may differ significantly from the results of this study.

1.6 Organisation of the thesis

The remainder of the thesis is divided into three chapters. The individual chapters are organised as follows: Chapter 2 is an introductory chapter — the main objectives are to introduce the reader to the theoretical framework that is used in the following chapters and to previous research concerning outdoor lighting. The chapter begins by providing a background to restoration theory. This is followed by a presentation of preference studies reflecting the restoration-preference connection. Then, the two main theories in restoration research — attention restoration and psychophysiological stress recovery — are presented. The reader is also introduced to how the theoretical constructs are measured. Furthermore, an overview of the empirical research activity on outdoor lighting and affective responses to urban nightscapes is provided. Finally, the chapter ends with a summary of the past research.

Chapter 3 presents five studies. The chapter begins with a general introduction to the studies. This is followed by a study on the effects of the focus of light on perceived restorativeness based on a publication in the *Journal of Light and Visual Environment* (I). The second study (2 B) investigates how changes in the focus of light affect perceived restorativeness, preferences and fears, and it is therefore an extension of the first study. It also investigates how changes in the actual scene contents (natural, mixed and urban) affect perceived restorativeness (2 A). The second study was published in the *Journal of Environmental Planning and Management* (II). The third study explores the relationships between the four components of attention restoration theory (being away, fascination, extent and compatibility) and perceived lighting attributes (brightness, distribution, glare, colour quality, safety and pleasantness). It was published online in *Lighting Research and Technology* (III). The fourth study explores the relationship between the perception of different lighting attributes and perceived safety and pleasantness of the lighting environment in five suburban locations after dark. It was published in the *Journal of Lighting Engineering* (IV). Each study

begins with a short introduction followed by a presentation of the methods and results.

Chapter 4 discusses the findings of this thesis in relation to previous research in the field. It offers insights into how lighting may enhance the perceived restorativeness and pleasantness of and preferences for particular night-time environments. It also discusses the limitations of the work and suggests directions for future research.

Chapter 5 concludes the thesis. It summarises the work and gives a short presentation on the main findings.

2 Review of the literature

2.1 The background to restoration theory: the experiences of wilderness and nearby nature

Nature as a source of freedom and inspiration and as a spiritual experience has been described in literature for centuries. The actual restoration theory has its roots in the wilderness experience research done by Rachel and Stephen Kaplan in the early 1970s. The Outdoor Challenge Program involved backpacking through a large wilderness area in Michigan's Upper Peninsula. (Kaplan & Kaplan, 1989.)

The first reported findings (Kaplan, 1974) were based on a small sample of 10 participants and a control group of 25. The results were obtained through self-reports and indicated that nature may promote self-discovery. The outdoor challenge group participants resulted having a more positive view of themselves. They also felt calmer and had a greater sense of self-sufficiency.

Over the years, the wilderness research broadened in scope. The results indicated that the transition towards the experiences of comfort and confidence when being in nature happens quite quickly. What seemed to be the general outcomes of the whole project were already reflected in the first results — self-discovery and becoming restored. Although the Outdoor Challenge Program included other factors besides the nature experience that affected the results, it served as a beneficial starting point for developing attention restoration theory. (Kaplan & Kaplan, 1989.)

The research work done by the Kaplans shifted towards everyday life as they started to study the effects of nearby nature — the natural contents that people see, pass through and even create themselves in their everyday surroundings. For example, street trees, backyards and unused lots may provide important recreational possibilities for the people nearby and passing through those locations. They found that the immediate outcomes of nearby nature include enjoyment, relaxation and reduced stress levels. The indirect, long-term results include increased satisfaction with one's home, job and life. In workplace environments, having access to nature was related to lowered levels of perceived job stress and higher levels of job satisfaction. Employees who could look out onto nature reported fewer ailments and headaches. They also found that people with access to nearby nature were healthier. (Kaplan & Kaplan, 1989.)

Besides offering a place to enjoy the pleasures of beauty, the Kaplans found that people's own yards are also important because they offer possibilities for marking out territory and enable people to do what they want in their 'own little spots'. Gardening and other nature-related activities contribute both to a sense of neighbourhood and life satisfaction. Also, observing is an important way of being involved with nature. Even conceptual involvement may be very important, e.g. simply knowing that there is nature nearby may be a pleasurable experience. Natural areas in general seem to serve as places where people can think and forget their worries, regain their sanity and a sense of serenity, and enjoy solitude. (Kaplan & Kaplan, 1989.)

The feelings of extent and intimacy are more highly valued than the actual size of the natural area. Large open spaces and designated parks do not contribute satisfaction as much as trees, landscaping and opportunities for gardening. Proximity, accessible greenery, is essential. Proximity may be measured in the form of time, distance or visual access. Since there is no clear consensus as to which of these is the most important form of proximity, they can all be considered important indicators. (Kaplan, 1973, 1980, 1985; Kaplan, & Kaplan, 1989.)

2.2 Preference studies

Preference has a frivolous and whimsical connotation, suggesting something of a random experience. Scholars have also claimed that an aesthetic reaction to landscape is largely or completely learned, a cultural pattern (e.g. Lyons, 1983). However, many theories see that aesthetic landscape responses are determined by affective and cognitive processes that have favoured well-being and survival during evolution. Appleton's prospect-refuge theory (1975), Ulrich's psycho-evolutionary framework (Ulrich, 1986; Ulrich et al., 1991) and the informational model proposed by Rachel and Stephen Kaplan (1989) provide examples of this approach.

Also, the work done by Wohlwill has been fundamental in the field of landscape preference research (1968, 1972). Wohlwill emphasises the role of arousal in aesthetic preferences and argues that humans develop an adaptation level to the stimuli as a function of past exposure (Wohlwill, 1973). He further suggests that hyper-stimulation is a source of stress, whereas under-stimulation has deleterious effects on behaviour. Wohlwill was inspired by Gibson's affordance theory, which describes what a perceiver would be able to do in a particular setting, and by Berlyne's collative variables. Berlyne

suggests that collative variables (complexity, novelty, uncertainty and incongruity) are sources of arousal potential and that aesthetic responses are linked to changes in arousal (Russell et al., 1997). From Berlynes collative variables complexity has received the most attention and the research has pointed to an inverted-U relationship between preference and complexity (e.g. Day, 1967). However, when Wohlwill (1968) extended the stimulus material from randomly generated nonsense material to photographs of outdoor environments and works of art, the inverted-U relationship did not reach significant levels. Later research has suggested that complexity predicts preference within the nature domain and within the urban domain, but that it does not account for the preference for nature in relation to the urban category (Kaplan et al., 1972).

It has further been suggested that people may process natural content more efficiently since the brain and sensory systems have evolved in natural environments (Ulrich, 1991), which is a bit of a vague explanation. Thus, more fundamental explanations have been presented. For example, Joye and van den Berg (2011) have proposed that the fractal characteristics of natural environments may promote more fluent processing and further preference and restoration. Later research has also pointed out that sensory organs are not globally adapted to natural stimuli, but optimised to account for biologically relevant stimuli (Machens et al., 2005). There is also evidence indicating that the global properties that describe the spatial and functional aspects of an environment are processed slightly faster than content-based categorisation (Greene & Oliva, 2009a) and that the rapid recognition of natural scenes is partially based on global properties and not just contents (Greene & Oliva, 2009b).

The informational model proposed by Rachel and Stephen Kaplan postulates that people have two very basic needs: to understand and to explore. They further suggest that the relationship between preference and extracting information from the environment can be described using a preference matrix (Table 1).

	Understanding	Exploration
Immediate	Coherence	Complexity
Inferred	Legibility	Mystery

Table 1. The Preference Matrix.

The matrix contains an immediate — an inferred dimension, referring to the availability of information, and understanding — exploration dimension that refers to basic informational needs (Kaplan & Kaplan, 1989). The resulting combinations are complexity (how intricate the scene is), coherence (a sense of order), legibility (understandable and memorable — Kevin Lynch introduced this concept in *The image of the City* in 1960) and mystery (a suggestion of further information, e.g. a curving pathway). The Kaplans have further proposed that there are evolutionary advantages to making quick predictions about the informational possibilities of an environment, thus incorporating an evolutionary perspective into their informational model (Kaplan, 1987).

What served as an important starting point in the development of the Kaplans' informational mode was a study assessing the roles of complexity and content in preference (Kaplan et al., 1972). In the study, participants rated preference and complexity for 56 slides showing both natural and urban contents. While they greatly preferred nature scenes to urban scenes, there were differences in people's preferences within the natural category as well. The most preferred scenes contained either a trail disappearing around a bend or a brightly lit clearing partially obscured by intervening foliage. This promise of more information was labelled mystery in the informational model. The formation of a coherence variable has its origins in the same study. In the pre-test situation, participants complained that some of the scenes were difficult to understand. They lacked the symmetry, repeating elements and unifying elements that contribute an understanding of a particular scene. The degree to which the scene hangs together was later labelled coherence in the informational model.

From the informational factors presented in the table, coherence and especially mystery have proved to be significant in terms of predicting preference (Herzog, 1992; Herzog & Kutzli, 2002; Herzog & Miller, 1998), whereas the role of complexity and legibility is less evident (Kaplan & Kaplan, 1989, p. 65). However, there is also evidence that supports the importance of complexity and legibility (Herzog, 1992) and calls into question the roles of

coherence and mystery (Stamps, 2004). A meta-analysis on the relationships between preference and informational factors has indicated that the theory has not generated reproducible results (Stamps, 2004). It was pointed out that, for example, mystery was sometimes negatively related to preference, sometimes it was done positively and strongly and sometimes there was no connection at all. However, Stamps's meta-analysis consists of two categories (urban and natural), while Herzog & Leverich's (2003) study indicates that the setting category needs to be delineated more precisely; for example, field and forest settings should be studied separately. Also, other studies have indicated that the informational factors are sensitive to the context (Herzog & Kropscott, 2004; Herzog & Miller, 1998).

Appleton's prospect-refuge theory has roots in habitat theory. Habitat theory asserts that aesthetic landscape preferences have evolutionary origins. They arise from a spontaneous reaction to that environment as a habitat satisfying all of our biological needs. Inspired by the ethological approach of Konrad Lorenz, in which every creature looks for conditions where it is possible to see without being seen, Jay Appleton reduced the scope of the habitat concept and proposed a prospect-refuge theory of human landscape aesthetics. Appleton postulates that, as seeing (prospect) without being seen (refuge) is an intermediate step in the satisfaction of many biological needs, the capacity of an environment to ensure this need becomes a more immediate source of aesthetic satisfaction. (Appleton, 1975.)

Appleton (1975) suggests that the components of a landscape may be classified according to their conduciveness to seeing and hiding, thus referring to their tactical character. An unimpeded opportunity to see is *prospect*, whereas a hiding opportunity is *refuge*. Appleton also argues that the capacity to savour danger lies at the very heart of prospect refugee theory, since both prospect and refuge demand the presence of a *hazard*. Therefore a 'tamed' environment where one can taste a hazard safely is preferred, and striking the right balance between prospect, refuge and hazard is important. Appleton further states that prospect symbols include light and especially a blue-coloured light, which operates as a distance cue. The supreme prospect symbol within the solar system is the sun and it is also symbolic of distance on a supra-terrestrial scale. However, the intensity of sunlight hinders the participation of the sun in the composition of the human landscape. Thus, the stars and moon better facilitate the experience of a supra-terrestrial scale. Light is also essential for the realisation of other prospects, whereas a lack of light is conducive to not being seen. Thus, for Appleton darkness is a symbol of refuge.

In contrast to Ulrich and the Kaplans, Appleton (1975) gives some consideration to the nocturnal landscape as well. He considers the landscape of night as an inversion of the daytime landscape. The upper part of the field of vision is dominated by the extreme refuge symbol of darkness and prospects can be found in the pools of light created by artificial light sources. Thus, a limited number of prospects are set within an infinite refuge. Appleton also suggests that the light shining from human habitats transmutes common refuge symbols of daytime into limited and localised prospects of the nocturnal landscape. Nowadays, the artificial light of human habitats shines so strongly that the experience of a supra-terrestrial scale is hindered in large areas of the world, thus reducing the scope of human landscape experience. Notably, Appleton (1975) also discusses (p. 140) the perception of prospect and refuge under mesopic and scotopic conditions, forming an inversion of colour perception.

Appleton's prospect-refuge theory (1975), Ulrich's psycho-evolutionary framework (Ulrich, 1986; Ulrich et al., 1991) and the informational model proposed by Rachel and Stephen Kaplan (1989) all find that both scene configuration and scene contents are important determinants of the preference responses. Content refers to a specific object or element, whereas configuration refers to the way in which the elements are arranged within the scene (Kaplan & Kaplan, 1989).

The Kaplans have examined the preference judgements by using the Category-Identifying Methodology (CIM) (Kaplan & Kaplan, 1989). A common theme in content-based categories is the division between human-influenced and natural scene contents. However, there is also evidence indicating that rapid scene categorisation for natural and urban scenes may be partially based on spatial and functional aspects and not just on contents (Greene & Oliva, 2009b). Thus, more research on the basis of scene categorisation and human perception is needed.

The degree of human influence seems to be an underlying component of perception (Kaplan & Kaplan, 1989; Hartig & Staats, 2005). However, the human influence is not a unitary concept; rather, it depends on the context. In some instances, different kinds of human influences are perceived as essentially similar, whereas in other cases they are subcategorised. The sub-categorisation may be related to, for example, familiarity so that finer discrimination is used in a residential context. Also, the apparent importance of the content affects categorisation so that, for example, industrial scenes tend to form their own category whereas roads do not. Furthermore, the frame

of reference provided by the set of environments influences the categorisation as well (Kaplan & Kaplan, 1989).

In organisation-based categories, the underlying criterion for preference judgments seems to be the possibilities and limitations for action and orientation. The idea is very similar to Gibson's concept of 'affordance' — what the environment potentially offers for the perceiver. The two ways of distinguishing between organisation-based categories seems to entail a degree of openness and a degree of spatial definition. Both ends of the openness category continuum may be seen as limiting the perceiver's possibilities for action and orientation. Spatial definition is a more complex category, as the space can be defined in many different ways. What these different definitions seem to have in common is the presence of distinct edges or landmarks that help structure the setting. Thus, scenes receiving favourable responses tend to be open and yet defined. A savannah-like open park is one example of this kind of environment (Kaplan & Kaplan, 1989; Herzog, 1992).

Ulrich (1986) argues that a high-preference natural landscape has both content-based and organisational qualities:

- The complexity is from moderate to high;
- The scene has a clear focal point, structure and form;
- There is a moderate to high level of depth in the scene and it is clearly defined;
- There is some factor deflecting the vista. There is also a sense of newly available information lying immediately beyond the observer's visual bounds;
- The ground texture is even and uniform and it is judged as favourable to movement;
- No visible signs of possible threats are present.

This leads to the prediction that low-preference scenes are either featureless and low in complexity or disordered and complex scenes with no focal point. Furthermore, although a deflected vista seems to be a conflicting factor between Ulrich's theory and Appleton's prospect-refuge theory, it should be pointed out that Appleton (1975) does not consider prospect only as an actual unobstructed field of view but also as a conceptual field of view. He too sees that the experience of serial prospects, or a deflected vista, can be the source of an exciting aesthetic experience.

The research indicates that there is both universality and variation in human preferences. One aspect of consistency, already discussed, is that people tend

to prefer natural vistas over urban ones (Kaplan & Kaplan, 1989). Verderber's preference studies (1986) show that in hospital environments, people prefer rooms with views of greenery, trees and people over urban vistas. The most disliked rooms were those with no view or a very deflected view. Neighbourhoods with vast grasslands without trees or shrubs have rather a low preference, whereas those areas with prominent trees tend to be especially favoured. Another aspect of consistency is that when a water feature is present, the preference is often especially high (Ulrich, 1986; Kaplan & Kaplan, 1989). Nasar (1998) found in his studies several elements that promote likeability in urban environments — naturalness, upkeep, openness and historical significance. Likeability is also often connected with order and social meaning.

Variations in people's preferences may be produced by many things. Familiarity is considered one of the major factors accounting differences in preference (Lyons, 1983). This familiarity may be produced by, for example, living surroundings, previous studies and the cultural norms of one's group. Living surroundings may account for variation when people have a direct experience with the environment in question, whereas the variation is not pronounced in the setting types in general — such as rural, urban and suburban categories. Previous studies demonstrate that people's level of expertise may affect the way in which they weigh the informational aspects of the environment. This may lead to significant differences in preference ratings between experts and laypeople. For example, a sense of mystery seems to account for substantial differences between these groups. For laypeople, the role of mystery is a much stronger predictor of preference than for the experts. In the area of cultural differences, the variation is often expressed through the actual preference (mean rating), whereas the relative preference seems to have a high degree of cross-cultural consistency. (Kaplan & Kaplan, 1989.)

2.3 Restoration as psychophysiological stress recovery

Restoration theories see stress as a process by which an individual responds to a potentially negative situation. Responses include psychological, behavioural and physiological components, such as appraisal of the situation, emotions, coping responses and avoidance responses as well as cardiovascular, skeletomuscular and neuroendocrine responses. Psychophysiological stress theory also sees attentional decline as a consequence of stress, whereas

attention restoration theory posits that insufficient attentional resources may be an antecedent of stress. (Kaplan, 1995; Ulrich et al., 1991.)

Restoring oneself from stress involves experiencing positive changes in psychological states, in levels of activity of the physiological systems and in behaviours or the ability to function. What is central is a shift towards a more positive emotional state and decreased levels of physiological arousal. Ulrich et al. (1991) postulate that the initial level of the way in which a person responds to nature is immediate and unconsciously triggered. A central contention in Ulrich's theory is the adaptive nature of responding. It motivates approach — avoidance behaviours that foster ongoing well-being and survival. These adaptive responses depend on the characteristics of the environment and the affective, cognitive and physiological state of the individual. For example, an encounter with a snake would result in a quick onset of such emotional reactions as fear, dislike and attention/interest, which in turn would initiate an adaptive physiological mobilisation and further avoidance behaviour. Only a minimum amount of cognitive activity would be required.

Ulrich further suggests that people have a biologically prepared readiness to acquire restorative responses very quickly with respect to natural settings and that they are not prepared in the same way to respond to urban settings (Ulrich et al., 1991). The existing research has also indicated that the benefit of nature contact is greatest for stressed individuals (Hartig, 1993; Morita et al., 2007; Ulrich, 1981, 1986; Ulrich et al., 1991).

Several studies provide support for an innate preference of savannah-like environments (Falk & Balling, 2010; Lohr & Pearson-Mims, 2006). However, these studies only examined aesthetic preference and not immediate affective responses. Some evidence for the rapid affective evaluation of natural and urban environments is provided in a study by Korpela et al. (2002). However, other researchers have questioned why it would have been beneficial for humans to evolve a capacity to respond affectively to greenery in general (Joye & van den Berg, 2011). It has thus been argued that conceptual arguments do not provide strong support for the evolutionary assumptions. Furthermore, the empirical evidence supporting the immediate affective responses is still very limited. However, Ulrich has also described other environmental qualities in addition to nature content that promote restoration, such as the patterns of scene configuration. Also, a study by Gatersleben & Andrews (2013) suggests that not all natural environments are restorative. They argue that only environments with high levels of prospect and low levels of refuge/concealment are restorative, thus combining aspects of restoration theories and prospect refuge theory. While the psychophysiological stress

recovery theory still leaves some unanswered questions, the empirical evidence gives support for the positive physiological and psychological changes experienced by people when they are in contact with nature. In 1979, Ulrich conducted a study comparing the anxiety-reducing effects of different views. He used slide simulations containing either urban or natural elements. The research results showed that nature views significantly improved the emotional states of stressed individuals and decreased their fear arousal, whereas urban scenes tended to diminish their emotional well-being. In a later study, Ulrich (1981) used both psychological and physiological measures and the subjects were unstressed individuals in normal arousal states. In this study, natural scenes increased a person's alpha amplitude, which is associated with lower levels of physiological arousal and wakeful relaxation. Also, the psychological results favoured scenes containing vegetation or water. Ulrich noted that nature scenes had a positive effect on a specific cluster of emotions, including sadness and fear arousal. However, the influence of natural and urban scenes was rather similar for feelings of dominance and stability. The positive physiological response to nature contents has been reported in several other studies that focused on certain physiological measurements, including blood glucose, salivary cortisol concentrations, hemoglobin concentrations and symphatetic and parasymphatetic nervous activity (Parsons et al., 1998; Ward-Thompson et al., 2012; Tsunetsugu et al., 2010; Ulrich et al., 1991). Furthermore, there is evidence that the natural environment has an effect on immunological functions (Li et al., 2007) and that patients with views having natural scene contents had shorter hospital stays than patients with views having urban scene contents (Ulrich, 1984).

However, Ulrich's health effect study (1984) focused on outdoor views and did not consider the possible health effects of daylight exposure. A later study by Joarder & Price (2012) indicates that both daylight intensity and the provision of an outdoor view affect the length of stay after coronary artery bypass graft surgery. Other factors that may be related to positive physiological responses when in contact with nature may include odorous compounds, tactile sensations and auditory stimulation (Tsunetsugu et al., 2010).

A meta-analysis by Bowler et al. (2010) did not find that urban and natural environments had a consistent effect on blood pressure and cortisol concentrations. One possible explanation for this may be because they were studying short-term effects during a walk or run. Thus, the environment may not have consistently added physiological benefits to the exercise context.

Other explanations may include the effect of ambient temperature on the physiological measurements (Tsunetsugu et al., 2010).

2.4 Attention restoration

The Kaplans developed the concept of restorative environments based on their research on the benefits of wilderness experiences and nearby nature in combination with previous environmental preference studies. According to the Kaplans' theory, restoration is needed in order to recover from mental fatigue. It is the worn out state we face after a prolonged overworked capacity for directed attention. It differs from stress in that it is not necessarily a result of events considered threatening or harmful. It may just as easily arise as a result of hard work done for an enjoyable project. In a state of mental fatigue, it is difficult to inhibit distraction and focus attention, which is why the state is also called directed attention fatigue. (Kaplan & Kaplan, 1989.)

The Kaplans (1989) identify two types of attention: involuntary attention and directed attention (voluntary attention). Involuntary attention refers to attention that requires no effort, like observing an exciting occurrence; it is activated automatically. In contrast, forcing oneself to pay attention, for example when proofreading a piece of writing, requires a level of attention that the Kaplans call directed attention. Directed attention is more reliant on cognitive control structures in the frontal and parietal brain regions than involuntary attention. Directed attention is also more controlled and goal directed, whereas involuntary attention is more automatic, autonomous and stimulus-driven. (Kaplan & Berman, 2010.)

Directed attention is essential for the effective performance of different tasks in modern society. Not being distracted is central when this type of attention is needed and considerable effort is devoted to maintaining inhibitory processes, which are often challenged by competing stimuli. This constant effort puts directed attention prone to fatigue. However, the fatigued directed attention may be recovered by stepping away from the distracters and demands on directed attention, making it possible for the inhibitory systems to rest and to mobilise involuntary attention that can sustain itself. (Kaplan & Kaplan, 1989; Kaplan & Berman, 2010.)

The Kaplans have suggested that fascination plays a central role in restoration (Kaplan, 1995; Kaplan & Kaplan, 1989). Involving involuntary attention fascination allows directed attention to rest and recover. Fascination may arise from processes like bird watching or from particular contents, such

as waterfalls. Fascination may also be experienced along a soft–hard scale. Walking in a forest is an example of soft fascination, whereas watching a rally race is at the hard end of the scale. For restorative purposes, the soft fascination is more useful because it offers an opportunity for reflection, thereby promoting the ability of a person to recover from directed attention fatigue (Herzog et al., 1997).

Besides fascination, being away, extent and compatibility are also considered central qualities in the restorative person–environment exchange. These components of ART tend to be perceived to a greater degree in natural environments in contrast to urban environments (Kaplan, 1995; Hartig et al., 1997). Thus, the restorative process is likely to benefit from the presence of a natural environment (Hartig, 1993; Kaplan & Kaplan, 1989).

The Kaplans' research programme on the benefits of wilderness experience lasted for ten years and served as a catalyst for ART. Their research method was based on a variety of open-ended and structured questions as well as other tasks. At first, the studies compared the experiences of the programme participants and control groups. However, after the initial two years they focused their research emphasis on the changes within the programme. The significance of nearby nature was studied by using resident interviews, questionnaires for employees and evaluations of photographs. The extensive work by the Kaplans, which lasted for two decades, convinced them of the remarkable power of the natural environment in the lives of people; they summarised their work in *The Experience of Nature – A Psychological perspective* (Kaplan & Kaplan, 1989).

Besides the Kaplans, other researchers have also examined the rationale for the idea that people can recover from a state of mental fatigue best when in contact with nature. In a study by Berto (2005), mentally fatigued participants viewed photographs of restorative environments, non-restorative environments or geometrical patterns. Only the restorative environment group improved their performance on the final attention test (SART). In another study, university dormitory residents with more natural views scored better on tests for directed attention (DSF, DSB, SDMT, NCPC, AFI) than residents with less natural views (Tennessen & Cimprich, 1995). However, the studies did not measure the illuminance levels, thus leaving open the possible illuminance effect on attention, as different window views may be connected with differing levels of illumination. In a study by van den Berg et al. (2003), participants first saw a frightening movie, and then were shown a video of a natural or urban environment. The results indicated that viewing natural environments elicited greater improvements in mood and marginally better concentration

(d2 Mental Concentration Test) than viewing built environments. In a study by Hartig et al. (2003), participants had varying restoration needs due to different pre-tasks. Their performance on an attentional test (NCPCT) improved slightly during a walk in nature, whereas it declined in an urban environment. Kuo (2001) compared the attentional functioning (DSB) and effectiveness in managing major life issues of 145 urban public housing residents randomly assigned to buildings with and without nearby nature. Mediation tests and tests for possible confounds indicated that a natural environment enhances residents' effectiveness by reducing their mental fatigue. Green outdoor settings have also been connected with reduced attention-deficit/hyperactivity disorder (ADHD) symptoms (Kuo & Taylor, 2004). Also, Ulrich (1981) has noted that views containing vegetation and water appear to sustain attention and interest more effectively than urban views.

Researchers have also suggested that fatigued persons may respond differently to environments due to their greater need for restoration. In a study by Hartig & Staats (2005), people who imagined themselves as being fatigued were less willing to walk in an urban environment than non-fatigued people. Their responses to forest environments did not differ significantly. This difference also occurred when the fatigued condition was caused by attending a long lecture. The decreased preference for urban environments by fatigued persons is also addressed in studies by Staats et al. (2003) and Hartig & Staats (2006). It has further been suggested (on the basis of cell residuals, not observed means) that the need for restoration makes a person's attitude about a forest walk more positive to the same degree that it makes their attitude about a city walk less positive (Hartig & Staats, 2006). Also, Ulrich (1986) has proposed that stressed individuals would benefit most from visual encounters with vegetation.

The Kaplans see that the explanation of attention restoration is evolutionary, too, as in the psychophysiological approach, but they have taken a more cognitive approach. In line with Appleton (1975), it is thought that if perception is to aid in an organism's survival, it is essential that the organism not only perceive what is safe but also prefer it (Kaplan & Kaplan, 1989, p. 41). Ulrich's model suggests that the initial response to environment is affective and that there is no need for extensive information processing. Another important difference between the theories is that Ulrich is more concerned with emotional and physiological responses than attentional deficits (Hartig et al., 1991).

Although the Kaplans point out that urban environments may also be restorative, the empirical research in the restoration research field may be criticised for treating urban and natural settings as global categories and for focusing on an urban-natural dichotomy. However, recent research has suggested that not all natural environments are restorative (Andrews & Gatersleben, 2010) and that the restorativeness of urban spaces varies as well (Lindal & Hartig, 2013).

ART has also been criticised for not providing a fine-grained explanation of why restorative responses to nature ultimately occur (Joye & van den Berg, 2011). Thus, an explanation based on the idea of fluent processing has also been proposed. It has been suggested that both attention restoration and stress recovery are by-products of fluent processing and that the fractal structure of natural environments promotes fluent processing.

2.4.1 Restorative experience

Besides the emotional and physiological changes, attention restoration is also an experience containing a particular type of content. The wilderness research done by the Kaplans was a key contributor to the concept of restorative experience. The experiences of wholeness and self-discovery were central for the participants. The participants also mentioned that they lived differently and felt differently during their immersion in a natural setting. Thus, the wilderness research made the Kaplans aware of the benefits of nature and some of the qualities of becoming restored. When reflecting on the outdoor challenge programme findings as well as the nearby nature research, the Kaplans identified four central components of a restorative experience: being away, extent, fascination and compatibility. (Kaplan & Kaplan, 1989.)

Being Away

> The concept of being away can have many meanings. It can mean physical escape from a stressful environment, putting aside ordinary work or mental escape. In general, it means withdrawing from worries and demands. (Kaplan & Kaplan, 1989.)

Extent

The concept of extent is defined by connectedness and scope. It is characterised by the interrelatedness of the immediately perceived elements. The environment has extent and it gives a feeling of being in a 'whole other world'. It is possible to enter this world and be surrounded by it. The extent can be either directly perceived or an imagined feeling of the world continuing beyond what is perceived. It is also possible to explore the environment without getting lost or confused. Thus, extent is accentuated by the qualities of coherence and the legibility of the preference matrix (Kaplan & Kaplan, 1989; Lindal & Hartig, 2013). Extent may also be conceptual, e.g. historical elements can promote a sense of being connected to past eras and environments (Kaplan, 1995).

Fascination

Fascination is caused by a stimulus that draws involuntary attention. It attracts people and allows them to function without directed attention, and is therefore an important part of the restorative experience.

Fascination can be driven by either contents or processes. There have not been many studies on what kinds of contents have this restoration property, but the possibilities might include, for example, sunsets, waterfalls and fire. The act of perceiving in and of itself, like bird watching, may be a type of process fascination. The process fascinations should, however, occur within a larger and understandable framework. Otherwise, they will only serve as mere diversions or distractions. (Kaplan, 1995; Kaplan & Kaplan, 1989.)

Compatibility

When human inclinations and activities match the demands imposed by the environment, a feeling of compatibility arises. The environment should also support the intended activities. Many people seem to experience nature as being highly compatible with their needs. It communicates a sense of reality and offers various meaningful patterns

> within which to act. Compatibility can lead to a sense of connectedness. This sense can have religious and meditative features. Compatibility is an extension of the person-environment congruence and fit concepts. (Hartig et al., 1996; Kaplan & Kaplan, 1989.)

ART proposes that all four of these components must characterise the environmental experience in order for the environment to be restorative. However, not all components need to be present in equal proportions. The theory also gives more emphasis to fascination since it mobilises indirect attention, making it possible for directed attention to rest. (Kaplan & Kaplan, 1989.)

Kaplan & Kaplan (1989) argue that there are several levels to restorative experience. At the first level, the head seems clearer. This is followed by the recovery of directed attention when it becomes easier to concentrate. On the third level, cognitive quiet and order become more prevalent. The last level appears in line with a deeply restorative experience. It includes engaging in a process of self-reflection on one's life, priorities, actions and goals and the general meaning of life. An increase in positive feelings and a decrease in negative feelings is central to the psychological component of restoration.

A study by Herzog et al. (1997) gives some support for the assumption that reflection and attention recovery are distinct benefits of restorative experiences. They found sports/entertainment settings to be higher in restorative effectiveness for attentional recovery than for reflection, whereas natural environments have the highest overall restorative effectiveness. They found that urban settings have the lowest restorative effectiveness.

The Kaplans' theory about the four components of restorative experience has received some empirical support. A factor analysis study by Laumann et al. (2001) suggested a five-factor solution, so that being away was split into two factors: novelty (being physically away) and escape (being mentally away). However, novelty was not correlated with other factors, thus suggesting that being physically away may not be a restorative component at all. Other factors were moderately positively correlated. The results also implied that fascination and compatibility are connected with preference, whereas being away and compatibility are connected with relaxation. In another study, Hartig et al. (1997) suggested a two-factor solution so that being away, fascination and compatibility were all loaded with one factor and coherence with another. In both studies, the factors were sensitive to the nature–urban differences between settings.

2.4.2 Measurement of theoretical constructs

Self-reported measures were the first psychological measures used. They include various measure forms from diary-like free reporting to more structured questionnaires. The mood state of individuals has been measured using scales like POMS (abbreviated profile of mood state) (e.g. van den Berg et al., 2003; Tennessen & Cimprich, 1995) and ZIPERS (Zuckerman's Inventory of Personal Reactions) (e.g. Hartig et al., 2003; Ulrich, 1979). Self-esteem has been measured using the Rosenberg Scale of Self Esteem (e.g. Kaplan, 1974) and a subjective rating of attentional functioning has been done using the Attentional Function Index (AFI) (Tennessen & Cimprich, 1995).

The recovery of attentional fatigue has been tested using performance tests such as the Necker Cuba Pattern Control Test (NCPCT) and Search Memory Test (SMT); of the two, the NCPCT has shown a better degree of sensitivity (Berto, 2005; Hartig et al., 1996; Tennessen & Cimprich, 1995). Also, the Sustained Attention to Response Test (SART) (Berto, 2005), Symbol Digit Modalities Test (Tennessen & Cimprich, 1995) and Digit Span Backwards test (DSB) (Kuo, 2001) have been used.

To use restoration theory both for psychological research and environmental design purposes, easy measurement tools are necessary. Such measurement tools are often essential when seeking willing research participants to fill in questionnaires. The Perceived Restorativeness Scale (PRS) was the first psychometric restoration measurement tool used for this purpose (Appendix 3). It measures attitudes concerning the four factors central to environmental restoration: fascination, extent, compatibility and being away. The questionnaire includes various statements concerning these characteristics, which the subject responds to using a semantic differential scale (Hartig et al., 1996, 1997; Laumann et al., 2001).

The PRS has been sensitive to the theoretical constructs when used in various settings with different respondents and converging measures, which indicates that it is a valid and reliable measure (Berto, 2005, 2007; Chang et al., 2008; Hartig et al., 1991, 1997; Laumann et al., 2001). Hartig et al. (1997) has described the ways to validate the PRS tool in a journal article entitled 'A measure of restorative quality in environments'.

There are also several studies connecting perceived potential to being restored and attentional, physiological and mood changes. In a study by Hartig et al. (1991), higher PRS scores related to natural environments were positively correlated with the proofreading scores referring to better attentional capabilities. The nature group also had higher ratings for overall happiness

and higher ZIPERS positive affect scores than the group responding to urban and relaxation conditions. However, there were no significant differences between the groups in terms of physiological measures (blood pressure and heart rate). Hartig et al. suggested that this was due to the fact that no ambulatory monitoring was done during the treatment and that the physiological measurements took place 50 minutes after participants had completed the tasks. An earlier study by Ulrich & Simons (1986) indicates that a return to baseline level may occur within ten minutes, thus providing support for this assumption. Chang et al. (2008) used ambulatory measures and connected PRS with physiological changes so that improved PRS scores were connected with lower blood pulse volume (BPV) measurements and increased electromyography (EMG) and electroencephalography (EEG) readings. Berto (2005) used a short version of the PRS to rate the restorative value of each scene. Mentally fatigued participants viewed photographs of restorative environments, non-restorative environments or geometrical patterns. Only participants exposed to restorative environments improved their performance on the final attention test (SART). In another study by Hartig et al. (1997), the PRS tool was sensitive to the setting category so that natural environments scored better than urban environments. The PRS was also positively correlated with a positive affect and negatively correlated with anger/aggression.

In conclusion, the Perceived Restorativeness Scale (PRS) has been used together with the measurement tools for attentional capabilities, mood and physiological changes. Both on-site measurements and simulations have been adapted. Some studies provide absolute values (pre-test vs. post-test), whereas most of the studies provide only relative (post-test) values. The results have provided evidence about the connection between the perceived potential to be restored and attentional, physiological and mood changes.

The Restoration outcome scale (ROS) is a newer tool. Hartig et al. first presented it in 1998. Later, it has been used in studies by Staats et al. (2003) and Korpela et al. (2008). It seeks to measure the particular changes related to restoration: relaxation, attentional recovery and reflection. The ROS tool uses a semantic differential scale like PRS. It has shown sensitivity to the urban-natural setting category division. However, more research using converging restoration outcome measures is still needed.

2.5 Studies of light at night

Studies on the night-time environment and lighting have focused on three main fields. The first field deals with the question of the direct *physiological effects* of light. The second one is concerned with the perceptual aspects focusing on the *visual performance* in night-time environments. The last research field has a more affective approach. It examines lighting in relation to a *fear of crime*.

The effect of light on circadian rhythms was discovered in the 1980s (Czeisler et al., 1981), and at the beginning of the new millennium a new retinal photoreceptor, which is responsible for non-imaging vision functions like circadian regulation, was discovered (Berson et al., 2002; Thapan et al., 2001). Since then, there has been a growing concern with the effects of light exposure during night-time (Navara & Nelson, 2007). As the day-night pattern of natural light is now modified by artificial light, people's circadian rhythms may become disrupted. This disruption may affect health — such as contributing to tumour growth (e.g. Blask et al., 2005), cardiac disease (e.g. Penev et al., 1998) and metabolic syndrome (e.g. Turek et al., 2005). Nocturnal light also harms other animals (Longcore & Rich, 2004). Thus, it may be that as our knowledge of the physiological effects of light increases, it will also be taken into account in lighting recommendations and standards (Rea et al., 2002).

During the last few years, a great deal of research has focused on the eye's spectral sensitivity at low light levels (e.g. Goodman et al., 2007; Viikari et al., 2008; Eloholma, 2005). It has been documented that as we move from a high luminance daylight condition (photopic vision) to a low luminance lighting environment, such as an urban nightscape (mesopic vision), the eye becomes more sensitive to shorter wavelengths of light. It has been suggested that using light sources that produce radiation matching the mesopic spectral sensitivity curve, which peaks at between 507 and 555 nm, would produce good visual conditions with lower energy consumption (CIE 191:2010). However, since the human circadian system is sensitive to bluish light (peak sensitivity around 460-490 nm), the effects of our light use need further research (Berson et al., 2002; Takahashi et al., 1984; Lockley et al., 2003).

2.5.1 Affective responses to urban lightscapes

Fear of crime

The use of lighting to promote safety has a long history. In the sixteenth century, homeowners in big cities were ordered to keep the lanterns burning outside on dark nights in order to impose structure and order on the city at night. Besides houses, all residents going out at dark also had to identify themselves by carrying a light. Anyone failing to do so was regarded as suspect and could immediately be arrested. In the seventeenth century, this private 'navigation' lighting turned into a public service in Paris and lights were hung over the middle of the street, representing the absolutist state. Later, in the 18th century, public street lighting was also introduced in London to increase safety and reduce crime. Street robberies were so frequent in industrialising cities like London and Paris that if possible, people avoided going out after sunset. (Brantingham & Brantingham, 1993; Schivelbusch, 1988.)

By converting darkness into dusk, gas lanterns enabled a new level of control over the lived environment (Mcquire, 2005). Although providing technological improvements, gas lighting still retained the lively quality of an open flame, whereas people felt that electric light was rigid, cold and distant when it first came onto the scene (Schivelbusch, 1988). In addition to the quality of light, the quantity of light also changed. Since the emergence of electric lighting, light use has increased rapidly, and at the beginning of new millennium it is difficult to find complete darkness in urban areas. Despite the sea of light, the fear of crime is still present in urban environments. In particular, women and older people feel more vulnerable and avoid going out after dark (Banister & Bowling, 2004; Keane, 1998). They may avoid certain places that they believe entail a high risk of social danger or isolated places with low social control. This avoidance reaction is also present during dusky Nordic nights, highlighting the importance of the idea of 'social night', not just of physical darkness (Koskela & Pain, 2000).

There are contradictory views on the effect lighting has on actual crimes (Atkins et al., 1991; Boyce, 2003; Cozens et al., 2005; Nair et al., 1993; Pease, 1999). However, a recent meta-analysis by Welsh & Farrington (2008) concludes that lighting significantly reduces crimes. The crime reduction effect has mainly been explained on the basis of two theories (Welsh & Farrington, 2008). One suggests that improved lighting increases surveillance and deterrence, whereas the other focuses on the role of lighting improvements in increasing community pride and informal social control. The Welsh &

Farrington meta-analysis (2008) indicates that the night-time crimes did not decrease any more than daytime crimes. Thus, a theory focusing on community pride and informal social control was regarded as more plausible than a theory focusing on increased surveillance and deterrence. Also, Pease (1999) has assessed the effect of lighting on crime during daytime hours. However, although the effect of lighting on crime may be regarded as commonplace, it is also conditional. An untargeted general increase is presented to be less effective than a targeted increase (Pease, 1999).

It has also been pointed out that lighting may promote criminal activity by increasing social activity outside home, thus bringing a greater number of potential victims and offenders into the same environment. Lighting also makes it possible to observe suitable targets and people that may intervene in crimes (Pease, 1999; Welsh & Farrington, 2008). Furthermore, most of crimes, including those that take place at night, are committed in well-lit areas with plenty of people — such as areas that are close to stations and restaurants. Also, very few criminals say that they look for dark or poorly lit areas — only 1% of car thieves and 4% of robbers look for such areas (Herbert & Davidson, 1994).

It is also expected that lighting positively affects a fear of crime (Blöbaum & Hunecke, 2005; Herbert & Davidson, 1994; Johansson et al., 2011; Loewen et al., 1993; Nair et al., 1997; Pease, 1999). Even still, there are studies showing that lighting only has minor effects (Atkins et al., 1991) or no effects (Nair et al,. 1993) on fear of crime. The factors that might help explain the inconsistency include variations in the preliminary lighting conditions, the follow-up times, the characteristics of the residents, halo effects and the complex nature of reactions that cannot be reached by practical interventions with only a limited amount of control (Farrington & Welsh, 2002).

It is unfortunate both for research purposes and in terms of practical applications that many lighting intervention studies do not fully characterise the lighting in place. Herbert & Davidson (1994) study described a lamp and luminaire changes transforming the colour appearance and evenness of the area in question. However, they do not provide any photometric values.They only state that the new lighting has illumination levels based on the category 3.2 in the BS 5489, but do not provide any values as further explanation. Also, they do not provide the illuminance values prior to the intervention. A study by Atkins et al. (1991) does not characterise the lighting intervention at all. Also, studies by Nair et al. (1993), Loewen et al. (1993) and Blöbaum & Hunecke (2005) do not describe the lighting characteristics. Furthermore, also other environmental improvements were carried out at the time of the data

collection of the Nair et al. (1993) study. The study by Johansson et al. (2011) is one of the few studies that provides a reference point for the lighting conditions: lamp type, colour temperature, luminous intensity distribution and horizontal and cylindrical illuminances. However, they do not give the luminance values that serve as a good reference point for the brightness perceptions.

There are certain environmental features that have been connected to a fear of crime — social and physical incivilities, territorial functioning and certain spatial features (Perkins et al., 1992; Brantingham & Brantingham, 1993); Newman's concept of defensible space provides a neighbourhood-level approach to the spatial features, whereas Appleton's prospect-refuge theory provides a more individual approach. Environmental features serve as cues to the local residents and passers-by and signal that the area is potentially dangerous (Perkins et al. 1992).

Signs of social incivilities include such problems as public drunkenness, drug dealing and loitering youths. Physical incivilities are signalled by, for example, graffiti, litter and broken windows. Broken or malfunctioning luminaries harm the visual control of the environment, but for the residents they are also signs of physical disorder and indifference. As these incivilities proliferate, people perceive more problems in the locale and their confidence in their neighbourhood and officials weakens. Fearful residents and weak social control emboldens offenders and attracts criminals from adjoining areas, creating a self-reinforcing downward spiral. (Perkins et al., 1992.)

Territorial functioning may increase people's perceived sense of safety and diminish the factors causing insecurity. Territorial functioning includes environmental maintenance, adding aesthetical features and using symbols to increase the feeling of safety. In a practical sense, territorial functioning is manifested through such things as decorations, plantings and signs. This functioning enhances a sense of having the possibility to affect one's living environment. It may also enhance the territorial bond of the people within the neighbourhood and lead to a positive self- reinforcing cycle (Perkins et al., 1992). An aesthetically pleasing environment may thus strengthen the positive image of a safe environment (Herzog & Chernick, 2000). It has been suggested that certain spatial features that form a 'defensible space' affect crime and the fear of crime (Perkins et al., 1992). It is argued that when the residents have a sense of territorialism, they will become key agents in ensuring safety. Furthermore, the feeling of control over the neighbourhood and the feeling of responsibility for the neighbourhood may be affected through certain design features. The defensible space concept aims to

encourage territoriality, natural surveillance and the feeling of security produced by the physical environment. The design actions include enabling social control by, for example, the orientation of the buildings, better lighting or reducing obstructions so that no protection is provided for the offenders.

The defensible space concept sees that a clear distinction between the public and private domain within a neighbourhood structure is important. This distinction may be created by using real barriers like gates or symbolic barriers like gardens. Also, lighting may support the way in which the built structure is classified. Furthermore, lighting promotes the visual control of the environment by enabling the performance of visual tasks, such as facial recognition, and by expanding the field of vision. Better visual control contributes to natural surveillance, which may further lead to a decreased fear of crime. However, the concept of defensible space may also be criticised for assuming that an offender is an unknown outsider. An offender may just as easily be a local resident.

Appleton's prospect-refuge theory has also inspired fear of crime research. However, besides the prospect and refuge factors presented by Appleton, fear of crime studies tend to also emphasise escape opportunities (Fisher & Nasar, 1992; Nasar et al., 1993). Appleton (1975) considered the darkness of night as an ultimate refuge. However, humans are not able to perform efficiently in darkness. Therefore, it serves as a refuge only when there is no need to move. Due to limited visual performance, darkness is also a poor escape for humans. Thus, environmental research that focuses on the fear of crime in urban nightscapes views darkness in general as an assailant's refuge, since assailants can conceal themselves in the darkness and wait for appropriate targets (Blöbaum & Hunecke, 2005; Haans & de Kort, 2012; Nasar et al., 1993). Nasar et al. (1993) have labelled this assailant's refuge as concealment. They have found that a high level of concealment, a limited prospect and a blocked escape route are connected with a fear of crime.

In reality, crimes against persons only rarely include the amount of planning and patience required for waiting for an appropriate target in the darkness. In Finland, men are subjected to physical abuse in restaurants, on streets or at work while women are subject to physical abuse at work or at home (Siren & Honkatukia, 2005). Thus, the fear of crime does not correlate with the actual risks. This mismatch has been explained by the tendency to distance the violence from oneself: an offender is unknown and assaults happen outside the home. This has also been explained by the fact that the general public discourse and media overemphasise the risk of assaults in public spaces (Pain, 2000; Siren & Honkatukia, 2005). Furthermore, if Appleton's assumption that

safety perceptions have evolutionary origins is correct, then the avoided threats were biologically relevant threats during human evolution. This would suggest that perception still involves looking for cues about, for example, predators hunting at night. However, this does not exclude the fact that more cognitively-based sources of fear could also evoke fear as well.

Lighting provides visual access (prospect) for pedestrians and enables them to observe escape opportunities. Haans and de Kort (2012) indicate that pedestrians especially appreciate near-field prospects and escape opportunities. In their study, prospect, escape and concealment (assailant's refuge) were manipulated through the way in which lighting was distributed. The study demonstrated that in terms of feeling safe, pedestrians value more lighting in their immediate surroundings than further away in the street, thus indicating that an extensive 360 degree prospect in the near field is more important than a far field but very narrow prospect.

However, although prospect is fundamental to feeling safe, there is also research evidence suggesting that some spatial limitation is needed for a feeling of safety during daytime (e.g. Jorgensen et al., 2002) and that the perception of enclosure created by lighting may be connected with feelings of safety (Wännström Lindh, 2012). Therefore, people may feel that a large, open, illuminated space is unsafe even though it provides a large prospect. Kaplans (1989) and Ulrich (1986) suggest that this kind of an open space would also be less liked than more defined and closed space. Thus, more research is needed on the near/far field prospect and escape and feelings of safety.

When standing in a pool of light that provides a prospect, a pedestrian can also be seen by a potential assailant. The pool of light also limits both the prospect and the escape possibilities if there are strong and sharp luminance differences. Appleton's theory would thus suggest that pedestrians would like to be located within a dimmer spot (not seen) in the illuminated environment (being able to see). This is the ideal refuge provided by daytime environments, which is quite hard to achieve in urban nightscapes. However, new light sources with intelligent lighting control would facilitate some aspects of this kind of environment. The study by Haans and de Kort (2012) indicated that people prefer to walk in a spotlight rather than to walk in a dark spot. Thus, the study gives some indications that 'not being seen' is not very important for feeling safety during night-time.

Thus, humans do not seem to have a strong need to hide themselves at night; rather, they want to expose themselves by gathering around a fire or other sources of light. The relationship between humans and fire seems to be very distinctive in comparison to other mammals; whereas other mammals are

often terrified by fire, humans seem to be fascinated by it. The control of fire was likely a major turning point in human evolution. Besides the various other benefits of fire, it also provided protection from predators (Price, 1995). Thus, being close to fire may have been a biologically relevant survival strategy for humans. As the control of fire may date back to at least the time of Homo erectus, the human attraction to light during dark hours may also have origins other than the ability to perform visual tasks. It may also reflect the sense of being protected against the beasts of the night: the power of fire.

Since the actual lighting interventions have included changes in various lighting attributes and failed to fully characterise the lighting, it is difficult to say which factors in the lighting environment decrease the fear of crime. In terms of photometry, luminance, and thereby illuminance, is considered central. Horizontal illuminance is considered to describe how well lighting facilitates surveillance in general, whereas semi-cylindrical and vertical illuminances describe more the possibilities that lighting provides for facial recognition. It has further been suggested that illuminance uniformity, glare and spectral power distribution may also affect fear of crime. (Boyce, 2003.)

The importance of illuminance in determining people's perceptions of safety at night is supported by Boyce et al. (2000). They suggest that the relationship between perceived safety and illuminance is not linear; rather, it weakens after a certain level of illuminance is reached. Furthermore, their study indicates that women require higher illuminance levels before they feel that the illuminated environment has a good amount of security lighting. They also note that lower illuminance is needed in suburban areas than in urban areas for people to feel that the illuminated environment has a good amount of security lighting. If the risk of social threat is higher, then more light is appreciated. The surrounding luminance levels are higher in urban areas, which affect people's perceptions of the lighting in the neighbouring areas as well. However, the urban-natural context may also affect brightness perceptions. Tsunetsugu et al. (2010), citing the findings of Takayama et al., claim that during the daytime participants felt that the forested area was as bright as the urban area, even though the illuminance in the forest was only 1/22 that in the city. Unfortunately, the original paper by Takayama et al. is in Japanese, hindering closer evaluation of the research results.

Also, Stamps has found in his studies that safety is strongly correlated with the lightness of the scene (Stamps, 2005a) and that the impression of safety is more strongly influenced by locomotive than by visual permeability, highlighting the importance of escape possibilities (Stamps, 2005b). Blöbaum and Hunecke (2005) reached similar conclusions. Lighting, prospect,

opportunities to escape and a person's gender were all relevant factors affecting perceived danger in an area. However, the opportunity to escape seemed to be the strongest factor. Increasing the illuminance levels may also have negative effects. More intense lighting may increase fear if it makes the unpleasant things more visible (Herbert & Davidson, 1994). It is also possible that lighting may create a feeling of being watched by an assailant lurking in the darkness (Nair et al., 1993). This feeling may be created by a 'barrier of light' formed either by glare or by strong luminance differences, thereby making it difficult to control the environment visually. The spectral power distribution may also affect people's perceptions of safety (Boyce, 2003). There is evidence that spectral power distribution has an effect on brightness perceptions (Fotios & Cheal, 2007, 2011; Rea et al., 2011) and that people's perceptions of greater levels of brightness may well have an effect on their fear of crime, as stated earlier. This suggestion is also supported by Fotios et al. (2005). Likewise, the research conducted by Rea et al. (2009) indicates that people feel that the lighting provided by metal halide lamps (with fairly good CIE CRI and a higher colour temperature) is brighter and safer than the lighting provided by high-pressure sodium lamps (with moderate CIE CRI and a relatively low colour temperature). In terms of its acceptability for social interaction, facial recognition and many aspects of eyewitness identification, there were no clear differences between the types of lighting. However, a study conducted by Knight (2010) suggested that spectral composition also affects perceptions of comfort.

Previous studies have mainly compared metal halide and high-pressure sodium light sources. Therefore, it is difficult to clarify how well the results can be generalised to other light sources and the extent to which researchers should distinguish between the effects of colour-rendering properties and the effects of colour temperature. If spectral power distribution affects perceived safety due to mesopic vision, adapting the mesopic photometry would restrain the effect. However, it is also possible that the spectral power distribution affects people's perceived safety when it is mediated by some factor other than brightness perception. Possible candidates could include mood (Knez, 2001) or pleasantness (Johansson et al., 2011), or a combination of different factors.

The evidence supporting the importance of glare and illuminance uniformity in relation to people's perceptions of safety is less notable (Boyce, 2003); in fact, the evidence is even controversial, since the results of one study indicate that people feel that a non-uniform, high-contrast lighting environment is safer than a uniform and low-contrast lighting environment (Wänström Lindh, 2012). However, the way in which the lighting design is applied may explain

the contradictory results. Wänström Lindh (2012) used lighting design techniques that emphasised the physical structures of aesthetically appealing spaces, whereas non-uniform lighting that contradicts the physical structures may create a confusing spatial experience. It is also possible that the level of luminance uniformity affects people's perceptions of brightness so that they feel that spaces with non-uniform luminance distributions are brighter (Tiller & Veitch, 1995).

Preference

Lighting in relation to mood and behaviour has mostly been studied in indoor environments. These studies have suggested that people tend to like bright and non-uniform lighting that emphasises vertical surfaces (Boubekri et al., 1991; Flynn et al., 1973; Hendrick et al., 1977). However, it is possible that lighting preferences vary according to the time of day and context. Therefore, interior studies conducted during daytime may not adequately describe the night-time outdoor lighting preferences.

There is hardly any research concerning people's aesthetic or affective response to outdoor lighting conditions. Hanyu conducted one such study in 1997. He studied people's affective responses to different visual properties at night in several residential neighbourhoods. Surprising similarities were reported for the daytime and night-time evaluative images. Even though the night-time environments usually got lower scores, the order remained similar. In both night-time and daytime environments, an increase in naturalness, openness and visibility enhanced the perceived pleasantness and safety of the environment. When vehicles were present, the relationship was negative. Furthermore, the results indicate that safe/active appraisals are positively correlated with bright and uniform lighting, whereas arousal is negatively connected with people's appraisals of uniform lighting. The results seem to contradict with the results for daytime environments. However, in non-uniform interior lighting conditions, there is still plenty of light in the darker spots too, whereas non-uniform lighting at night-time offers a visually incoherent environment. This kind of non-uniformity would probably also be unacceptable in most interiors. It may also be that visual clarity is more appreciated at night-time, when people tend to feel more vulnerable. Yet another important point of view is that the non-uniformity of Hanyu's study was not designed to include, but rather contradicted, the physical structure of

the environment, whereas emphasising the spatial construction of the environment by focusing on lighting distribution may enhance people's feelings of safety (Wännström Lindh, 2012).

In a study by Boyce et al. (2000), good lighting at night was connected with the perceptions of lighting as being bright, even, comfortable, extensive in area and well-matched to the site. However, the participants were unfamiliar with the areas and the questionnaire focused on safety perceptions and visual conditions. Thus, instead of general lighting preferences, the results may in fact emphasise the relationship between lighting and perceived safety.

2.6 Conclusions of the literature review

There is mounting evidence that natural environments have restorative effects. A meta-analysis by Velarde et al. (2007) provides an overview of 31 studies on the positive health effects of viewing landscapes. They understood health as individual and social health and well-being. The health effects were mainly explained by referring to psychophysiological stress recovery theory or attention restoration theory. Most of the research efforts have concluded that natural landscapes have more positive health effects than urban ones. The main health effects included short-term recovery from stress or mental fatigue, faster physical recovery from illness and long-term overall improvement in people's health and well-being. Most of the studies examined the nature versus urban setting category and the lack of mixed environments represents a fundamental knowledge gap. Therefore, the restorative qualities of mixed environments deserve further attention. Furthermore, restoration research has focused on daytime environments. Other contexts also deserve research attention. It would be beneficial to consider soundscapes, smells and tactile sensations, as suggested by Tsunetsugu et al. (2010) in their paper. So far, restoration research has focused on visual exposure. However, there is evidence indicating that the sounds of nature, as compared with environmental noise, facilitate recovery from sympathetic activation (Alvarsson et al., 2010), thus emphasising the importance of other factors besides visual images. Finally, further development of restoration theories is still needed.

The review of urban lightscape studies revealed a fundamental knowledge gap in the research field. Most of the studies have concentrated on fear in urban streets, whereas other factors and contexts have received only minor

attention. Furthermore, most of the studies on fear have documented the lighting conditions fairly weakly, thus giving only faint indications of the lighting attributes that might affect fear. The research indicates that lighting may have a positive effect on fear of crime via two main mechanisms: first, by improving visual performance, which affects both prospect and deterrence. Second, an aesthetical and well-kept lighting environment may enhance community pride and send a positive cue of a safe environment. In general, it is assumed that the perception of greater brightness has a positive effect on fear of crime. However, this connection may not be linear (Boyce et al., 2000). Spectral power distribution, uniformity and glare may also affect fear of crime, although the evidence supporting the importance of these factors is weaker.

In conclusion, there is a demand for night-time visual appraisal studies that do not focus just on fear of crime. Furthermore, there appears to be no research describing people's lighting expectations in relation to different contexts. As new LED technology makes it easier to adjust lighting to suit different human needs, more research on, for example, spectral distribution and brightness preferences in different outdoor lighting environments is needed.

3 Lighting, perceived restorativeness, fear, preference and pleasantness in nightscapes

3.1 General Introduction

Public lighting should promote opportunities for restoration during the hours of darkness, enabling people to distance themselves from their everyday worries and regain their attentional capabilities. A pleasant environment that encourages walking and cycling would also promote general well-being.

The following studies explore the restorative potential of outdoor lighting and the connections between lighting perceptions and perceptions of fear and preference. Despite the decisive impact of lighting on night-time environmental image, only a small amount of research has focused on the effect of lighting on people's positive experiences and on the significance of near-home lighting environments. The judgements of local residents and outsiders differ substantially; local residents put more weight on, for example, social factors (Zube et al., 1985). Thus, people's lighting expectations for familiar, everyday environments may differ substantially from their expectations for unfamiliar environments. In unfamiliar environments, the need to observe the environment thoroughly may be more pronounced, whereas the need for relaxation and feelings of pleasure may be more prominent in near-home environments.

Although ART does not discuss directly the restorative potential of light, it sees light as a potential source of fascination. The Kaplans (1989) suggest that light may evoke both content and process (mystery) based fascination. They suggest that a classical example of a scene high in mystery includes a winding pathway and a brightly lit area that is partially obscured by foreground vegetation. An example of a content-based fascination is a sunset. There is also evidence pointing that colour, especially red-green, and luminance contrasts attract attention (Frey et al., 2011; Koch & Ullman, 1985; Parkhurst et al., 2002). It could further be suggested that light reflected from the surface of water or light scattered through the leaves of trees would promote a perceived restorative quality, since both types of light have a fascinating 'play of brilliance' quality and connote the presence of nature: prominent trees and water.

Besides being a direct source of fascination, light may also promote the use of involuntary attention via the way it augments people's perceptions of the environment. Lighting may promote the restorative features of the environment and diminish the role of less restorative features. Lighting may also enhance or hamper the appearance of colour; for example, saturated and vivid greenery may well affect perceptions of restorativeness. It could also be suggested that disruptive lighting, like glare, may harm the restoration process.

This thesis explores how the perception of different outdoor lighting attributes is connected with the perceived restorative potential of a particular environment. It is based on the theoretical foundation of ART while also utilising research efforts within the fields of lighting technology and environmental psychology. Besides the restorative potential, fear and preference variables are also examined.

3.2 Study 1: Restorative lighting environments - Does the focus of light have an effect on perceived restorativeness?

3.2.1 Introduction

The daytime image of city space is reshaped by lighting during the dark periods. Artificial light constructs the space by revealing some features and hiding others. Thus, lighting is able to emphasise certain features in the environment while diminishing others. As a restorative experience, restoration and perceived restorativeness are based on the visual exposure of environments (e.g. Berto, 2007; Hartig et al., 1996; Hartig & Staats, 2006; Parsons et al., 1998; Ulrich, 1981); lighting may play a considerable role in perceived restorativeness.

Illuminated nightscapes are often dominated by street lighting and advertising, reflecting the forces of traffic and commerce in modern society. However, roads, car parks and commercial signs are also the most disliked scene contents during daytime (e.g. Nasar, 1998). When the light emphasises negative scene contents, does it have an effect on human perceptions of nightscapes? In this study, it is hypothesised that focus of light has a considerable effect on the perception of the restorative potential of lighting in such a way that focusing light on natural elements results in higher restorative

potential ratings than focusing light on urban elements (see hypothesis 1 in Section 1.2). Because restoration may, although not necessarily, be connected to antecedent stress experiences according to ART, the preceding conditions of stress and fatigue were also measured.

3.2.2 Methods

Three scenes were modelled using the Lightscape computer programme. All three scenes were illuminated through simulations in two different ways: one focused light on parking lots and roads and the other on vegetation. According to the hypothesis, this should have an effect on perceived restorativeness in such a way that people would rate the focus of light on the vegetation category more highly. The setting categories are presented in Table 2.

Setting category	**scene pair 1**	**scene pair 2**	**scene pair 3**
Focus on vegetation: higher perceived restorativeness	picture 5	picture 4	picture 2
Focus on roads & parking lots: lower perceived restorativeness	picture 3	picture 1	picture 6

Table 2. Setting categories.

The scenes were presented to the participants using Power Point slides (see Appendix 2), which provided eye-level (1.5 m) views of the settings. The slides were shown roughly at a rate of one every 3 minutes, during which time the participants filled in the questionnaires concerning each slide. All of the participants evaluated each of the scenes in an unrestrained manner. The projection was from the front of the screen. In addition to the projection light, some task light, both natural and artificial, was also provided so that the participants were able to fill in the test forms. Counterbalancing was done by presenting the slides to 20 subjects in reverse order. The slide order was generated so that the scene pairs would not follow one another.

Lighting

Metal halide spotlights (BEGA 8393, wide (optics), 70 W, 23 300 cd) from the Lightscape library were used to illuminate the scenes. All of the luminaires in the scene pairs were at the same height. The luminaries were moved horizontally to illuminate different elements of the scene. The illuminated area between the picture pairs was roughly matched and the extent to which their perceived levels of brightness were equal was also checked (Appendix 1). There were significant perceived brightness differences between pictures 3 and 5.

Participants

There were 35 participants (19 male and 16 female) who evaluated all of the scenes. Their age varied from 20 to 58 years. The mean age was 29 years (20-29 years, 26 participants; 30-39 years, 3 participants; 40-49 years, 2 participants; 50-59 years, 4 participants). The participants were unaware of the purpose of the study and participated in the experiment voluntarily.

Measures

Perceived restorativeness measures were obtained using the Perceived Restorativeness Scale (PRS) instrument, which is based on attention restoration theory (Appendix 3). According to attention restoration theory, the PRS scores for being away, fascination, extent/coherence and compatibility reflect the potential to be restored. PRS was used as it is validated measure and has been used before. After the PRS instrument, the Restoration Outcome Scale (ROS) was used, the results of which are not reported here.

The respondents indicated on a seven-point scale (0 = 'Not at all', 6 = Completely) the extent to which the given statement fit their experience with a given scene.

3.2.3 Statistical analysis and validity checks

Repeated measures and one-way ANOVA tests, together with linear correlation (SPSS programme), were used in the validity checks and tests for experimental effects. In a repeated measures ANOVA test, the scene pairs were specified as a priori contrast coefficients. There were five missing values in the data matrix, and Multivariate-Normal Missing-Value Imputation (NCSS programme) was used to fill in the missing values. A mean summary score of the PRS was used in the statistical analysis. No fixed pattern responses were detected.

The extent to which perceived brightness differences exerted differential effects on perceived restorativeness was also checked (Appendix 1). When comparing scene brightness, picture 3 was picked as the dimmest scene by all participants. Repeated measures ANOVA with contrast tests were run to find out if the differences in brightness affected the results. The contrast test results for the PRS ($F(2, 68)=2.84$, $p<0.065$) ratings do not support the hypothesis that slight changes in the brightness would significantly affect the perceived restorativeness. The ratings for picture 3 do not differ significantly from the similar setting category ratings for pictures 1 (PRS, $p=0.207$) and 6 (PRS, $p=0.246$). Picture 3 also got higher mean ratings with the PRS measures (Table 3) than picture 6, which the participants felt was brighter. However, the small sample size makes the detection of a brightness effect difficult.

The mean score differences between the setting categories are not higher for pictures 5 and 3 than for the other scene pairs, which also indicates that slight changes in brightness do not affect perceived restorativeness Nor is the setting category difference more significant for pictures 5 and 3 than for other two picture pairs. Therefore, it could be said that there is no evidence that the slightly lower brightness of picture 3 would have exerted different effects on perceived restorativeness. In general, the findings indicate that content differences rather that perceived brightness variations were decisive in accounting for the restoration ratings.

The extent to which the slight changes in brightness between the pictures, based on the order in which they were presented, affected the results was also checked. A one-way ANOVA with a presenting order as between-subjects factor was conducted to find out if the brightness differences in the order in which the pictures were presented had an effect on the results. No indication was found that the order in which the photos were presented and the changes in brightness would have had an effect on the results. Furthermore, all of the slide pairs resulted in consistent effects, regardless of their position in the

picture series (see Table 3). However, the small sample size makes the detection of an order effect difficult (see Discussion p. 89 for a meta-analysis of an order effect).

3.2.4 Results

Calculations of internal consistency (Cronbach's α) showed that the average inter-correlations among the items were high across all of the pictures (α >0.88; see Table 3). As expected, the focus of light on the greenery category received the highest mean ratings with the PRS measures. The setting category effect was significant for the PRS ($F(5,165)= 15.756$, $p<0.001$) measures in all of the picture pairs. Thus, the results supported the hypothesis that the perceived restorativeness is higher when light is focused on natural elements than when light is focused on parking lots and roads.

		PRS				
		M	SD	α	p	power
natural	picture 4	3.4	0.9	0.94	<0.001	0.998
urban	picture 1	2.4	0.8	0.88		
natural	picture 5	2.9	0.8	0.89	0.001	0.877
urban	picture 3	2.2	0.8	0.91		
natural	picture 2	2.6	0.9	0.93	0.003	0.941
urban	picture 6	2.1	0.8	0.88		
	Contrasts:	4-1				
		5-3				
		2-6				

Table 3. Mean ratings (M), standard deviations (SD), Cronbach's alphas (α), significance levels (p) and power of contrast tests using the PRS scale for the picture pairs 4-1, 5-3 and 2-6.

The main effect of mental fatigue as a between-subjects factor was insignificant in the overall PRS ratings ($F(1,33)= 0.140$, $p= 0.710$, power=0.065) (repeated measures ANOVA with picture pairs as contrasts). Thus, the results do not support the view that mental fatigue is a significant factor in perceived restorativeness evaluations. However, it may be that the state of mental fatigue has to be stronger in order for it to be a significant factor. The participants attended the experiment as part of their normal day and did not undergo any antecedent stress manipulation. It is also possible that they would need to perceive of the environment as being either very high

or very low in restorativeness in order for the difference to occur. Furthermore, the effect might be stronger in real environments or with more realistic simulations.

In conclusion, the results suggest that focus of light may either increase or decrease the restorative quality of urban nightscapes, thus giving the first indication of the restorative potential of lighting. Also, a new context for restorative experiences was provided, expanding the restoration research into urban nightscapes.

3.3 Study 2A: The effect of scene contents on perceived restorativeness, fear and preference in nightscapes

3.3.1 Introduction

The aim of the second study is to investigate how the content of the scene, but not the spatial configuration, affects perceived restorativeness, fear and preference in nightscapes. In the first study, changes in the focus of light also changed the visible scene configuration from a more horizontal (parking lots) to a more vertical one (greenery), which may also have affected the results.

With the same spatial configuration, urban scenes are generally less preferred and considered more frightening than natural ones during the day (Herzog & Miller, 1998). Whether or not the response is similar during the night has not yet been studied. It is possible that the signs of human presence are more appreciated during the night than during the day. However, it is also possible that the fear of social danger is more dominant than the possibility of social control, which is facilitated by human presence.

It was expected that people would perceive of natural scenes as being more restorative (hypothesis 1.1), preferred (hypothesis 2.1) and less frightening than urban scenes. It was further expected that preference and PRS would have a positive correlation (hypothesis 4), whereas preference and fear would have a negative correlation (hypothesis 5).

3.3.2 Methods

Two night-time scenes were modelled using the Lightscape computer programme. Both scenes were furnished in three different ways using urban or natural elements or a combination of both (=mixed). The urban scenes only contained man-made constructions and elements. The mixed scenes included both natural and man-made elements. The natural scenes included only natural elements. The spatial configuration, viewpoint and lighting setting remained the same. No people were present. The man-made constructions did not include physical incivilities such as litter and graffiti. The scenes can be seen in Appendix 4 and the setting categories in Table 4.

	Greenery category	Mixed category	Urban category
Opening series	picture 6	picture 2	picture 5
Pathway series	picture 4	picture 3	picture 1

Table 4. Setting categories.

Participants

There were 28 participants, with a mean age of 30 years (18-27 years, 20 subjects; 28-40 years, 3 subjects; 41-58 years, 5 subjects). The subjects were unaware of the purpose of the study and participated in the experiment voluntarily.

Measures

As in the first study, the restoration measures included the Perceived Restorativeness Scale (PRS) and the Restoration Outcome Scale (ROS) (the results of which are not reported here). The PRS was scored using 16 statements concerning the components that reflect the potential to be restored: being away, fascination, extent and compatibility. A mean summary score for perceived restorativeness was computed using all of the statements. The subjects were asked to imagine that they were actually in the environment depicted in each image and to respond to the statements on the basis of that assumption. Fear (1 statement: the place is frightening) and preference (1

statement: I like this place) variables were also measured and included at the end of the PRS section (see Appendix 5).

There was no special stress/fatigue manipulation before the test. The subjects participated in the test during their normal study day and suffered from moderate fatigue. The self-reported mean level of fatigue before the test was $M_{fatigue}$=2.9 (on 0-6 scale, SD=1.7). Two questions of the questions measured the fatigue/stress of the participants.

The participants indicated on a seven-point scale (0= not at all, 6= completely) the extent to which they felt that the given statement reflected their attitude about the scene depicted in the slide.

3.3.3 Statistical analysis and validity checks

Repeated measures ANOVA with contrasts and linear correlation (SPSS programme) were used in the validity checks and tests for experimental effects. The second test suffered from technical problems, as the projector in the healthcare institution could not project all of the colours equally. The warm tones in particular suffered from this problem, which might have affected the results. To check this, the test was also set as a between-subjects factor (subjects in Test 1 vs. subjects in Test 2). We found no indication that the colour problems would have had a significant effect on the results (the significance of the test as a between-subjects effect was p_{pref}=0.217; p_{fear}=0.460; p_{ROS}=0.626; p_{PRS}=0.569). However, this may be due to the fairly small size of the sample.

3.3.4 Results

The calculations for the internal consistency (Cronbach's α) of the PRS scales showed that the reliability coefficients were high across all the pictures (α >0.88; see Table 5). According to the repeated measures ANOVA, there were significant differences in the way the participants evaluated the different scenes in terms of the PRS measures ($F(3.6, 93.9)= 21.84$, $p<0.001$; $\eta_p^2 = 0.46$) (Greenhouse-Geisser corrected), preference ($F(5, 130)= 15.49$, $p<0.001$, $\eta_p^2 = 0.37$), and fear ($F(3.6, 92.5)= 5.56$, $p=0.001$, $\eta_p^2 = 0.18$) (Greenhouse-Geisser corrected) in both picture series. None of the two-way or higher order interactions were significant.

		PRS				PREFERENCE			FEAR		
		M	SD	α	p	M	SD	p	M	SD	p
Opening series	picture 6	3.37	0.96	0.89	0.067	3.30	1.61	0.100	1.96	1.95	0.119
	picture 2	2.99	1.15	0.93	0.003	2.74	1.72	0.020	1.30	1.49	0.060
	picture5	2.16	0.84	0.86		1.67	1.41		2.00	1.57	
Pathway series	picture 4	3.73	1.08	0.93	0.001	3.89	1.63	0.002	1.37	1.47	0.364
	picture 3	2.84	1.00	0.94	<0.001	2.59	1.45	<0.001	1.63	1.55	0.002
	picture 1	1.66	0.82	0.88		1.07	1.24		3.00	1.94	

Table 5. Mean ratings (M), standard deviations (SD), Cronbach's Alphas (α) and the significance levels of the contrast tests (p) (ANOVA) for PRS, preference and fear for pictures 6-2, 2-5, 4-3 and 3-1.

The greenery category received the highest means in PRS and preference ratings and the urban category received the lowest scores in these scales, as expected in hypotheses 1.1 and 2.1. For the fear ratings, both the mixed (picture 2 in opening series) and greenery categories received the lowest scores and the urban category received the highest fear scores in both series, as expected in hypothesis 3.1.

With all of the dependent measures, the ratings of the mixed category were closer to those in the greenery category than to those in the urban category. The differences between the mixed and greenery categories were significant in terms of the PRS scores and preference ratings for the pathway series. The differences between the mixed and urban category ratings were significant for all of the pictures and factors, except for the fear ratings in the opening series (pictures 2 and 5), where the difference was only marginally significant. There were no differences in any of our dependent measures (PRS, preference and fear) between the greenery and mixed categories in the opening series. The correlation between preference and PRS was very strong (r_{1urban} =0.83, p<0.001; r_{2mixed}= 0.93, p<0.001; r_{3mixed}=0.93, p<0.001; $r_{4greenery}$=0.90, p<0.001; r_{5urban}=0.74, p<0.001; $r_{6greenery}$=0.88, p<0.001); this was to be expected based on hypothesis 4 and it corroborated earlier findings. The correlation with fear and PRS was significant in pictures 2, 4, 5 and 6 (r_{1urban} = -0.36, p=0.066; r_{2mixed}= -0.40, p=0.035; r_{3mixed}= -0.29, p=0.133; $r_{4greenery}$= -0.40, p=0.036; r_{5urban}= -0.39, p=0.039; $r_{6greenery}$= -0.39, p=0.038). The preference-fear correlation reached a significant level only in picture 6 (r_{1urban} = -0.27, p=0.170; r_{2mixed}= -0.33, p=0.092; r_{3mixed}= -0.29, p=0.140; $r_{4greenery}$= -0.29, p=0.128; r_{5urban}= -0.23, p=0.231; $r_{6greenery}$= -0.40, p=0.035). Therefore hypothesis 5, which assumed a negative preference-fear correlation, was not confirmed. There was also no indication that the setting category would affect the correlation.

3.4 Study 2B: Effect of focus of light on perceived restorativeness, fear and preference

3.4.1 Introduction

Study 1 (I) suggested that emphasising the natural features of a scene by the focus of light has a positive effect on perceived restorativeness. Study 2B (II) extends the research by adding preference and fear variables. The aim of this study is to examine whether changes in the focus of light affect fear and preference in addition to perceived restorativeness.

Restoration is connected with preference and the lack of signs of a threat. Urban scenes are generally less preferred and less restorative and considered more frightening than natural ones during the day (Herzog & Miller, 1998; Kaplan & Kaplan, 1989). It is thus suggested that focusing light on natural scene contents results in higher ratings of perceived restorativeness and preference and lower ratings of fear (hypotheses 1, 2 and 3). It is also hypothesised that preference and PRS have a positive correlation (hypothesis 4) and that preference and fear have a negative correlation (hypothesis 5).

3.4.2 Methods

The same set of scenes was used as in study 1 (see Section 3.2.2 on methods). The pictures were presented using PowerPoint slides and the projection was done from in front of the screen. Counterbalancing was performed so that 19 subjects saw the slides in the original order and 22 subjects saw them in reverse order. The slide order was generated in such a way that the picture pairs would not follow one another.

Participants

Forty-one participants participated voluntarily in the experiment. There were 19 male and 22 female participants and their ages ranged from 20 to 53 years. The mean age was 30 years. The participants were unaware of the purpose of the study and participated in the experiment voluntarily.

Measures

The restoration measures were obtained using the Perceived Restorativeness Scale (PRS) instrument based on attention restoration theory, just as in Study 1 (see Section 2.1.2). Preference (2 statements scoring like-dislike feelings, e.g. I like this place) and fear (4 statements scoring experiences of fear, threat and safety, e.g. I would be frightened to proceed any further in this place) variables were also measured. These statements were included in the PRS section (see Appendix 6).

The subjects indicated on a seven-point scale (0=Not at all, 6=Completely) how well they felt that a given statement reflected their attitude about the scene depicted in the slide. One participant had a pattern response to one picture expressing that he totally disagreed with all the statements.

3.4.3 Results

The reliability coefficients (Cronbach's α) were high for all of the pictures in terms of the PRS and fear scales (αs >0.81; see Table 6). The ratings were considerably lower in the case of the preference scale (0.36<αs <0.78; see Table 6), reflecting the fact that there were only two questions that measured preference.

A repeated measures ANOVA revealed that the environment had a highly significant main effect on the PRS ($F(4.0, 159.9)= 16.87$, $p<0.001$; $\eta_p^2 = 0.30$) (Greenhouse-Geisser corrected), preference ($F(5, 200)=12.61$, $p<0.001$, $\eta_p^2 =0.24$) and fear ($F(5, 200)= 8.06$, $p<0.001$, $\eta_p^2 = 0.17$) measures. The greenery category received the highest mean scores in the PRS ratings, as expected in

hypothesis 1. It also received the highest mean ratings for preference, as expected in hypothesis 2. It got the lowest mean ratings for fear, while the urban category got the highest mean ratings, as expected in hypothesis 3. The results corroborate with those of study 1 (I) and are in line with the daytime findings.

Preference correlated very strongly with PRS ($0.73<r<0.93$, $p<0.001$), lending support to hypothesis 4, which projected a positive correlation between preference and perceived restorativeness. The preference-fear correlation was significant only in pictures 1 ($r=-0.47$, $0=0.002$) and 6 ($r=-0.40$, $p=0.035$), both of which were from the parking lots and roads category. Therefore hypothesis 5, which assumed a negative correlation between preference and fear, was only marginally confirmed. Fear had a moderate and negative correlation with PRS in four pictures: 1 ($r=-0.39$, $p=0.013$), 4 ($r=-0.40$, $p=0.036$), 5 ($r=-0.39$, $p=0.039$) and 6 ($r=-0.39$, $p=0.038$). The correlation did not reach significant levels in the other pictures.

In conclusion, the results suggest that, in addition to affecting the perception of restorative potential, the focus of light may also affect perceptions of safety and preference. When light enhances the green appearance of a particular environment, perceptions of restorativeness, preference and safety may be higher than when the focus of light calls attention to the presence of parking lots and roads.

	PRS				**Preference**				**Fear**			
pict.	M	SD	α	p	M	SD	α	p	M	SD	α	p
4	3.29	0.94	0.91	<0.001	3.82	1.29	0.74	<0.001	1.82	1.21	0.88	<0.001
1	2.48	1.00	0.91		2.74	1.37	0.36		2.68	1.30	0.77	
2	2.66	0.95	0.90	<0.001	3.16	1.45	0.73	<0.001	2.10	1.24	0.84	0.002
6	1.79	0.75	0.85		2.15	1.24	0.51		2.88	1.45	0.91	
5	2.97	1.15	0.93	<0.001	3.52	1.55	0.78	<0.001	1.98	1.52	0.87	0.001
3	2.03	0.89	0.89		2.35	1.28	0.41		2.95	1.49	0.81	

Contrasts: 4-1
2-6
5-3

Table 6. Mean ratings (M), standard deviations (SD), Cronbach's Alphas (α) and the significance levels of the contrast tests (p) (ANOVA) for the PRS, preference and fear scales.

3.5 Study 3: Perceived restorativeness and walkway lighting in near-home environments

3.5.1 Introduction

Besides providing access to environments that are perceived to be restorative, lighting may also affect perceived restorativeness by promoting the restorative features of the environment, as suggested in studies 1 and 2B. However, other lighting attributes may also have an effect on the perceived restorative quality of the night-time environment. This field study explores the relationships between the four components of attention restoration theory (being away, fascination, extent and compatibility) and the perceived lighting attributes (brightness, distribution, glare, colour quality, safety produced by the light and the pleasantness of the lighting environment). The aim is to explore how the perception of different lighting attributes is connected to the perception of the components of ART in a suburban pedestrian setting.

Based on attention restoration theory and empirical studies within the fields of environmental psychology and lighting technology, we suggest that people's perceptions about the lighting attributes — brightness, evenness, extensiveness, colour quality, glare, safety produced by the light and the pleasantness of the lighting environment — may form connections with the components of ART. However, due to the explorative nature of the study, no hypotheses were formulated and the quantitative results are presented together with the qualitative results.

3.5.2 Method

Participants

In Roihuvuori (areas A-C), 29 participants (14 female, 15 male) participated in the study, with a mean age of 39 years (12-67 years). In Herttoniemi (areas D-E), 26 participants (16 female, 10 male) participated in the study. Their

mean age was 40 years (18-63 years). Most of the participants were quite familiar with the areas they evaluated (in Herttoniemi 88%, in Roihuvuori 79%).

Test areas

In Roihuvuori, there were three test areas (A-C) located quite close to each other so that the subjects could easily walk from one area to another (see Figure 1). The test areas were pathways located between residential buildings. The height of the luminaire was 5 m in all of the Roihuvuori test areas. In Herttoniemi, there were two test areas (D-E). They were sidewalks along the same street in a suburban area surrounded by residential buildings ranging from small apartment buildings to single-family houses. The pole heights were 9 m and 8 m. The environmental factors related to perceived restorativeness, preference and fear are presented in Table 7.

Figure 1. The three upper pictures are areas A, B and C in Roihuvuori. The two lower ones are areas D and E in Herttoniemi.

Feature	**Area A** pathway	**Area B** pathway	**Area C** pathway	**Area D** pavement	**Area E** pavement
water feature	no	no	no	no	no
prominent trees	yes	yes	yes	some	some
pathway curvature	no	yes	yes	no	no
vehicles	no	no	no	yes	yes
walkability and prospect limitations	hill, metal fence	bushes	no	hedges, cars	hedges, cars, hill
surrounding buildings	block of flats at the end of walkway	service centre	block of flats	block of flats	terraced houses, detached houses
walkway surface	asphalt	asphalt	gravel	asphalt	asphalt
connected with	forest, playground (unlit)	playground	games court	asphalted front gardens	front gardens
social environment during the experiment		playing kids, people walking	playing kids, people walking	people walking	people walking

Table 7. Key environmental features in the test areas.

The mean luminance (L_{ave}), overall luminance uniformity (U_o), longitudinal luminance uniformity (U_l) and threshold increment (TI) values of all the areas are presented in Table 8. The luminance measurements were conducted using an LMK Mobile Advanced 1009 imaging luminance photometer with a Canon EOS 350D camera (calibrated by the manufacturer 2010; accuracy ±2.5 %). TI values provide some reference for the subjective perceived glare values. However, TI values describe disability glare in road lighting conditions, whereas perceived glare describes the subjective feeling of discomfort. The CCT and CIE Colour Rendering Index (CRI) measurements (measured beneath the luminaire at a height of 1.5m), which provide a reference for the perceived colour quality, were conducted using a Konica Minolta CL-500A illuminance spectrophotometer (calibrated by the manufacturer 2012;

accuracy ±0.3 nm; E_v ±2% ±1 digit of displayed value) (Table 8). It is noteworthy that the horizontally measured CCT values (CCT_h) produced by old mercury vapour lamp installations seem to be rather low (CCT_h=2805-3546 K). The CCT values were clearly below the nominal 4000 K value, even in an area where there was no high-pressure sodium lamp lighting nearby.

	Area A pathway	**Area B** pathway	**Area C** pathway	**Area D** pavement	**Area E** pavement
Light source	mercury vapour	LED	LED	mercury vapour	LED
CCT_h (K)	3546	3899	4560	2805	4239
CCT_v (K)	3260	3664	4432	3058	4028
Ra_h	49	65	69	46	76
Ra_v	49	59	68	47	79
$L_{ave\ walkway}$ (cd/m²)	0.47	0.46	0.59	0.28	1.07
$L_{ave\ walkway\ mesopic}$ (cd/m²)	0.47	0.48	0.64	0.28	1.10
$L_{ave\ surrounds\ left}$ (cd/m²)	0.14	0.20	0.17	0.14	0.32
$L_{ave\ surrounds\ right}$ (cd/m²)	0.12	0.18	0.40	0.30	0.13
U_o	0.54	0.70	0.56	0.59	0.49
U_l	0.50	0.75	0.39	0.34	0.27
TI(%)	7	4	2	3	2

Table 8. Horizontal (CCT_h) and vertical (CCT_v) values for the Correlated Colour Temperatures (K); horizontal (Ra_h) and vertical (Ra_v) values for the CIE Colour Rendering Indices; mean luminances (L_{ave}) (cd/m²) on the walkway and in the surroundings; overall luminance uniformity on the walkway (U_o); longitudinal luminance uniformity on the walkway (U_l); and Threshold Increment (TI) (%) values for the areas.

Measures

The participants used a seven-point Likert scale to indicate their experience with the study areas, except for glare ratings, where a three-point scale was used. A shorter and easier scale was used for the glare measures for several reasons. First, the participants were not able to use the visual assistance of a

semantic scale but had to indicate their experience verbally. Second, they were multitasking. Third, they were describing a continuous experience with a fixed visual target. As eye movements are related to more difficult questions rather than to easier ones (e.g. Day, 1964), an easy task was preferred. The participants were also told that they were free to comment on the lighting environment in their own words, if they wished to do so.

Perceived colour quality was measured using the following statement: 'The colour of the light makes the environment pleasant — unpleasant'. Further statements related to the lighting factors were as follows: brightness — 'The lighting on the pathway is too strong — totally inadequate'; distribution — 'The lighting on the pathway is too uneven — very even' and — 'The lighting on the area surrounding the pathway is too abundant — totally inadequate'; pleasantness — 'The lighting in the area is very pleasant — very unpleasant' and — 'The lighting fits the area well – not at all'; perceived safety — 'The feeling of safety produced by the light is very good — very weak'. The perceived restorativeness measures were obtained using a short version of the PRS (Berto, 2005; Hartig et al., 1997) (See the full questionnaire in Publication III.)

The perceived glare was measured by having the subject walk between two adjacent poles while looking straight ahead. The perceived glare on a 0-3 scale (0= no glare, 3=very strong glare) was written down in a graph by an assistant who walked slightly behind the subject. In the following statistical analysis, perceived glare is the average glare value while walking one pole space.

Statistical analysis

The Shapiro-Wilk test indicated that some of the factors were not normally distributed. Normality corrections for multiple factor analysis were performed, but they did not result in normal distributions. Therefore, single items were used in the subsequent regression analyses, and the significant relationships revealed by the Linear Regression analyses were also checked using the Spearman correlation. Independent analysis rather than mixed design was used since it was important to obtain area-specific results. Although the areas within neighbourhoods were rather similar, different neighbourhood and lighting components may yield different connections between the factors.

The regression analyses were performed as follows. First, possible lighting factor candidates (walkway brightness, walkway evenness, extensiveness of the surrounding lighting, glare, colour quality, the feeling of safety produced by

the light, pleasantness of the lighting and the extent to which the lighting suits the area) were explored using a stepwise method that revealed statistically significant relationships between the lighting attributes and dependent variables. Regression analyses were then performed again using only these variables (enter method). Finally, significant relationships were checked using Spearman correlation.

The statements provided by the participants ranged from a very negative to quite positive. However, their responses to the statement, 'The lighting on the pathway…' ranged from too strong to totally inadequate, and 'The lighting on the area surrounding the pathway…' statement ranged from too abundant to totally inadequate. These statement scales opened up the possibility of a nonlinear regression, which was also tested. However, the nonlinear effects were weaker than the linear ones. This may be due to the fact that the brightness responses were concentrated along a fairly narrow area of the scale, so that, with the exception of area D, the scale indicated just a few values below three, whereas in area D the scale indicated only two values above three, thus leading to a linear effect. For the distribution responses, area C accounted for differing views among the participants in terms of whether the lighting surrounding the pathway was too strong or totally inadequate. This may be due to the fact that there was a great deal of difference between the right-hand side and the left-hand side of the luminance. We also checked that the perceived brightness responses corresponded to the free responses. There were two instances where the semantic scale evaluation was the same for the two areas, even though the free responses indicated that there should be a difference. In one instance there was a clear contradiction.

Procedures

The experiments were organised in Helsinki at the beginning of November 2011, starting around 6-7 p.m., so that it was completely dark. There was no snow on the ground and the tests and measurements were carried out in dry weather. There was still some foliage on the trees.

The subjects could walk freely around the test areas, but the desired evaluation direction was indicated in the test maps and verbal reminders of this were also given during the test. As perceptions are affected by prior and adjacent experiences, the direction of the evaluation was such that the visual background was as similar as possible between the test areas. However, since

most of the participants were already familiar with the areas, the evaluation was probably partially based on prior visits to the study areas.

In Roihuvuori (Areas A, B, and C), the mean test duration was approximately 40 minutes. Half of the subjects (14 out of 29) conducted the test in reverse order (Area C first). In Herttoniemi (Areas D and E), the mean test duration was approximately 25 minutes and all subjects conducted the test in the same order (Area D first). This was done to prevent the subjects from perceiving the areas against an undesired background prior to the study, which may have affected the results.

3.5.3 Results

Data on the significant correlations (Spearman correlation, $p \leq 0.05$ and $p \leq 0.0025$) between the variables are provided in Table 9. The results indicate that the components of perceived restorativeness are related to the attributes describing the perceived pleasantness of the lighting environment. Besides the pleasantness, the perceived safety produced by the lighting also seems to form connections with the components of perceived restorativeness. The results are in line with restoration theory, where preference and lack of threat are central (Kaplan, 1995, 2001; Kaplan & Kaplan, 1989), and the empirical findings support the theory (Berto, 2007; Chang et al., 2008; Herzog & Rector, 2009; Herzog et al., 2003). The results were also similar when a summed up scale was used (see Appendix 7), so that a lighting environment that the participants perceived as being pleasant was strongly related to the PRS measures in the three areas. Also, the perceived safety provided by the lighting and pathway brightness formed single connections.

The perceived colour quality, described by the statement 'The colour of the light makes the environment pleasant — unpleasant', was connected to being away in two areas and the correlation coefficients indicated quite strong connections (Table 9). Evenness and glare formed no significant connections at a level of $p<0.0025$. However, glare had two negative connections ($p=0.009$ and $p=0.021$), and it would be reasonable to expect that strong glare would harm the restorative experience. Walkway brightness and extensiveness formed single connections at a level of $p<0.0025$. Brightness was connected with being away, whereas extensive lighting was connected with extent.

Compatibility and especially being away formed a number of connections significant at a level of $p<0.0025$, whereas the other components formed fewer and less significant connections.

	Component of PRS			
Lighting attribute	Being away	Fascination	Extent	Compatibility
Safety: Perceived safety produced by the light	A, 0.60* C, 0.52		A, 0.64*	A, 0.46
Pleasantness: Pleasant lighting	C, 0.55*	E, 0.68*	E, 0.54	C, 0.65* E, 0.72*
Pleasantness: Lighting suited to the area	B, 0.54 E, 0.85*	B, 0.53		B, 0.65*
Colour quality	D, 0.71* E, 0.87*	C, 0.48		
Distribution: Evenness of lighting on the walkway			D, 0.40	
Distribution: Lighting is extensive			D, 0.64* E, 0.44	
Brightness: Perceived brightness on the walkway	D, 0.67*	E, -0.54	C, 0.52	
Glare		B, -0.48		D, -0.46

Table 9. Spearman correlations ($p \leq 0.05$) in the five test areas (A-E).
*($p \leq 0.0025$).

Table 10 presents three items that the participants mentioned most often in relation to each area in the free descriptions. In areas C and E, almost 40% of the subjects commented that they felt the lighting was too bright. The pleasantness of the lighting in area B and the dark spots in area A also received many comments (11 subjects).

The participants used the free responses to give more detailed descriptions of their perceptions. Thus, the questionnaire biased the free responses on a thematic level. However, two new themes also appeared: the connection between lighting and atmosphere and lighting expectations (especially brightness) in relation to different functions. The participants linked bright

lighting with the daytime hours, bicycling, playing areas and the areas surrounding public buildings. They connected dim lighting to the night-time hours, dark season, calming down, parks and old neighbourhoods. Thus, the participants seemed to expect that considerable variations in the level of brightness would be in line with seasonal and diurnal light variations and various functional needs. However, their colour quality expectations seemed to be much more limited and grouped around their perception of orange and white colours. A couple of participants said that they liked white/cool colour appearances.

	Area A pathway	**Area B** pathway	**Area C** pathway	**Area D** pavement	**Area E** pavement
	dark areas (11)	pleasant (11)	too bright (11)	pleasant	glaring/bright
	safety (6)	pleasant	cold(6)	colour (5)	(11)
	cold (3)	colour (7)	dim surrounds	pleasant (4)	cold (6)
		even (6)	(6)	dim/unclear	good/sufficient
				(3)	(6)

Table 10. Three items that were most often referred to in the free responses and their frequencies.

We analysed the free descriptions further in order to get some indication of why the participants mentioned that the level of brightness was too high. Table 11 shows descriptions that were related to different brightness perceptions in the free responses. The responses suggest that the negative brightness experience may be related to the perception of pointless light use in relation to the participants' expectations and their perceptions of unnaturalness, blue/cold colours, an unpleasant atmosphere and unpleasant visual conditions. The table also indicates that perceptions of brightness and dimness may be related to both positive and negative experiences. Further research is needed to clarify the cool colour-brightness connection and whether it is a question of mesopic vision, chance, negative interaction or some other factor.

Bright neg.	**Bright pos.**		**Dim pos.**	**Dim neg.**	**Dark neg.**
Pointless (2)	Safe	Calm	Soft (2)	Blurred	Unpleasant
Unusual		Cosy	Atmospheric		Bleak
Unnatural			Traditional		
Artificial					
White (2)					
Blue					
Cold					
Pale					
Grim					
Harsh (3)					
Glary					

Table 11. Descriptions related to different brightness perceptions and their frequencies in the free descriptions.

In conclusion, the results indicate that people's perceptions of a pleasant lighting environment are connected with perceived restorativeness in near-home environments. The results also give some indications that the perception of brightness and dimness may be experienced both positively and negatively. Furthermore, the results suggested that people's perceptions of the colours of the environment as being pleasant may be connected with the being away component of PRS. However, given the explorative nature of the study, single-item scales, the large number of environmental factors, limited control, and the small sample sizes, the results must be regarded with caution.

3.6 Study 4: Lighting promoting safety and creating a sense of pleasantness in suburban environments after dark

3.6.1 Introduction

Research has suggested that several lighting attributes may be connected with perceived safety and pleasantness (Boyce et al., 2000; Hanuy, 1997; Johansson et al., 2011). Practical lighting interventions tend to use an increase in luminance as a general tool to enhance safety, whereas only minimal attention has been paid to pleasantness. The present field study explores the relationship between the perception of five lighting attributes (colour quality, evenness, extensiveness, brightness, glare) and appraisals of the perceived level of safety provided by the light and pleasantness of the lighting environment in suburban neighbourhoods. The aim is to reveal the most significant connections between the variables. In doing so, the study will clarify whether an increase in the level of brightness is a general tool to enhance perceived safety in near-home environments. The results will also clarify whether the same attributes are connected with both safety and pleasantness or whether there are there conflicting factors.

3.6.2 Method

For more on the participants and test areas, see Section 3.4.2.

Measures

Perceived colour quality was measured using the following statement: 'The colour of the light makes the environment a pleasant — unpleasant one'. Further statements related to the lighting factors were as follows: brightness — 'The lighting on the pathway is too strong — totally inadequate'; evenness — 'The lighting on the pathway is too uneven — very even'; and extensiveness — 'The lighting in the area surrounding the pathway is too abundant — totally inadequate'. The pleasantness of the lighting environment was measured with the statement — 'The lighting in the area is very pleasant — very unpleasant'; the perceived safety of the lighting environment was measured with the statement — 'The feeling of safety produced by the lighting is very good — very

weak'. All of these statements were evaluated using a seven-point Likert scales. For a description of the glare measures, see Section 3.4.2. The subjects also were free to comment on the lighting environment in their own words if they wished to do so.

Statistical analysis

When examining multicollinearity, we noted that the highest significant value for Pearson's product-moment correlation was 0.61. The Shapiro-Wilk test indicated that some of the factors were not normally distributed. Since normality corrections did not result in normal distributions, the significant relationships revealed by the Linear Regression analyses were checked with the Spearman correlation as well.

Possible connections between the lighting attributes and safety/pleasantness appraisals were first explored using linear regression analysis (enter), which revealed significant relationships between the perceived lighting attributes and dependent variables. Only these attributes were included in the subsequent regression analysis (enter). Finally, suggested connections were tested with the Spearman correlation as well. For two statements, we also checked the nonlinear regression. However, the nonlinear connections were weaker than the linear ones (see page 80).

3.6.3 Results

Data on the significant correlations (Spearman correlation, $p \leq 0.05$ and $p \leq 0.01$) between the variables are presented in Tables 12 (perceived safety provided by the lighting) and 13 (pleasant lighting). The results indicate that in suburban nightscapes, the perceived level of safety provided by the light is most strongly connected with the perceived colour quality. In the study, it also had single connections with even, extensive and bright lighting. Also, a pleasant lighting environment is most strongly connected with the perceived colour quality. It had a single positive connection with the level of brightness in area D and a negative connection with the glare in area E.

	Areas				
Attributes	A	B	C	D	E
Colour quality	0.58*	0.49			0.72*
Evenness			0.49*		
Extensiveness	0.60*				
Brightness				0.72*	
Glare					

Table 12. Spearman correlation (p≤0.05) between the perceived safety produced by the light and the five lighting attributes, p≤0.01*.

	Areas				
Attributes	A	B	C	D	E
Colour quality	0.85*	0.51*		0.56*	0.93*
Evenness					
Extensiveness					
Brightness				0.49*	
Glare					-0.65*

Table 13. Spearman correlation (p≤0.05) between pleasant lighting and the five lighting attributes, p≤0.01*.

In the free responses, the participants referred to pleasant lighting using words like beautiful, relaxing, good, even, soft, atmospheric and tender. They referred to unpleasant lighting as harsh, grim, cold, unnatural, even, uneven, dark and too bright. In terms of the lighting attributes, the participants mentioned dark surroundings and uneven pathway lighting most often in relation to the perceived safety of area A. In other areas, they expressed fewer ideas concerning perceived safety.

In conclusion, the results of this study indicate that in mundane, near-home settings, the perception of a pleasant lighting environment is most strongly connected with the perceived colour quality. The other lighting attributes formed only single connections (brightness and glare) or else no connections at all were formed (evenness and extensiveness). The perceived feelings of safety produced by the light followed the same pattern: three connections were formed by the colour quality, two of which were significant at p≤0.01 level, whereas single connections were formed via other factors (evenness, extensiveness and brightness). However, although the perception of a pleasant colour quality seems to be the strongest indicator of feelings of safety , the results do not suggest that the connection between perceived safety produced by the lighting and brightness is weak. Rather, it follows that the relationship

between brightness perception and safety is not straightforward, which is line with the findings by Boyce et al. (2000). Furthermore, the results may be different in environments with safety problems or very low illuminance levels.

4 Discussion

The theory that motivated study 1 (I) was that lighting may affect perceived restorativeness because it is able to hide, reveal and attract attention during the hours of darkness. Indeed, the results signal that mixed-scene content environments in which the focus of light is on greenery may promote perceived restorativeness, whereas focusing light on parking lots and roads may have negative effect (I & II). Furthermore, the results indicate that by promoting potentially restorative scene contents, such as greenery, the focus of light may enhance perceptions of preference and safety (II). Therefore, hypotheses 1, 2 and 3, which assume that when light is focused on greenery instead of parking lots and roads, the perceived restorativeness, preference and feeling of safety are higher, were all supported by this thesis.

The analogous hypotheses, hypotheses 1.1, 2.1 and 3.1, were also supported by this thesis. The participants reported that green environments are more restorative, preferred and less frightening than urban environments after dark. Thus, the results were consistent with prior research concerning daytime environments. The participants assessed mixed scenes as being similar to natural ones.

However, the lack of a sound environment may overemphasise the effect of the visual environment, especially when it comes to the fear ratings (Toet & Schaik, 2012). On the other hand, the restorative effect may be stronger in real environments or when simulations with higher experiential realism are used (de Kort & Ijsselsteijn, 2006; de Kort et al., 2006). Thus, research with more scenes, more scene types and more field experiments is needed in order to validate the suggested connections.

The order bias effect was studied by combining the PRS data of studies 1 and 2. One-way ANOVAs were run to find out if the presentation order had an effect on the results. There were no significant differences in the PRS ratings of different presentation orders ($0.438<p<0.872$).

The more positive assessment results of focusing on the greenery category as compared with focusing on the urban contents category supplement the restoration research field by suggesting that perceptions of the restorative potential of an environment and the experiences of preference and safety during night-time follow the daytime pattern (I & II). The results also corroborate with restoration theory in that the perceptions of pleasantness, preference and safety are connected with the components of perceived restorativeness (II & III). Thus, the results provide support for hypothesis 4,

which assumes a positive correlation between preference and perceived restorativeness, and corroborate with earlier findings (Staats et al., 2003; van den Berg et al., 2003).

Contrary to hypothesis 5, the preference–fear correlation was only marginally significant (II). Since earlier research on daytime environments suggests a modest negative correlation between preference and fear (Herzog & Kutzli, 2002; Herzog & Miller, 1998), the results are somewhat surprising. Although a larger number of subjects might increase the statistical significance, the correlation coefficient would still remain low. Since the response sub-grouping would need more data, we can only hypothesise as to why preference and fear did not have a significant negative correlation. One possible explanation might have to do with gender-differentiated response patterns for fear. It may also be that some people experience night-time scenes as always being fraught with fear, even though they perceive variations in preference; or, more probably, even though they feel that the environment is safe, they still perceive of it as being low in preference, whereas scenes that are perceived as high in fear tend to be low in preference. Furthermore, the presence of other people during the experiment, the lack of a sound environment and the fairly coarse quality of the simulations may have affected the fear results. Further research with more subjects, more scenes, more realistic simulations and more field experiments is needed in order to bring more light to the preference–fear relationship during night-time.

The results reflect the importance of the perceived colour quality. Of the studied lighting attributes (colour quality, evenness, extensiveness, brightness, glare), we found the strongest connections with both the perceived safety produced by the lighting and the pleasantness of the lighting (IV). Furthermore, in two areas the participants positively and quite strongly connected colour quality to the being away component of ART (III). Thus, the results of this thesis indicate that, in addition to the perception of brightness, the perception of other lighting attributes may also be important for environmental experiences. A study by Johansson et al. (2011) also found that perceptions of unpleasantness, unnaturalness, and monotony were more important for safety perceptions than perceived brightness. However, there were no special safety concerns in the study areas for this thesis. Since earlier research indicates that perceptions of brightness and safety are connected (Johansson et al., 2011; Nasar & Jones, 1997; Boyce et al., 2000), the results might be different in areas suffering from serious safety concerns. It may also be that the differences in colour quality were perceived as being more prominent than the perceived brightness differences, thus giving more

emphasis to perceived colour quality. However, a number of participants commented on brightness perceptions in the free responses, thus indicating that they felt that brightness was a prominent factor.

In the free comments provided as a part of study 3 (III), approximately 40% of the participants said that the lighting was too bright in areas C and E. The brightness perception was also connected with a number of negative descriptions. It is quite surprising that there were far more comments regarding the fact that the lighting was too bright rather than too dim. However, besides being related to the perception of a bright pathway, the perception that the lighting was too bright may also be related to, for example, adaptation or to the feeling of being exposed to high brightness when walking beneath the light fitting. Furthermore, the free responses suggested that negative brightness experiences may be related to perceptions of pointless light use in relation to the expectations and perceptions of unnaturalness, cool colour, an unpleasant atmosphere and unpleasant visual conditions. The connection between perceptions of cool tones of light and brightness may be explained by chance. However, it is also possible that the perceptions of coolness and brightness interact with one another. More research is needed on brightness and colour perceptions and expectations.

There is also somewhat contradictory evidence pointing to the fact that people prefer bright outdoor lighting after dark (Boyce et al., 2000; Hanuy, 1997). However, in Hanuy's study bright and uniform lighting was positively connected with safe and active appraisals, but not with pleasant and relaxing appraisals. Furthermore, although the written text suggests a positive correlation between safety and brightness, a more extensive table for the results indicates a negative correlation, thus leaving the direction of the correlation somewhat unclear.

In a study by Boyce et al. (2000), the results show a correlation between brightness and having lighting of a good quality. However, whereas a number of the questions in the questionnaire had to do with visibility and safety concerns, none of them had to do with pleasantness. Thus, the good-bad rating scale may reflect considerably the perceptions of how good the lighting is from the point of view of safety. Furthermore, the evaluated sites consisted mostly of streets and avenues where people's expectations for good lighting may also be higher.

In conclusion, there seems to be a gap in lighting preference research on urban nightscapes. Even if preference-related items are scored, they are included within a fear-dominated questionnaire. It would be interesting to see more research scoring only positive factors. Furthermore, it should be pointed

out that this thesis does not suggest that brightness perceptions in urban nightscapes are always connected with negative experiences. Instead, it suggests that people may perceive excessive brightness and that brightness and dimness may be experienced both positively and negatively as well. Thus, more research is needed to further explore the possible connections between restoration/preference and brightness.

Besides the negative brightness perceptions in areas C and E, the results of this thesis gave some indications that the perceptions of high levels of brightness and glare may be negatively connected with the fascination and being away components of ART (III). Although the significance did not reach a level of $p<0.0025$, the connection received both explicit and implicit support from the free responses as well. For example, it was considered easier to calm down in a dimmer environment. The brightness-fascination connection has also received theoretical support from the Kaplans (1989), who suggest that a sense of mystery would be created in an environment with a darker foreground and brighter spots beyond. The free responses also indicated that perceptions of too much brightness may be related to disturbing experiences, thus indicating less favourable conditions for attentional recovery.

This is, to our knowledge, the first indication that perceived brightness may be experienced as being too high in outdoor environments (III). There may be various reasons why previous studies have not reported a negative brightness effect. Previous controlled experiments have tended to examine areas other than near-home areas and light sources other than LEDs (Boyce et al., 2000; Johansson et al., 2000). It is possible that people are more sensitive to the brightness values in their near-home areas and have higher brightness expectations in unfamiliar areas or that their perceptions that the lighting is too bright are related to some special quality of LEDs, e.g. their spectral power distribution. Furthermore, previous outdoor lighting studies have focused primarily on fear (Blöbaum & Hunecke, 2005; Boyce et al., 2000; Johansson et al., 2000; Nasar & Jones, 1997). Thus, more emphasis may have been placed on perceived levels of brightness.

However, it should also be noted that previous lighting studies have used bright-dark scales (Flynn et al., 1973; Boyce et al., 2000; Hendrick et al., 1977; Kuhn et al., 2012; Newsham et al., 2005). Also, a study by Johansson et al. (2011) uses the words bright, light and dimmed in their lighting quality assessment. Thus, the scale that they used did not indicate whether or not people felt that the lighting was too bright. Instead, too high brightness was mixed with the experiences with appropriate and pleasant levels of brightness. The scales also serve as guides for the participants and implicitly suggest how

they should interpret the environment. Thus, including the possibility to perceive the lighting as being too bright may increase our awareness of appropriate levels of brightness. In this thesis, in addition to the indications provided by the quantitative regression results, the free responses also gave evidence of the extent to which people felt the lighting was too bright. However, as discussed previously, the perception that the lighting is too bright is related to various factors, including lighting expectations and prior and adjacent perceptions, affecting adaptation.

Although prior outdoor lighting research does not indicate that people might prefer dimmer lighting in indoor environments, there is research evidence indicating that lower illuminance levels are related to experiences of feeling calm and relaxed. In a study by Miwa and Hanuy (2006), a room with low illuminance (150 lx) increased self-reflection more than a room with a high level of illuminance (750 lx). The low illuminance condition also increased feelings of safety, comfort and relaxation (Miwa & Hanuy, 2006). The study investigated the effects of interior design on participant's impressions of an interviewer and their level of self-disclosure in a counselling room. For the bright light conditions, two 40W fluorescent ceiling lamps were turned on and they produced a 750 lx illuminance on the table's surface. For the dim light condition, one incandescent table lamp and two wall lamps (36W) were turned on and they produced a 150 lx illuminance on the table's surface. The authors do not provide a description of the spectral quality of the fluorescent lighting. Thus, in addition to the level of illuminance, the spectral quality may also have affected the results.

A study by Baron et al. (1992) investigated the effects of illuminance and spectral distribution separately. The high illuminance condition that they used was 1500 lx on a table's surface, whereas they used 150 lx for the low illuminance condition. The CCTs were 3000K and 4200K. The lighting was provided by four lamp-recessed fluorescent luminaries with flat prismatic lenses. The subjects reported being more calm and less tense under the low illuminance and lower CCT lighting conditions than under the high illuminance and higher CCT lighting conditions. Furthermore, the results indicated that warm white lighting induced more positive affects under low illuminance conditions, whereas high CCT lighting induced more positive affects under high illuminance conditions.

Also, a study by Flynn et al. (1973) indicates the importance of high intensity overhead lighting on people's perceptions of tense (and relaxation). The participants evaluated the appearance of a medium-sized conference room. The authors used the semantic differential rating scales to assess each of six

different lighting arrangements with varying levels of illuminance, distribution and quality (diffuse or not). The lighting arrangements that participants evaluated as the most tense on the relaxed-tense scale were those with only diffuse overhead lighting. In particular, high-intensity diffuse lighting was connected with a more tense experience. In general, the evaluative response to diffuse overhead lighting was negative. The most relaxed lighting arrangement was a combination of low-intensity overhead lighting and wall lighting. Since a deeply restorative experience is also characterised by feeling relaxed and reflecting upon one's life and priorities, the results have parallel indications.

However, we might also question whether the indoor study results are applicable to outdoor environments. People have different expectations for indoor and outdoor lighting in general. The illuminance levels for the indoor studies were higher and the perceived luminance contrasts were likely to be lower. In indoor environments, illuminance is measured at the surface level of the table and participants tend to be sitting down, whereas ground surface measurements are conducted in outdoor environments and participants tend to be standing. Thus, there is a significant difference between the observer's eye level and the measured surface. Also, in outdoor environments people tend to be walking and having a dynamic light-space experience, making it even more difficult to compare indoor and outdoor environments. Furthermore, the indoor study environments were not open public spaces. Thus, in addition to the indoor-outdoor context difference, there is also a public-private context difference, both of which may induce different expectations. Also, the time of day may affect people's assessments of the quality of lighting. Besides having the possibility to affect lighting preferences as such, it affects the prior and adjacent lighting conditions. In conclusion, referring to indoor studies is questionable when discussing outdoor lighting situations. However, since there is an absence of preference- and pleasantness-related research in outdoor lighting environments, it may be regarded as justified.

Study 3 also indicated that an electric lighting environment may be perceived as both natural and artificial. The perceptions of unnaturalness in suburban nightscapes were related to perceptions of brightness and cool tones of light. It could be hypothesised that the perception of naturalness is based on diurnal and seasonal variations in daylight. However, the natural light of night, moonlight, has a fairly cold tone, whereas the results of this thesis indicate that lighting with a dim and warm appearance is perceived of as natural in suburban pedestrian environments. Thus, the results would suggest that perceptions of naturalness are based on learned expectations for environments dominated by tungsten halogen or sodium lamp lighting. Alternatively, it

could be suggested that the use of fire is so deeply rooted in human history and has offered biologically relevant survival benefits that humans have evolved a preference for a fire-like lighting environment at night. Further research is needed to validate the indication that lighting with a dim and warm appearance is perceived of as natural in suburban pedestrian environments.

4.1 Application

The current practice in urban nightscapes is to focus the lighting almost solely on the most disliked scene contents, i.e. roads, car parks and signs (Nasar, 1998). These urban contents are also often experienced to have only minor restorative qualities. This thesis suggests that this may have an effect on the perceptions of restorativeness, preference and fear during the hours of darkness (I&II).

Another current practice is that outdoor lighting interventions tend to use higher illuminance as a general enhancement tool. This thesis indicates that brightness may be perceived as excessive and perception of excessive levels of brightness may be connected with negative experiences (III). Furthermore, the results of this thesis give some indication that an experience of fascination and a high level of brightness may have a negative connection after dark (III). Thus, increased levels of brightness may not always result in better appraisals. However, further research is needed in order to validate these indications.

This thesis suggests that in order to increase people's perceptions of restorativeness, preference and safety, lighting interventions should include such actions as promoting the most liked environmental features, diminishing the role of the less liked features and using light sources with a colour appearance that is perceived as being pleasant.

Promoting restorative features of the environment could be done by focusing the light on greenery, water features, works of art and environmental features with historical or social significance. Studies 1 (I) and 2 (II) indicated that it may be enough to illuminate just some key features in the environment in order to promote perceived restorativeness. Less, not more, luminaires were used to illuminate scenes that people perceived as being more restorative. Thus, energy issues do not contradict with the creation of restorative lighting environments. Simple changes in the luminance distribution may be enough to change restorative potential.

The interventions to reduce the role of the less restorative features could include using lower illuminance levels and limiting their exposure times. More

sophisticated lighting controls could also be used along roads and in parking lot lighting. These actions would also save energy.

The results of this thesis give some indications that in terms of suburban outdoor lighting, people prefer colour quality that is perceived as warm. Thus, we suggest that in order to create the sense that lighting enhances the outdoor environment, light sources with good CRI (Fotios & Cheal, 2011) and warm colour appearances should be used. However, it is possible that in city centres where the illuminance levels are higher, colder colour appearances may also be acceptable. There may also be learned cultural differences in terms of lighting preferences. Furthermore, in Finland outdoor lighting is mainly used during the cold season. Since the perceptions of colour temperature and ambient temperature are connected (Laurentin et al., 2000), people's preferences may be different in different climate conditions.

This thesis indicates that the CCT value of an old mercury vapour luminaire may be lower than its nominal value (4000 K) (III). The yellowing of the plastic cover may produce a CCT value close to 3000 K. Since existing field values serve as lighting quality references for the local residents, the actual field values should be taken into account when conducting lighting interventions.

This thesis suggests that perceived brightness measures should take into account the perception that the lighting is too bright. The bright-dark scale does not differentiate between perceptions of appropriate levels of brightness and excessive brightness, which would be important both for research and application purposes. Furthermore, since pedestrian environments may have different functions, the function-brightness connection should also be taken into account. For example, a participant may rate the environment as dim and feel that it will be easy to relax in such a lighting environment (dim and appropriate). On the other hand, the participant may also feel that the lighting is blurred and will make it difficult to ride a bike (dim and inappropriate). Thus, if a simple bright–dark scale is used, a participant may try to give a generic brightness evaluation or he or she may rate the environment based on the functional intentions. Also, researchers have reported large illuminance preference differences between different behaviours and settings in indoor environments (Butler & Biner, 1987).

4.2 Limitations

As with all research, this study has potential limitations. First, the research on restoration is limited to perceived restorativeness. Restoration on a behavioural and/or physiological level was not studied. Restoration on an experiential level was studied in the form of ROS and the results were in line with the PRS results (I). Thus, it may be questioned whether the results are indicative when it comes to restoration. However, the results were in line with the restoration theory. Furthermore, there is research evidence that environments that are perceived to have a high restorative potential tend to be restorative (Hartig et al., 1991, 1996, 1997). The PRS scale has also been used for reaction time measures, indicating priming effects (Hietanen et al. 2007; Hietanen & Korpela, 2004; Korpela et al., 2002). Furthermore, there is research evidence that the self-reported measures on the four components of the PRS scale are connected to physiological responses (Chang et al., 2007). Thus, the results may also be regarded as indicative when it comes to restoration. However, studies scoring participants for attentional and psychophysiological changes are needed in order to validate the findings.

Second, since the sample of settings was small the results cannot be generalised to all scene contents and environmental contexts. The low number of scenes also harms the reliability. In particular, the reliability of explorative field studies 3 and 4 may be questioned since numerous factors were confounded within the perceived environments. Both the quantitative and qualitative data seemed to account for the corresponding results, thus supporting the findings. However, more research both in the field and in controlled conditions is needed in order to validate the findings.

The third limitation is the use of simulations instead of real environments in studies 1 and 2. The Lightscape simulations were also rather coarse at the time, thus they differed considerably from photographs or real environments and call into question the validity of the results (Daniel & Meitner, 2001). However, there is also research evidence pointing to the fact that the use of simulations is a valid and acceptable method in environmental experience research. In a study by Rohrman & Bishop (2002), the appraisals differed according to the lighting conditions and time of day, which are also the key issues in this study. Also, the results obtained from simulated office lighting environments have been quite similar to those obtained from real

environments (e.g. Newsham et al., 2005). Furthermore, static images are widely used in the restoration research field, both in psychophysiological stress and attention restoration studies, and they have proven to have strong validity (Hartig et al., 1997, 1996; Ulrich, 1981). Also, preference ratings obtained via simulations have correlated strongly with on-site ratings (Kellomäki & Savolainen, 1984). However, environmental perception is multimodal and a study by Toet & Schaik (2012) indicates that in the absence of sound, as in this study, people pay more attention to visual details, such as signs of disorder. Thus, the effect of the focus of light may be weaker in real environments, especially when it comes to the perceived safety factor. It is also likely that the presence of other people affected the perceived safety scores. On the other hand, the effect of greenery and the play of light in the branches of trees may be stronger in real environments and in more natural and immersive representations (de Kort et al., 2006).

Fourth, the time of day and season may affect lighting preferences (Iskra-Golec et al., 2012; Rautkylä et al., 2010). Studies 1 and 2 were conducted during daytime, even though the scenes represented night-time environments, which may have affected the results. Repeated presentations of an image were not done and further research is needed.

Fifth, single-item scales were used in studies 3 and 4 in order to limit the evaluation time. Single items harm the reliability of the results. However, qualitative data obtained from the free responses corroborated the quantitative results. Furthermore, the lighting quality statements were simple and the results corroborated the photometric lighting measurements. Also, in the PRS section several constructs were included within a single statement; for example, fascination was scored by referring to experiences of fascination, interest and exploration. Thus, the results may be regarded as indicative in terms of providing suggestions for future research.

Sixth, studies 3 and 4 used local residents, which is a potential source of bias. However, there were remarkable similarities in the perceptions of people in the two suburban districts. In both neighbourhoods, certain areas yielded perceptions that the lighting was too bright and the tone of light too cold. Also, in both neighbourhoods people's perceptions of pleasant colour qualities formed the strongest connections with their perceptions of the pleasantness and safety of the lighting environment. Thus, the results may be regarded as suggestive when it comes to near-home environments after dark. However, people's perceptions in unfamiliar areas, in fear-dominated areas and in areas with a different lighting culture may be significantly different. Seventh, the participants in studies 3 and 4 were aware of the purpose of the study. Thus,

they may have given stronger emphasis to the effect of lighting than they would have normally done in their everyday lives.

The eighth limitation of the study concerns the cultural aspects. Since there may be differences in people's lighting preferences due to cultural reasons, the cultural aspect needs more attention.

Ninth, the use of outdoor lighting is mainly restricted to colder seasons in Finland. Since there is research evidence connecting people's perceptions of colour temperature and ambient temperature (Laurentin et al., 2000), the results may be different in different climate zones.

The tenth limitation of the study concerns the nonlinear brightness and extensiveness scales, which may have confused the participants. However, with the exception of a few of cases, the scale ratings corresponded well with the free descriptions. Furthermore, the responses were concentrated on either end of the scale, thus leading to a linear effect.

The eleventh, and final, limitation of the study concerns the salience of the stimuli used. Experiments in real environments applying eye tracking method and luminance measurements would add understanding of what the participants are actually looking at.

4.3 Directions for future research

The work carried out in this thesis has generated open research problems for future work:

i. This thesis focuses on perceived restorativeness. The possible effects of lighting on restoration on a behavioural and/or physiological level need to be studied with a targeted study.

ii. In the simulation studies, a setting category division between greenery, mixed environments and parking lots and roads was used. More versatility is needed in the study areas in order to shed more light on the context in which restoration might occur during night-time. In the field studies, the research concentrated on suburban areas. Again, greater variety in the types of settings is needed.

iii. Mental fatigue has been connected with aggressive expressions (Kuo & Sullivan, 2001) Thus, an interesting new line of research may

be suggested — does lighting affect aggressive behaviour through the recovery of directed attention?

iv. Study 3 gave some indications that the being away component of ART and the perceived colour quality of lighting may be connected. In indoor environments, there are reports indicating that spectral power distribution is connected to mood and performance (e.g. Baron et al., 1992; Knez, 1994). Depleted attentional resources may also have a negative effect on mood and cognitive performance. Is the being away component of ART involved in the relationship between spectral power distribution and mood and performance?

v. Does restoration during evening benefit good sleep? After a demanding work day, internal noise may prevent people from relaxing, which is necessary for falling asleep. Restoration promotes cognitive clarity and a relaxed mood, thus it may potentially enhance good sleep. There is also preliminary research evidence connecting mental fatigue and disturbed sleep (Åkerstedt et al., 2003).

vi. What are the perceived brightness and spectral power distribution expectations related to different outdoor functions? This thesis indicates that there may be considerable differences in the perceived brightness expectations related to different functions, whereas there were no direct considerations concerning the colour preferences related to different functions. In general, the preferred colour appearance in near-home suburban environments seems to be located between white and orange colour appearances.

vii. There was no analysis of the impact of other response scales than commonly used 7-point scale. Further research is needed to compare results with other response scales.

5 Conclusions

This thesis gives the first indication of the restorative potential of light. The main finding is that the perceived quality of the lighting environment correlates with the perception of the potential for restoration. Perceived restorativeness was promoted by the focus of light in natural/pleasant scene contents, whereas a hampering effect was produced by the focus of light in urban/unpleasant scene contents. Perceived restorativeness may also be positively connected with the perception of a pleasant colour quality.

Another important indication is that, besides enhancing the perceived restorative potential, focusing light on a pleasant scene contents may enhance preference and a feeling of safety. The research also suggests that the perception of a safe and pleasant lighting environment is connected with the perception of a pleasant colour quality.

Usually, improving the lighting conditions tends to refer to adopting higher illuminances. This thesis suggests that quality-based approaches should be considered as well, and that lighting expectations related to different functions should be taken into account. Perceptions of brightness and dimness may be experienced both positively and negatively depending on a person's needs and expectations. Thus, the needs and expectations of the local residents deserve more attention. The near-home lighting environment may not be a place dominated by fear and insecurity; rather, it should be seen as a potential scene for pleasurable recreational activities and restoration.

However, given the explorative nature of studies 3 and 4, arbitrary field conditions, single-item scales and the small sample sizes, the results must be regarded with caution. Studies 1 and 2 were controlled experiments, but only a small number of scenes were studied and the experiments were based on simulations. Thus further research is needed to validate the findings.

6 References

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Appendix 1

The perceived levels of brightness in the pictures were assessed by 12 subjects, who were different than the actual test subjects. They could see all 6 slides at the same time on a PC monitor so that they could more easily compare the levels of brightness. They were asked to assess the level of brightness in each picture on a 0-6 scale (0=dark, 6=bright) based on their first impressions. As all of the factors were not normally distributed Friedman-test was performed to detect if there are significant brightness differences between the scene pairs ($p<0.05$). Pairwise comparisons indicated that the perceived brightness of picture 3 differed significantly from pictures 1 ($p=0.017$), 5 ($p=0.009$) and 4 ($p<0.001$). Picture 3 was also assessed as the darkest by all subjects (Table 14). The ratings for the other pictures were more mixed, even with the possibility to compare them with each other (pairwise comparisons $p>0.183$).

	N	minimum	maximum	Mean	SD
picture 1	12	1	5	3.58	1.4
picture 4	12	2	6	4.33	1.3
picture 3	12	1	3	1.75	0.9
picture 5	12	1	6	4	1.5
picture 6	12	1	4	3.17	0.8
picture 2	12	2	4	2.83	0.8

Table 14. Perceived brightness: mean values and standard deviations.

If the slight increases in perceived levels of brightness are significant for the perceived restorativeness and brightness increases for the perceived restorativeness, then the setting category effect should be strongest between views 3 and 5. Repeated measures ANOVA with contrast tests was run to find out if the differences in brightness had an effect on the results. The contrast test results for the PRS ($F(2, 68)=2.84$, $p<0.065$) and ROS ($F(2, 68)= 1.957$, $p<0.149$) ratings do not support the hypothesis that slight brightness changes would significantly affect the perceived restorativeness. The ratings for picture 3 do not differ significantly from similar setting category ratings for pictures 1 (PRS, $p=0.207$; ROS, $p=0.938$) and 6 (PRS, $p=0.246$; ROS, $p=0.096$). Picture

3 also received higher mean PRS and ROS ratings (Table 3) than picture 6, which was assessed as being brighter (Table 14).

The mean score differences between the setting categories are not higher between views 5 and 3 than for the other scene pairs, which also indicates that slight brightness changes do not affect perceived restoration (Table 3). Nor is the setting category difference more significant between views 5 and 3 than between the other two picture pairs. Therefore, it could be said that there is no evidence that the slightly lower level of brightness in picture 3 would have exerted differential effects on perceived restorativeness. The findings indicate that content differences rather than slight perceived brightness variations were decisive in accounting for the restoration ratings.

Besides the brightness differences between the picture pairs, we also checked whether there were significant brightness differences between the pictures in relation to the order in which they were presented (see Appendix 2). It is possible that the brightness level of the previous picture might have affected the perceived brightness of the latter picture. The most significant brightness difference in the presenting order is between pictures 3 and 4, which is due to the low brightness of picture 3. This may have affected the perceived levels of brightness for these pictures and also the results. Because 20 subjects in the actual test saw the test slides in reverse order, it was possible to compare the results for the different presenting orders and check whether the slight brightness changes between pictures affected the results.

A one-way ANOVA with a between-subjects factor presenting order was run to find out if the brightness differences in the presenting order had an effect on the results. In picture 4, there was no significant difference in the PRS (ΔM= 0.30, $F(1,33)=0.853$, $p=0.362$) or ROS (ΔM= 0.18, $F(1,33)=0.298$, $p=0.59$) ratings. Neither was there a difference in the picture 3 ratings (PRS, ΔM= 0.003, $F(1,33)=0.013$, $p=0.91$; ROS (ΔM= -0.14, $F(1,33)$= 0.022, $p=0.64$). There is therefore no indication that the presenting order and brightness changes would have affected the results. For the actual test subjects, it was very difficult to detect brightness differences between the scene pairs because the scenes were presented in mixed order and one scene at a time with no possibility to directly compare the scene pairs with each other. The brightness differences were also quite moderate.

There is research evidence that vertical depth can possibly be used to predict preference and may therefore have an effect on restoration (Hartig et al., 1991). The vertical depth (distance to the furthest visible point) of the picture pairs was roughly equal between the picture pairs. Also, the illuminated area of the picture pairs was roughly equal. To check this, a grid was placed above

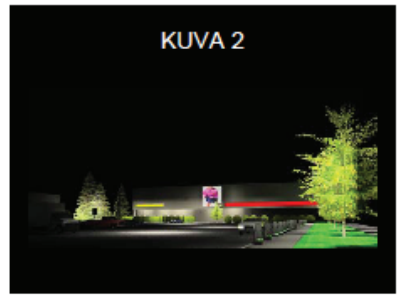
each picture. If more than half of each square was clearly illuminated, it was ranked as illuminated. This type of grid method has also been used by Nordh et al. (2009). The number of illuminated squares was divided by the total number of squares to get a rough estimation of the illuminated area. The picture pairs did not differ in terms of the percentage of the area that was illuminated (Table 15).

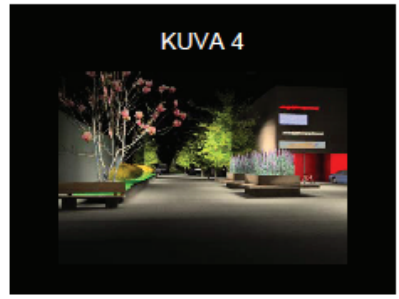
	illum. area	z	p
picture 1	53%	1.51	0.13
picture 4	46%		
picture 6	22%	0.29	0.77
picture 2	23%		
picture 3	17%	-1.54	0.12
picture 5	22%		

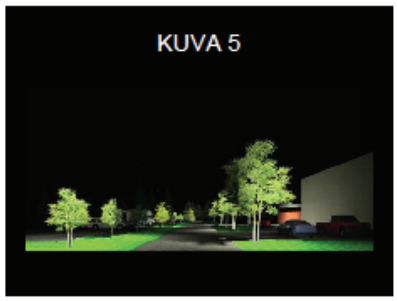
Table 15. Illuminated picture area (%), z-score (z) and the significance levels for the differences in the illuminated area (p) (Tixel programme).

Appendix 2

Slides used in studies 1 and 2B







Appendix 3

The PRS items grouped by a priori subscale membership.

Being Away:

- It is an escape experience from my daily routines
- Spending time here gives me a good break from my day-to-day routine

Fascination:

- My attention is drawn to many interesting things
- The setting has fascinating qualities
- I would like to get to know this place better
- I want to explore the area
- I would like to spend more time looking at the surroundings

Compatibility:

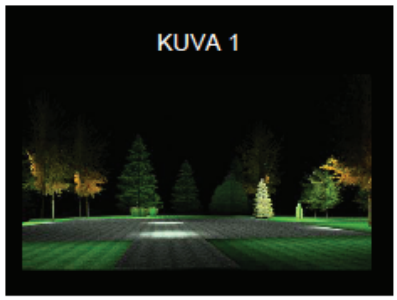
- I can do things that I like here
- Being here suits my personality
- I could find ways to enjoy myself in a place like this
- I have a sense that I belong here
- I have a sense of oneness with this setting

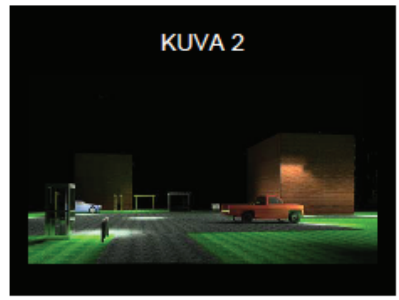
Extent:

- It is a confusing place
- It is chaotic here
- There is a great deal of distraction
- The setting feels restless

Appendix 4

Slides used in study 2A





Appendix 5

English version of the questionnaire used in study 2A.

Questionnaire date _____

During the experiment 6 night time scenes will be projected on the screen.
Each picture is projected on the screen roughly 3 minutes.
There is a serie of statemets concerning each slide. Please read each statement carefully and indicate on 0-6 scal**e - how much does this statement apply to your experinece on the given setting?**
To indicate your answer, circle one of the numbers on the scale beside it.
Verbal describtions for the scale values are as follows:

0 = Not at all
1 = Very little
2 = Rather little
3 = Neither little nor much
4 = Rather much
5 = Very much
6 = Completely

Background information

Gender: O Male

O Female

Age: _____ years

Field of study _____

	disagree						agree
1. I feed stressed	0	1	2	3	4	5	6
2. I feel tired	0	1	2	3	4	5	6

Imagine that you are present in the environment presented by each slide and respond to the statemets based on that asumption.

	disagree						agree
1. My attention is drawn to many interesting things	0	1	2	3	4	5	6
2. Being here suits my personality	0	1	2	3	4	5	6
3. The setting feels restless	0	1	2	3	4	5	6
4. I could find ways to enjoy myself in a place like this	0	1	2	3	4	5	6
5. It is an escape experience from my daily routines	0	1	2	3	4	5	6
6. I have a sense that I belong here	0	1	2	3	4	5	6
7. I have a sense of oneness with this setting	0	1	2	3	4	5	6
8. The setting has fascinating qualities	0	1	2	3	4	5	6
9. I want to explore the area	0	1	2	3	4	5	6
10. I would like to get to know this place better	0	1	2	3	4	5	6
11. It is a confusing place	0	1	2	3	4	5	6
12. There is a great deal of distraction	0	1	2	3	4	5	6
13. It is chaotic here	0	1	2	3	4	5	6
14. I would like to spend more time looking at the surroundings	0	1	2	3	4	5	6
15. Spending time here gives me a good break from my day-to-day routine	0	1	2	3	4	5	6
16. I can do things I like here	0	1	2	3	4	5	6
17. I like this place	0	1	2	3	4	5	6
18. It is frightening here	0	1	2	3	4	5	6

Imagine that you have just spent an hour walking in the setting and respond to the statements based on that assumption.

	disagree						agree
1. I feel peaceful and relaxed	0	1	2	3	4	5	6
2. I feel lame and exhausted	0	1	2	3	4	5	6
3. I don't really feel being my self	0	1	2	3	4	5	6
4. I feel live	0	1	2	3	4	5	6
5. I expect the rest of the day with pleasure	0	1	2	3	4	5	6
6. I feel tensioned	0	1	2	3	4	5	6
7. My thoughts are disordered	0	1	2	3	4	5	6
8. Worries weigh on my mind	0	1	2	3	4	5	6
9. I feel confident	0	1	2	3	4	5	6
10. I would be ready to meet difficult challenges	0	1	2	3	4	5	6
11. It feels easy to concentrate	0	1	2	3	4	5	6
12. It feels easy to make plans for the future	0	1	2	3	4	5	6
13. It feels easy to deal with my daily experiences	0	1	2	3	4	5	6
14. It is difficult to think about important issues	0	1	2	3	4	5	6
15. It is easy to think about myself in relation to other people	0	1	2	3	4	5	6

Appendix 6

English version of the questionnaire used in study 2B.

Questionnaire date _____

During the experiment 6 night time scenes will be projected on the screen.
Each picture is projected on the screen roughly 3 minutes.
There is a serie of statemets concerning each slide. Please read each statement carefully and indicate on 0-6 scal**e - how much does this statement apply to your experinece on the given setting?**
To indicate your answer, circle one of the numbers on the scale beside it.
Verbal describtions for the scale values are as follows:

0 = Not at all
1 = Very little
2 = Rather little
3 = Neither little nor much
4 = Rather much
5 = Very much
6 = Completely

Background information

Gender: O Male

O Female

Age: _____ years

Field of study _____

	disagree						agree
1. I feed stressed	0	1	2	3	4	5	6
2. I feel tired	0	1	2	3	4	5	6
3. It feels easy to concencentrate	0	1	2	3	4	5	6
4. I feel irritated	0	1	2	3	4	5	6
5. I feel patient and calm	0	1	2	3	4	5	6

Statements regarding the slides:

PICTURE 1.

Imagine that you are present in the environment presented by each slide and respond to the statemets based on that asumption.

	disagree						agree
1. My attention is drawn to many interesting things	0	1	2	3	4	5	6
2. Being here suits my personality	0	1	2	3	4	5	6
3. The setting feels restless	0	1	2	3	4	5	6
4. I could find ways to enjoy myself in a place like this	0	1	2	3	4	5	6
5. It is an escape experience from my daily routines	0	1	2	3	4	5	6
6. I have a sense that I belong here	0	1	2	3	4	5	6
7. I feel safe here	0	1	2	3	4	5	6
8. The place is unpleasant	0	1	2	3	4	5	6
9. I have a sense of oneness with this setting	0	1	2	3	4	5	6
10. The setting has fascinating qualities	0	1	2	3	4	5	6
11. I want to explore the area	0	1	2	3	4	5	6
12. I would be frightened to proceed further	0	1	2	3	4	5	6
13. I would like to get to know this place better	0	1	2	3	4	5	6
14. It is a confusing place	0	1	2	3	4	5	6
15. There is a great deal of distraction	0	1	2	3	4	5	6
16. It is chaotic here	0	1	2	3	4	5	6
17. I would like to spend more time looking at the surroundings	0	1	2	3	4	5	6
18. Spending time here gives me a good break from my day-to-day routine	0	1	2	3	4	5	6
19. I can do things I like here	0	1	2	3	4	5	6
20. The place feels threatening	0	1	2	3	4	5	6
21. I like this place	0	1	2	3	4	5	6
22. It is frightening here	0	1	2	3	4	5	6

Imagine that you have just spent an hour walking in the setting and respond to the statements based on that assumption.

	disagree						agree
1. I feel peaceful and relaxed	0	1	2	3	4	5	6
2. I feel lame and exhausted	0	1	2	3	4	5	6
3. I don't really feel being my self	0	1	2	3	4	5	6
4. I feel live	0	1	2	3	4	5	6
5. I expect the rest of the day with pleasure	0	1	2	3	4	5	6
6. I feel tensioned	0	1	2	3	4	5	6
7. My thoughts are disordered	0	1	2	3	4	5	6
8. Worries weigh on my mind	0	1	2	3	4	5	6
9. I feel confident	0	1	2	3	4	5	6
10. I would be ready to meet difficult challenges	0	1	2	3	4	5	6
11. It feels easy to concentrate	0	1	2	3	4	5	6
12. It feels easy to make plans for the future	0	1	2	3	4	5	6
13. It feels easy to deal with my daily experiences	0	1	2	3	4	5	6
14. It is difficult to think about important issues	0	1	2	3	4	5	6
15. It is easy to think about myself in relation to other people	0	1	2	3	4	5	6

Appendix 7

	Area				
Lighting attribute	A	B	C	D	E
Safety: Perceived safety produced by the light	0.822 p≤0.001				
Pleasantness: Pleasant lighting			0.651 p≤0.001		0.751 p≤0.001
Pleasantness: Lighting suited to the area		0.622 p=0.001			
Colour quality					
Distribution: Evenness of lighting on the walkway					
Distribution: Lighting is extensive					
Brightness: Perceived brightness on the walkway				0.677 p≤0.001	
Glare					

Table 16. Significant (p≤0.01) connections and standardised coefficients for the PRS and lighting attributes in the five test areas (A-E), as suggested by linear regression analysis (stepwise method).

Errata

(1) Term confusion in Publication I

– ‘restorative experience’ and ‘experienced restoration’ should be replaced with ‘perceived restorativeness’

Except in the first line of paragraph 8: ‘What is important is that a restorative experience is possible when all of these interrelated aspects characterise the experience of a scene or setting.’

This thesis considers outdoor lighting as a fundamental factor affecting environmental experiences after dark. It explores the restorative potential of outdoor lighting within the framework provided by attention restoration theory (ART). Also, perceived safety and preference variables are included in the research work. These factors may have a major effect on outdoor space use after dark and on the level of satisfaction with the neighbourhood in which a person lives.

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