Powered by nature : the psychological benefits of natural views and daylight

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The psychological benefits of natural views and daylight

Femke Beute

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For my mother, Annemarie, my tower of strength.
and
For Fenna, my lovely niece. Five days with you was far too short.
You will always be in our hearts.

Contents

Part I

Psychological pathways

And it left me wondering
Should I jump into this
Head first or feet first
(Junip - Head first)

Chapter 1

Salutogenic effects of the environment.
Health protective effects of nature and daylight[1]

Eyes open wide, blinded by the sun now
Orange and white, dark red, green and yellow
Rainbow colours! Do not hide, see the view!
Step aside, go through!
(Jonsi - Sticks and stones)

[1] This chapter is based on: Beute, F., & de Kort, Y.A.W. (2014) Salutogenic effects of the environment: Review of the health protective effects of nature and daylight. *Applied Psychology: Health and Well-being, 6,* 67-95.

Abstract. Both nature and daylight have been found to positively influence health. These findings were, however, found in two separate research domains. This chapter presents an overview of effects found for daylight and nature on health and the health-related concepts stress, mood, and executive functioning and self-regulation. Because of the overlap in effects found and the co-occurrence of both phenomena, we point to the need to consider daylight factors when investigating effects of nature and vice versa. Furthermore, the existence of possibly shared underlying mechanisms is discussed and the need to unify the research paradigms and dependent variables used across the two research fields. Last, in view of the beneficial effects of both phenomena on health our objective is to raise awareness amongst the general public, designers, and health practitioners to use these naturally available phenomena to their full potential.

1.1 Introduction

Environmental factors influence our health in many ways, both positively and negatively. Noise and density are examples of factors that can affect our health negatively (Cohen, Glass, & Phillips, 1979); other factors, such as a view to nature, are seen as containing health protective qualities. Such beneficial or even protective effects were already recognized by Aaron Antonovsky. His salutogenic theory (1979) focuses on how people use resources to remain healthy when faced with a variety of stressors, as opposed to pathogenic studies investigated which factors cause illness. These resources, which maintain and promote health, have been labeled general resistance resources (Lindström & Eriksson, 2005). In this dissertation we will discuss two environmental factors that could serve as general resistance resources - daylight and nature.

Beneficial effects of natural environments have been found for stress, mental fatigue, and self-regulation failure. In this chapter, a closer look will be taken at how viewing nature can help overcome these very prominent threats to mental and physical health of our present-day society. In addition, literature which indicates that exposure to daylight can have very similar beneficial effects will be introduced. We will present an overview of the proposed pathways through which both factors can influence health and will critically assess the empirical evidence for their beneficial effects.

An extensive search for relevant publications was performed in scientific domains including medical and psychiatric sciences, epidemiology, clinical, social, environmental, and health psychology, architecture and landscape architecture, describing studies that report (or refute) effects of exposure to nature or daylight. Our aim was to cover the most important classes of health effects and mechanisms. In bringing together empirical findings on health outcomes from these different research domains, we reveal the overlap in beneficial health effects of both phenomena.

The subject area of the current dissertation is wide and hence we had to exclude certain topics that are interesting in themselves, yet less relevant in the context of the comparison of nature versus daylight effects. Two important restrictions need to be mentioned explicitly here. First, for nature the main focus will be on passive exposure to either real or mediated (slideshows and videos) nature - as opposed to active engagement with it through for instance gardening or hiking. Second, in considering the effects of light, there is a large body of evidence suggesting melatonin suppressing and alerting effects of bright light exposure during the biological night. As we restrict ourselves to effects of daylight, we will not report on these effects (for an overview, see e.g., Boyce, Hunter, & Howlett, 2003; CIE, 2009). We will, however, report on effects of daytime light exposure on the circadian rhythm and sleep. Studies using bright white electric light will therefore also be reported, as long as the studies were conducted during the biological day. Daylight and natural scenes are both part of nature. In the remainder of this dissertation, however, we will often refer to nature when speaking of views to natural scenes only, continuing an existing tradition within restoration research to abbreviate natural scenes or natural environment to 'nature'.
Even though exposure to nature and daylight often coincide, whether outdoors or indoors through windows, in the scientific literature both phenomena are almost exclusively studied separate from each other. One disadvantage of this detachment is that in some studies restorative outcomes of one phenomenon potentially confound the other, thus blurring the causal processes behind them. In this dissertation, we aim to learn more about potential underlying mechanisms and ways to explore those further.

In this dissertation, we take the broad perspective on health advocated by the World Health Organization: 'Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (1946, pp. 100). This definition stresses not only the importance of physical health, but also of mental health and wellbeing as central components of health. We will sequentially discuss effects of nature and daylight on stress, mood, and executive functioning and self-regulation as important elements of health, and lastly discuss reported effects on health. But first, we will take a look at the proposed underlying pathways for beneficial effects of nature and daylight.

1.2 Pathways described in literature

1.2.1 Nature

Effects of nature on health are generally attributed to underlying psychological pathways, often with an evolutionary basis. Preference is a core component of theories explaining beneficial effects of nature and has been proposed to serve adaptive purposes by guiding human beings to approach healthy environments and avoid threatening environments (Hartig et al., 2010; S. Kaplan, 1987; Ulrich, 1983). Preference can be formed instantly and without conscious cognitive deliberation (Zajonc, 1980), but learned associations or cultural values can also influence preference (Ulrich, 1983; Tuan, 1974). Psycho-Evolutionary Theory (PET) argues that evolution has favored those individuals who had an adaptive response to unthreatening natural environments that contained elements beneficial for wellbeing (stress reduction and restoring energy) as well as for survival (i.e., low risk, food and water available; Ulrich, Simons, Losito, Fiorito, Miles, & Zelson, 1991). Indeed, we will see that research indicates that (unthreatening) natural environments are generally preferred over urban environments.

According to Ulrich and colleagues (1991) a pre-cognitive emotional response exists which subsequently influences attention, physiological responding, and behavior. Viewing unthreatening nature in these modern urbanized times should therefore still help people restore from stress by reducing negative affect, increasing positive affect, and decreasing physiological arousal (Ulrich et al., 1991). In line with the salience of environmental characteristics for approach and avoidance behavior, the biopsychosocial model of challenge and threat (Blascovich & Mendes, 2000) proposes that person-environment interactions consist of affective, cognitive, and physiological responses. Indeed, research into the effects of nature has found effects in all three components, as we will see in later sections.

Recently, some criticism has been put forward regarding the central role of evolutionary preferences in restoration (see Joye & van den Berg, 2011). Although preferences generally correlate substantially with (perceived) restorative potential, little is known about the causal direction in this relationship (van den Berg, Koole, & van der Wulp, 2003). It could be that we prefer restorative environments because they are good for us, but natural environments could also be restorative because we prefer them and hence induce positive affect. The fact that preference for natural scenes increases when in need of restoration (Hartig & Staats, 2006) implicitly supports the first pathway. On the other hand, people sometimes are unaware of beneficial effects of nature and underestimate the restorative potential of nature (Nisbet & Zelenski, 2011), which implicitly pleads against it. Preference, thus, appears to be highly interrelated with restorative potential but does not necessarily cause it.

Attention Restoration Theory (ART; S. Kaplan, 1995) was proposed to explain beneficial effects of nature on executive functioning. Stephen Kaplan (1995) argues that certain activities and environments, including modern life in urban environments, can cause a phenomenon labelled attention fatigue. Urban environments place demands on our attention by for instance the possibility of crime (Cohen & Spacapan, 1978). ART distinguishes between two types of attention, labelled ‘voluntary’ and ‘involuntary’. Voluntary attention, also called directed attention, is under conscious control. Prolonged exertion of this control requires effort. Over time, the resource necessary to control attention will become depleted resulting in directed attention fatigue. This effect will occur even for pleasant tasks (Parsons, 1991). Directed attention fatigue is characterized by fatigue, an inability to concentrate, and irritability (S. Kaplan, 1995). This conceptualization of directed attention as a limited resource is quite similar to the notion of self-regulatory capacity – ego-strength (Baumeister,

1998) – as a limited resource and may even describe the same phenomenon (Kaplan & Berman, 2010).

ART states that it is through the mechanism of involuntary attention that the depleted directed attention resource can become replenished (Berman, Jonides, & Kaplan, 2008; Kaplan & Kaplan, 1982). Involuntary attention is a bottom-up controlled process (Berman et al., 2008) that needs no conscious control or inhibition, because attention is drawn immediately by fascinating stimuli. It has further been postulated that especially soft fascination makes stimuli restorative (S. Kaplan, 1995). Softly fascinating stimuli draw attention while at the same time leaving room for contemplation. Hard fascination, on the other hand, also draws attention automatically but in an all-consuming fashion. An example of hard fascination is watching engaging television content. Soft fascination such as that elicited by nature enables restoration from directed attention fatigue. In a similar fashion, Cohen (1978) has proposed that nature can help overcome overstimulation.

1.2.2 Daylight

Whereas proposed underlying mechanisms for restorative effects of nature are considered mostly psychological, beneficial health effects of daylight are mainly attributed to biological processes. There are at least two known biological pathways through which daylight can positively influence health. First of all, vitamin D is produced when sunlight touches our skin, which in turn has been linked to many health outcomes, such as reduced risks of cancer and cardiovascular disease (Webb, 2006; Holick, 2008), but also to improved mood via the production of serotonin (Landsdowne & Provost, 1993).

A second pathway for daylight to affect health is through the circadian system. The discovery of retinal ganglion cells with a direct connection to the suprachiasmatic nucleus (SCN) has induced a strong increase in light research (Berson, Dunn, & Takao, 2002; Foster, Provencio, Hudson, Fiske, De Grip, & Menaker, 1991). The SCN is where our internal biological clock resides. This so-called non-image forming pathway is thought responsible for the entraining and phase-shifting effects of light on our biological rhythm (Berson et al., 2002). One important finding is that these ganglion cells are particularly sensitive to light with wavelengths within the blue spectrum (Brainard, Hanifin, Greeson, Byrne, Glickman, Gerner, & Rollag, 2001; Thapan, Arendt, Skene, 2001). Daylight naturally contains light across the full visual spectrum, including blue light. In this way, daylight acts as an environmental cue to correctly entrain our circadian rhythm.

Recent research indicates that the brain's responses to light extend beyond entrainment of the biological clock and include direct responses in alertness-related subcortical structures (hypothalamus, brainstem, thalamus) and limbic areas (amygdale and hippocampus), and even modulation of activity in cortical areas (Vandewalle, et al., 2009). Furthermore, effects on brain serotonin turnover have been proposed to run through retinal light exposure (aan het Rot, Benkelfat, Boivin, & Young, 2008). This implies that, in addition to entraining the biological clock to the night-dark cycle, light also shows immediate effects on alertness, cognitive performance, and even affective responses (VandeWalle et al., 2009; Vandewalle et al., 2010).

These first pathways for the effects of daylight on health pertain to purely biological mechanisms, but psychological mechanisms have also been proposed, since humans have a strong preference for daylight as opposed to artificial light (e.g., Boyce et al., 2003). It is therefore possible that – much like nature – daylight positively influences wellbeing through affective, associative, or appreciative routes.

Having introduced the proposed underlying pathways, we will now look at the evidence for salutogenic effects of nature and daylight on stress, mood, executive functioning and self-regulation, and mental and physical health. In Appendix A, overview tables can be found of all individual studies, including brief characterizations of study type, sample size, intervention type, and study outcome. Furthermore, we report whether and how possible confounds were controlled in each study .

1.3 Stress

We all experience stress from time to time. Stress influences our mental state, inducing a shift towards more negatively toned emotions (Thayer & Brosschot, 2005; Ulrich et al., 1991). It also impacts our physiological status - often labelled the fight-or-flight response (Selye, 1950). This fight-or-flight response has evolutionary significance by enhancing quick physical responses to dangerous situations, for instance by enabling quick transport of oxygen and nutrients to the muscles. Importantly, this physiological response is also activated for stressful situations in which no physical response is required. Moreover, we turn on this response when we are ruminating over a stressor in the past or when we are anticipating a stressor in the future, which will result in prolonged physiological activation (Brosschot, Pieper, & Thayer, 2005). The stress response consists of a complex interplay between the central nervous system and peripherally located functions, and includes for instance the inhibition of vegetative functions and an increase in cardiovascular tone (Chrousos, 2009).

It is exactly this prolonged activation of this stress response that can be harmful for health. More specifically, it is the accumulating effect of activating the stress-response (‘allostatic load’, Mcewen, 1998) that can increase the risk for certain diseases (e.g. cardiovascular disease, arthritis, diabetes) as well as worsen already existing illnesses (Cohen et al., 2012). Prolonged stress can even cause damage to the hippocampus, degrading memory (Sauro, Jorgensen, & Pedlow, 2003). Last, high levels of arousal and an increase in negative emotions can influence cognitive performance directly as well (Ellenbogen, Schwartzman, Stewart, & Walker, 2002).

Some claim that it is mostly a lack of restoration that causes stress to affect health negatively (Brosschot et al., 2005). Several ways are proposed to restore from stress, as for instance engaging in social interaction, exercise, or meditation (Smith & Baum, 2003). We will now discuss how nature and daylight can help recover from stress.

1.3.1 Nature and Stress reduction

Research points at negative effects of urban environments. However, it is not always clear whether this effect is due to a lack of nature or the presence of other urban factors and stressors. A recent fMRI study demonstrated that living and growing up in urban areas changes brain responses to stress in a negative way as compared to small-town and rural dwellers (Lederbogen, et al., 2011). Prolonged urban stress produced higher brain activity in brain areas related to stress as well as negative affect. Natural elements in urban areas, in contrast, are demonstrating restorative effects. An exploratory study in a deprived area of Scotland revealed that more green in the neighbourhood was related to a steeper cortisol slope (indicating a more healthy cortisol secretion system), together with lower levels of self-reported stress (Ward Thompson, Roe, Aspinall, Mitchell, Clow, & Miller, 2012).
The stress reducing potential of nature was, among others, reported by Ulrich and colleagues (1991) who let participants watch a stressful movie followed by one of six movies recorded in either a natural or an urban environment. They found that physiological recovery from the stressor was faster after viewing nature movies than after urban movies. Furthermore, positive affect increased more, and negative affect decreased more, after watching movies of natural scenes than after watching movies of urban scenes. Other studies also report that watching nature can lower physiological arousal (Laumann, Gärling, & Morten Stormark, 2003) and increase mood (Berman et al., 2008; Hartig, Evans, Jamner, Davis, & Gärling, 2003). In a study by Laumann and colleagues (2003), cardiac inter-beat interval was continuously monitored. Heart rate decreased for participants viewing a natural video after performing a task inducing mental fatigue as compared to their baseline, while for participants watching an urban video heart rate remained constant. Hartig and colleagues (2003) demonstrated that walking in a natural as opposed to an urban environment resulted in a decrease in blood pressure.

Evidence for the stress-reducing effect of viewing natural environments was also found in a study not specifically designed to test nature restoration theories. Fredrickson and Levenson (1998) studied the effects of positive affect on recovery of the cardiovascular system following an emotional stressor. They found that cardiovascular recovery was faster when viewing movies with positive content as compared to watching either a neutral or sad movie (abstract movie of sticks and sad movie scene in which a boy watches his father die respectively). Importantly, both positive movies consisted of content that could be categorized as natural: the first one showed waves breaking on a beach, the other portrayed a playful puppy. This finding was replicated in a later study as well (Fredrickson, Mancuso, Branigan, & Tugade, 2000). Furthermore, they investigated spontaneous recovery (no movie after the stressor) and found that faster recovery indeed was due to viewing the natural content.

There is also evidence suggesting an immunizing effect of viewing natural scenes on stress (Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998). In this study, participants viewed a video of a simulated drive just before and immediately after a stressor. The content of the simulated drives was either natural or urban. Not only did they find that stress recovery was faster when viewing the natural scenes after stress induction, the findings also suggested that the pre-stressor simulated drive through a natural area decreased the intensity of the stress response to the stressor. This buffering effect was, however, only found on one of the four indicators (i.e., on skin conductance, not on cardiovascular measures, facial EMG, or performance). In a cross-sectional study, Wells and Evans (2003) further found that nearby nature in rural areas buffered the negative effects of stress on well-being of children.

1.3.2 Daylight and stress reduction

There are some indications in the literature that light too has stress-reducing effects. In a survey among nurses, Alimoglu and Donmez (2005) found that nurses who reported receiving less than three hours of daylight on an average working day, reported higher work-related stress and lower work satisfaction than nurses receiving more than three hours daylight per day. These findings must be considered with caution, as nurses receiving less than three hours of daylight per day also had significantly more night duties and generally worked more in high-demanding units such as the intensive care and emergency department. Another study reported the efficacy of bright light treatment for tackling emotional exhaustion in burnout (Meesters & Waslander, 2009). Additional evidence comes from a study in which exposure to bright -as opposed to dim- electric light was found to improve heart rate variability in healthy subjects (Rechlin, Zimmerman, Schneider, Weis, & Kaschka, 1995). Heart rate variability has been positively related to activation of the parasympathetic nervous system (Bilchick & Berger, 2006), suggesting stress reducing effects of bright light. Light has also been found to influence cortisol production, but with mixed directions. The transition from dim to bright light in the very early morning resulted in elevated cortisol levels during the morning peak (Leproult, Colecchia, L'Hermite-Balériaux, & van Cauter, 2001). In contrast, exposure to bright light – either during the night or morning - was found to acutely suppress cortisol production in a second study (Jung, Khalsa, Scheer, Cajochen, Lockley, Czeisler, & Wright, 2010) or showed no effect on cortisol levels at all in a third one (Rüger, Gordijn, Beersma, de Vries, & Daan, 2005).

1.3.3 Reflection

Exposure to nature and bright (day)light can reduce stress albeit that the evidence for stress-reducing effects of daylight is still very preliminary and certainly needs more and closer inspection. Table 1 of Appendix A presents an overview of the studies described in this section. This table reveals that the stress-reducing potential of nature is often studied by contrasting effects of nature with the effects of urban environments. Moreover, not all urban environments used are equal and particularly the attractiveness of these environments varies substantially. Without a no-stimulus, or other type of control condition – such as for instance neutral content with geometrical patterns as used by Fredrickson & Levenson (1998) - such studies do not rule out the alternative explanation that the effects are due to detrimental effects of urban environments rather than beneficial effects of natural environments. Another option is taking baseline measures to better understand the direction of effects as was for instance included in the study by Hartig and colleagues (2003). In addition, differences between natural and urban environments stretching beyond mere visual aspects, as for instance differential behavioral options and social factors, could influence the restorative potential of natural versus urban scenes.

Despite the issues raised above, there are commonalities in the stress reducing effects of daylight and nature through the cardiovascular system, and in particular through activation of the parasympathetic system. Moreover, both natural scenes and light have been found to influence cortisol production, a hormone related to stress, although the reported effects of light are inconsistent. This inconsistency has been attributed to differences in research designs, including duration of exposure, timing of exposure (differences in circadian phase), and intensity of the light (Jung et al., 2010). Moreover, differences in spectral composition of the light could also be a factor here. In the next section, we will take a closer look at a concept closely related to stress, namely mood.

1.4 Mood

An important outcome of stress is a change in mood, in particular an increase in negative affect and a decrease in positive affect. Several scholars have proposed a relation between positive mood and physical health (e.g., Salovey, Rothman, Detweiler, & Steward, 2000; Seligman & Csikszentmihalyi, 2000). In an extensive review on how positive affect influences health, Pressman and Cohen (2005) found convincing evidence for beneficial effects of positive emotions on mortality, morbidity, disease severity, and subjective health. However, they also found that arousal plays an important role in the effects of positive affect on health. When positive emotions are accompanied by arousal they may also harm health (Pressman & Cohen, 2005). Extreme positive emotions can have the same effect on our physiological system as the stress-response, although the magnitude of effects of strong positive emotional arousal on the cardiovascular system is often smaller than for negative emotions such as anger (Pressman & Cohen, 2005). Moreover, heart rate responses have been found to persist longer after negative than after positive emotions (Brosschot & Thayer, 2003). Therefore, calm positive emotions are especially beneficial to health (Pressman & Cohen, 2005).

Positive emotions can also improve health by helping people build resources to buffer future stressful events (Fredrickson & Joiner 2002; Pressman & Cohen, 2005). According to the Broaden-and-Build Theory (Fredrickson & Joiner 2002; Fredrickson, 2004) positive emotions broaden our mind-set, enabling more global, creative thinking. This, in turn, enables us to expand both our mental and social resources. These resources will help us cope with future stressors more effectively, buffering potential harmful effects of stress on our health. The present section discusses research investigating nature and daylight's potential to induce (calm) positive emotions and mood.

1.4.1 Nature and mood

According to Psycho-Evolutionary Theory (Ulrich et al., 1991), unthreatening natural environments should evoke a pre-cognitive affective response. Automatic affective responses to natural environments have indeed been reported (Hietanen & Korpela, 2004). However, as we will see in Chapter Two, these rapid affective responses to natural versus urban environments were not replicated in this dissertation.

As discussed in the previous section, viewing unthreatening nature after stress can result in an increase in positive affect and a decrease in negative affect (Berman et al., 2008; Hartig et al., 2003, Hartig, Böök, Garvill, Ollson, & Gärling, 1996; Ulrich et al., 1991). Hartig and colleagues (2003) compared mood effects of walking in a natural environment to those walking in an urban environment. They found that positive affect increased during the walk in the natural environment, and decreased in the urban environment. Conversely, anger and aggression decreased in the natural environment and increased in the urban environment. In the study by Ulrich and colleagues (1991) described earlier, participants viewed a video of either natural environments or urban environments after watching a fear-inducing movie. They found that participants who watched the natural movie reported lower levels of fear and anger/aggression and higher levels of positive affect than participants watching urban settings.

1.4.2 Daylight and mood

Mood enhancing effects of daylight exposure have been found in a number of studies. Exposure to daylight for 30 minutes (approximately 3000 lux falling on the eye) was found to improve positive mood in comparison to modest levels of electric lighting (lower than 100 lux on the eye and on the desk), although this was not accompanied by a decrease in fatigue or sadness (Kaida, Takahashi, & Otsuka, 2007). Similar mood effects of higher light levels (> 1000 lux) were reported in a field study, in which mildly seasonal participants wore a wrist-mounted device registering light exposure and reported on social interaction and mood (aan het Rot, Moskowitz, & Young, 2008). Technically, the device cannot distinguish between electric and natural light sources. However, light levels over 1000 lx are very likely to be due to daylight exposure. Mood in general was also better in summer than in winter. A study investigating daily light dosage effects in the general population found no relation between daytime light exposure and pleasure and arousal (Hubalek, Brink, & Schierz, 2010). In this study, however, mood was only measured in the evening and compared to an aggregated level of daytime light exposure excluding more subtle momentary effects of light level on mood. The brain's reward system (measured in positive affect) has also been found to exhibit a diurnal pattern (Murray et al., 2009)

The amount of daylight and sunshine are of course closely related to the weather. Interestingly, weather type is often used as an external information source for our current mood and vice versa (Messner & Wänke, 2011; Schwarz & Clore, 1983). Studies investigating the effects of weather on mood have, however, reported mixed results. More sunshine has been found related to decreased negative affect and tiredness in an online diary study (Denissen, Butalid, Penke, & van Aken, 2008). In an experience sampling study comparing momentary assessment of mood with hourly weather data, a relation was found between positive affect and amount of sunlight, while darkness was inversely related to alertness (Kööts, Realo, & Allik, 2011). To complicate this picture, weather studies also report that people can respond differently to the same weather or seasonal change (e.g., Denissen et al., 2008; Klimstra et al., 2011). Moreover, effects of weather on mood are dependent on age, amount of time spent outdoors, the season, and personality type (Denissen et al., 2008; Keller, et al., 2005; Kööts, et al., 2011).

As was reported earlier, sunlight on the skin promotes the synthesis of vitamin D, which has been linked to the production of serotonin (Landsdowne & Provost, 1993). Serotonin, among other functions, is a neurotransmitter related to mood, suggesting that via this route sunshine can also improve our mood. Indeed, serotonin concentrations in jugular veins have been found positively correlated to sunshine (Lambert, Reid, Kaye, Jennings, & Esler, 2002). Similarly, oral intake of vitamin D supplements during winter has been found to increase positive affect (Landsdowne & Provost, 1993). It has also been proposed that retinal exposure to bright light can increase brain serotonin production (aan het Rot, et al., 2008).

Mood-enhancing effects of light appear to extend beyond natural lighting. The use of bright electric light exposure has been associated with positive mood effects in a field study in office environments (Partonen & Lönnqvist, 2000). Office workers received four weeks of additional bright light exposure at their desk (approximately 2500 lux, 6500 K), alternating with four weeks of no additional bright light exposure. Bright light exposure reduced depressive symptoms and increased feelings of vitality. Note that this study was conducted in Finland, in the darker months of the year, with high morbidity rates for seasonal affective disorder. An improvement in mood was also found after bright light exposure at the workplace for people with subsyndromal symptoms of Seasonal Affective Disorder (Avery, Kizer, Bolte, & Hellekson, 2001). Although neither study focused on persons diagnosed with SAD, it is possible that the mood effects found are due to better synchronization of the biological clock.

On a different note, brain research is indicating that light -depending on its spectral composition- directly modulates the processing of emotional stimuli, with blue light increasing responses to auditory emotional stimuli (VandeWalle et al., 2009; Vandewalle et al., 2010). The authors project that their findings may help understand the mechanisms by which changes in lighting environment improve mood in mood disorders as well as in the general population (see also Section 1.6.2). Recall that daylight abundantly contains this blue component, whereas electric light -depending on the specific light source- generally contains much less.

Effects of light may even exist on a conceptual level. Light and dark are often used in our daily lives as a metaphor for the good versus the bad. Social psychology studies suggest that when making evaluations, people automatically assume that bright objects are good whereas dark objects are bad (Meier, Robinson, & Clore, 2004). Furthermore, people generally associate light with positive affect and dark with negative affect (Meier, Robinson, Crawford, & Ahlvers, 2007; Okubo, & Ishikawa, 2011). Interestingly though, later studies by Lakens, Semin, and Foroni (2012) indicated that the positive conceptual association of brightness is only activated when it is contrasted with darkness. Construal level has also been found under influence of light, with more global processing in dark than in bright environments (Steidle, Werth, & Hanke, 2011).

1.4.3 Reflection

Literature reports that both daylight and nature can positively influence mood (see Table 2 in Appendix A for an overview). Mood, in turn, can have health protective effects especially when calm positive emotions are elicited. This section demonstrated that -as opposed to research into stress- a strong empirical basis exists for the beneficial effects of daylight on mood.

Table 2 reveals that -again- most studies concerning the effects of nature on mood used a paradigm in which effects of nature were compared to effects of urban environments, leaving some ambiguity about whether effects are due to positive influence of nature or to a detrimental effect of urban environments albeit that again some studies have used a baseline comparison. A substantial number of studies have reported preference for natural over urban environments. As stated earlier, preference and restoration are highly correlated but it is not yet clear whether preference directly causes restorative effects.

For daylight, most of the research has focused on biological mechanisms underlying effects of daylight on mood and in some cases electric bright light exposure indeed did show similar effects to daylight exposure. Sometimes the type of source (natural vs. electric light) and the light intensity (illuminance on the eye) were confounded in research designs.

Not only has positive affect been linked with stress, it has also found relevant for self-regulation. In the next section, we will take a closer look at a third way through which nature and daylight can be good for health, namely by affecting self-regulation and executive functioning.

1.5 Self-regulation and Executive functioning

The lion's share of behaviours we engage in are automatic and require little conscious thought. When we need to overrule our inclinations or feelings, we need to exert (conscious) control over thoughts and behaviours. This process has been labelled self-control or self-regulation. Executive functioning, a higher-order cognitive process (Suchy, 2009), is often mentioned as the process through which self-regulation is exerted. Associations have been found between executive functioning and several health indicators (Hagger, 2010), for instance obesity (Boeka & Lokken, 2008; Elias, Elias, Sullivan, Wolf, & D'Agostino, 2003), cardiovascular disease (Elias et al., 2003; Grossarth-Marticek & Eysenck, 1995; Waldstein et al., 2003), and psychopathology (Bentall, Kinderman, & Manson, 2005; Goldberg et al., 1993; Kashdan, Weeks, & Savostyanova, 2011; Moritz, Birkner, Kloss, Jahn, Hand, Maasen, & Krausz, 2002) stressing the importance of self-control in daily life. In some instances, lower self-control capacity results in worse health outcomes (e.g., consider smoking behaviour). On the other hand, pre-existing illnesses can place a high demand on self-regulation, for instance by the continuous need to suppress pain or anxiety. The exertion of self-regulation does not come without a cost. Executive functioning requires much energy (Suchy, 2009) and has been found to rely on a limited resource (Baumeister et al., 1998; Hagger et al., 2010). Depletion of this resource has been labelled ego-depletion within the self-control strength model (Baumeister et al., 1998) and may be very closely related to directed attention fatigue as referred to in Attention Restoration Theory (Kaplan & Berman, 2010).

A term related to ego-depletion is subjective vitality, or *"one's conscious experience as possessing energy and aliveness"* which can further be defined as *"having positive energy available to or within the regulatory control of one's self"* (Ryan & Fredrick, 1997, pp. 530). Subjective vitality is related to both physical and psychological wellbeing and is a complex and dynamic concept, influenced by both somatic and psychological factors. Sleep patterns, blood glucose level, diet, exercise, social relatedness, mood, and the satisfaction of basic psychological needs can all influence subjective vitality (Ryan & Deci, 2000; Ryan & Fredrick, 1997). Ego-depletion can be overcome by increasing vitality (Muraven, Gagné, & Rosman, 2007; Ryan & Deci, 2008). Furthermore, people who feel vital will replenish their resources faster (Muraven et al., 2007). In other words, factors that increase vitality will also help overcome ego-depletion.

Because of the limited capacity for self-control and its implications for health, finding ways to overcome depletion -ego-replenishment- can yield positive health outcomes. Earlier research has already shown a number of ways through which ego-replenishment can occur, for instance consuming glucose (Gaillot et al., 2007), positive affect (Tice, Baumeister, Shmueli, & Muraven, 2007), and autonomy (Muraven et al., 2008). If nature and/or daylight could also serve to replenish the depleted ego, this would provide individuals with a free and generally easily available source for recovery. Indeed, there are some indications in the literature that this could be the case as will be discussed in this section.

1.5.1 Nature and executive functioning/self-regulation

Ego-depletion is typically demonstrated by having participants perform a task that requires self-control (and a control group performing a task that does not rely on this resource) and testing performance on a subsequent task, which also requires self-control. Ego-replenishment can be studied by adding a manipulation in between the two depleting tasks.

As mentioned earlier, the theoretical link between ego-depletion and restorative effects of nature has only been made recently (Kaplan & Berman, 2010). Consequently, few -if any- studies have explicitly employed this paradigm to test ego-replenishing effects of nature. However, quite a few studies report positive findings on executive functioning after mental fatigue induction, which also provides support for beneficial effects of nature on self-control. A number of studies followed a paradigm of inducing attention fatigue, followed by an outdoor walk and a subsequent cognitive performance test. Hartig and colleagues (2003) report that performance on an attention task (Necker Cube Pattern Control task) increased during and after walking in a natural environment but not in an urban environment. Berman and colleagues (2008) also found an increase in cognitive performance for those walking in a natural versus an urban environment. In both studies, improvements in executive functioning were accompanied by improvements in mood. This is relevant, as Tice and colleagues (2007) argue that positive affect may be the driving mechanism behind ego-replenishment. However, statistical analysis indicated that in Berman’s study (Berman et al., 2008), mood did not mediate the effect of nature on cognitive performance.

Other studies were conducted in a laboratory and involved participants watching pictures of nature. These studies also demonstrated that performance on tasks requiring directed attention (measured with the Attention Network Task and an attention-orienting task) improved after watching pictures of natural environments, but not after watching pictures of urban environments (Berman et al., 2008; Laumann et al., 2003). In addition, Laumann and colleagues (2003) found that watching a nature video decreased attentional selectivity. Kuo and Sullivan (2001) found that residents who had more greenery surrounding their homes performed better on an attention task (the Backwards Digit Span Task) and displayed less aggressive behavior. In general, there is a substantial body of experimental research supporting the idea that nature helps restore from attention fatigue.

In addition to experimental explorations, cross-sectional and quasi-experimental research has been employed to test for possible beneficial effects of nature. A series of experience sampling studies produced evidence that being in nature can increase subjective vitality (Ryan, Weinstein, Bernstein, Brown, Mistretta, & Gagné, 2009). More specifically, they found that being outdoors increased subjective vitality and this effect was mediated by the presence of nature. As we have seen, vitality can help overcome ego-depletion. Tennessen and Cimprich (1996) found that students living in a dormitory with a more natural view performed better (in their room) on a number of executive functioning tasks. A study investigating cognitive performance of children before and after relocation further found that children with more green in the proximity of their homes after the relocation than before also improved most in cognitive performance (Wells, 2000).

1.5.2 Daylight and executive functioning/self-regulation

Exposure to bright light – natural or electric - has been found to significantly increase vitality in healthy office workers (Partonen & Lönnqvist, 2000) as well as in working-aged people with mild depressive symptoms (Leppämäki, Partonen, & Lönnqvist, 2002). In the experience sampling study by Ryan and colleagues (2009) it was found that being outdoors increased vitality. This effect might be due to daylight exposure, but can also be attributed to other factors (e.g., physical activity or exposure to nature).

Direct effects of bright diurnal light on cognitive performance – and in particular executive functioning – have been reported. These were first established for individuals who had experienced substantial sleep deprivation (Phipps-Nelson, Redman, Dijk, & Rajaratnam, 2003). Later, similar beneficial effects of bright light on cognitive performance during the day were also found without sleep deprivation (Smolders, de Kort, & Cluitmans, 2012). Both studies found effects of light only on vigilance tasks, not on higher order executive functioning tasks. However, improvements on more complex tasks were reported in a recent study investigating executive functioning after spending eight hours in mainly daylight compared to only electric light (Münch, Linhart, Borisuit, Jaeggi, & Scartezzinni, 2012). Note that since light intensities in the daylight condition were much higher than the electric light condition, it is unclear whether in this particular study effects were due to the higher light intensity or caused by other characteristics of daylight. An fMRI study has further demonstrated that being exposed to bright light during cognitive performance influences thalamic activity (vandeWalle, et al., 2006). These thalamic brain structures are in turn related to cognitive performance. For now, it appears safe to say that vigilance is likely to benefit from bright light exposure, but for other elements of executive functioning insufficient empirical evidence exists.

1.5.3 Reflection

Both daylight and nature may influence health by helping overcome or even preventing depletion of self-regulation resources (see Table 3 of Appendix A). The evidence for nature's attention-restoring capacity is stronger than for daylight: studies have demonstrated effects of nature on both objective performance and on subjective vitality. Whether these effects are due to the information processing characteristics of nature, or instead run via positive affect induced by nature remains uncertain.

The evidence for daylight effects on executive functioning and self-regulation is as yet less strong. Bright light -electric or natural- consistently improves subjective vitality, a concept closely related to executive functioning, and enhances performance on subjective alertness and vigilance tasks. Evidence on more complex tasks requiring executive functioning or self-regulation is as yet largely unavailable. Furthermore, the studies differ substantially in duration of exposure. The effects of nature and daylight on self-regulation will be further explored in Chapters Five and Six of this dissertation. In the next section, the effects of nature and daylight on physical health will be further discussed.

1.6 Physical and mental health

1.6.1 Nature and health

Epidemiological research has illustrated a positive association between the amount of green space in the proximity of the home and health (van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012; Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006), between the amount of accessible green space and longevity (Takano, Nakamura, & Watanabe, 2002), between the amount of urban green space and mental health and well-being (White, Alcock, Wheeler, & Depledge, 2013). A higher amount of nature in the proximity of the home has further been found to lower the health-inequality between low and high incomes (Mitchell & Popham, 2008). Maas and colleagues found that people with a higher percentage of green space in the proximity of their home reported a higher general health. Effects of view content on reported health have been found in an office setting as well. People with a more natural view at work reported a better subjective health (R. Kaplan, 1993). Moore (1981) further found that inmates with a more natural view visited the doctor less often than those overlooking a courtyard. Physical exercise in natural environments has also been found to be more beneficial than in other environments (Barton & Pretty, 2010; Bodin & Hartig, 2003; Mitchell, 2012; Thompson Coon, Boddy, Stein, Whear, Barton, & Depledge, 2011). These correlational studies suggest a relation between nature and health for the general population.

In a clinical context, Ulrich (1984) found an effect of view content on recovery after surgery. He found that patients with a natural view had a shorter length of stay, received less negative notes from the nurses, and required less pain medication than patients overlooking a brick wall. An urban upbringing has further been related to increased risk of developing schizophrenia (van Os, Kenis, & Rutten, 2010). Similarly, Ellett, Freeman, and Garety (2008) found that walking in busy urban environments resulted in increased mental health problems for participants with persecutory delusions. Roe and Aspinall (2011) conducted a study comparing restorative effects of walking in a natural environment between healthy participants and participants with mental health issues. They found that walking in a natural environment resulted in positive changes in mood and in mind-set in relation to personal projects for both groups, but beneficial effects were greater for people with mental health problems compared to healthy individuals. In a second study they investigating the effects of natural environments compared to urban environments and found similar results for both groups. However, they also found a small restorative effect of walking in an urban setting for the individuals with mental health problems indicating that for them the mere effect of physical activity or exposure to daylight may have induced beneficial effects as well.

In a survey study, Kuo and Taylor (2004) found that nature activities reduced ADHD symptoms in children. In response, Canu and Gorden (2005) criticized the use of self-reports by the parents as the dependent variable in this study. However, two other studies examined the effects of natural surroundings on children with ADHD. Taylor and Kuo (2009) found beneficial effects of walking in natural settings as opposed to urban settings on concentration of children with ADHD and van den Berg and van den Berg (2010) also reported beneficial effects of nature on concentration. Hartig, Catalano, and Ong (2007) found that the use of antidepressants in Sweden increased when the weather in summer was bad. They attribute this effect to the lack of restoration potential, but it could also be due to a lack of daylight. Further effects of daylight on health will be discussed in the next section. In sum, although the majority of research in this domain has been correlational, quite extensive empirical work accounts of a relation between nature and health.

1.6.2 Daylight and health

Sunlight can have protective as well as detrimental effects on health. Too little exposure to sunlight can be detrimental (e.g., Seasonal Affective Disorder, rickets; vitamin D deficiencies), but too much exposure can be harmful as well (e.g., skin cancer). Beneficial effects of sunlight have often been ascribed to the production of Vitamin D, also called the sunshine hormone or ‘soltriol’. Vitamin D production has been found to exhibit health protective effects on a number of diseases as for instance depression, cancer, cardiovascular disease, influenza, diabetes, and some autoimmune diseases (Kauffman, 2009; Webb, 2006). Furthermore, a relation between vitamin D and mental health has also been established as neonatal vitamin D deficiency has been linked to an increased risk of schizophrenia (McGrath, Burne, Féron, Mackay-Sim, & Eyles, 2010). Research by Krause, Bühring, Hopfenmüller, Holick, and Sharma (1998) has indicated that sunbathing with UVB radiation can help overcome mild hypertension. Sunbathing with UVA radiation was ineffective in lowering blood pressure as only UVB radiation resulted in an increase in vitamin D production.

Two studies have reported effects of daylight on recovery from physical illness. Beauchemin and Hays (1998) have studied the effects of daylight on length of stay and mortality rate in a cardiac intensive care unit by comparing units located on the south side (sunny) with units located on the north side (dim). They found that women had a shorter length of stay in sunny rooms, whereas no differences in length of stay were found for men. Moreover, overall mortality rates were higher in the dim rooms than in the bright rooms. The authors postulate that depression may be one of the mechanisms through which light can affect length of stay and mortality rates, since depression can have negative effects on cardiac outcomes. A second study investigated the effects of daylight entrance on both health and psychological outcomes for patients recovering from spinal surgery (Walch, Rabin, Williams, Choi, & Kang, 2005). The amount of pain medication used was monitored as well as psychological well-being, including perceived stress, anxiety and subjective pain perception. Dim patient rooms were located on the east side, where an adjacent building blocked incoming sunlight, whereas bright rooms were located on the west side. Patients in the bright rooms used significantly less pain medication during the first day after surgery, reported significantly less stress at discharge, and reported a marginally greater decrease in pain than patients in the dim rooms.

Epidemiological studies have further revealed differences in the occurrence and severity of several illnesses between different latitudes and in different seasons, as for instance certain types of cancer and cardiovascular disease (Freedman, Dosemeci, & McGlynn, 2002; Holick, 2008; Straus, Bleumink, Dieleman, van der Lei, Strickler, & Sturkenboom, 2004; Wallis, Penchofer, & Sizemore, 2008).

Effects of light on the circadian rhythm can result in both positive and negative health outcomes. Negative effects often pertain to shifts in -or disruption of- the circadian rhythm by exposure to light at the wrong biological time. These detrimental effects are mostly caused by electric light as daylight is usually only available at the right biological time. However, differences in photoperiod between seasons can affect mental health. Through light exposure, the circadian rhythm of our body is synchronized with the light-dark cycle of our environment. Several circadian rhythms are orchestrated by the biological clock as for instance the release of the hormones cortisol and melatonin, but our cardiovascular system and core body temperature also follow a diurnal rhythm (Millar-Craig, Bishop, & Raverty, 1978; Rea, Bierman, Figueiro, & Bullough, 2008; Ruger & Scheer, 2009). Moreover, light exposure has been related to sleep quality through the biological clock (Hubalek et al., 2010; Riemersma-van der Lek, Swaab, Twisk, Hol, Hoogendijk, & van Someren, 2008). Conversely, diseases to the eye reducing retinal photo transduction have been linked with sleep disorders (Schmoll, Lascaratos, Dhillon, Skene, & Riha, 2011).

There are strong indications that a shortage of light is in effect at least partially responsible for the emergence of a condition labelled Seasonal Affective Disorder (SAD; Rosenthal et al., 1984). The exact causes for SAD are still unknown, but a number of pathways have been explored. These pathways pertain to serotonin production, melatonin production, weakened circadian signal, phase delays in circadian rhythm, and genetic influences (Avery & Dahl, 1993; Magnusson & Boivin, 2003). Even in the general population, negative effects as sadness, irritability, anxiety, lethargy, increased appetite, carbohydrate craving, and hypersomnia (Rosenthal et al., 1984) are experienced especially during winter and can vary in intensity from none or mild to debilitating (Schlager, Schwartz, & Bromet, 1993). Among the most advised and effective treatments for SAD today is optimally timed exposure to bright light (Terman & Terman, 2005).

Current bright light therapy almost exclusively uses electric bright light. However, depending on latitude, the prevailing daylight during winter may be equally efficient, even on overcast days (Wirz-Justice, Graw, Kräuchi, Sarrafzadeh, English, Arnedt, & Sand, 1996). Although overcast skies may appear dull and monotonous, initial measurements of overcast skies reveal a complex spectral distribution of color temperature, with substantial changes across time as well as an unexpected large quantity of blue light (Lee & Hernández-Andrés, 2005). Wirz-Justice and colleagues (1996) found that a one-hour walk per day outdoors resulted in a decrease in symptoms. This finding is particularly interesting since some have attributed SAD to grey cloudy weather as well (aan het Rot et al., 2006). Unfortunately, Wirz-Justice's study could not rule out that the effects were (partly) due to physical exercise per se. More importantly, effects of outdoor scenery also cannot be excluded.

The effectiveness of bright light therapy for non-seasonal forms of depression has also been established. A recent study demonstrated that bright light therapy improved mood and enhanced sleep efficiency in elderly patients with major depressive disorder (Lieverse et al., 2011). In a clinical setting, beneficial effects of bright versus dim hospital rooms have also been reported on depression. Two studies reported a relation between length of stay and the amount of sunlight entering the patient room. Beauchemin and Hays (1996) found that patients diagnosed with severe depression had a shorter length of stay in bright rooms than patients admitted to dim rooms. Benedetti, Colombo, Barbini, Campori and Smeraldi (2001) found a shorter length of stay for bipolar patients in rooms receiving sun in the morning (facing east) than patients in rooms receiving sunshine in the evening (facing west). They only found this difference in summer and fall and only for patients with bipolar depression (not for unipolar depression). Adding bright light therapy to exercise programs can enhance the decrease in depressive symptoms (Leppämäki et al., 2002).

Besides seasonal and non-seasonal depression, light therapy combined with sleep schedules –also known as chronotherapy- has also been successfully used to treat a range of other disorders including premenstrual dysphoric disorder, bulimia nervosa, dementia, and Parkinson's disease (Wirz-Justice, Benedetti, & Terman, 2009). A formal link between the prevalence of ADHD and solar intensity has recently been reported as well, with higher prevalence in areas with lower solar intensity (Arns, van der Heijden, Arnold, & Kenemans, 2013).

1.6.3 Reflection

Nature and daylight can influence both mental and physical health on many outcomes including depression, longevity, and general health (see Table 4 of Appendix A for an overview). This section has again indicated the large overlap in beneficial effects found on health. For instance, both vitamin D deficiency and living in urban areas have been linked with an increased risk for schizophrenia, both the amount of daylight entrance and nature viewed through windows in a clinical setting have been found to influence recovery after surgery, and both bright light therapy and natural environments were found to increase beneficial effects of physical exercise on mental health.

In general, there appear to be more studies reporting on direct effects on health in light research than for natural views, particularly in the clinical domain. There is, however, also an extensive amount of literature investigating the effects of active nature participation, as for instance animal-assisted therapy, wilderness experience, or horticulture therapy, which show beneficial effects of – usually – a combination of nature exposure, physical activity, and daylight exposure. We excluded most of these studies in this paper, because they either do not have an equivalent study in daylight research (e.g., animal assisted therapy) or because there is no control for the effects of physical exercise. There are a number of review articles summarizing the therapeutic effects of these interventions (Annerstedt & Währborg, 2011; Bowler, Buyung-Ali, Knight, & Pullin, 2010; Frumkin, 2001; Maller, Townsend, Pryor, Brown, & st. Leger, 2005; Pretty, 2004;). Importantly, benefits of horticulture therapy and wilderness experience have been attributed to being in a natural environment, whereas these activities are usually not only accompanied by physical exercise but also by exposure to daylight.

Chronotherapy – a combination of light exposure and sleep-wake restrictions – has been used to treat a multitude of disorders, both concerning mental health (e.g., depression) and physical health (e.g., rheumatic arthritis) (Wirz-Justice, Benedetti, & Terman, 2009). The exact underlying pathway(s) of the beneficial effects of light are not clear yet. Whether the effects of light in the health interventions reported here should be attributed to amount of direct sunlight, illuminance at the eye, photoperiod, or to biological versus psychological pathways remains largely unknown. A multitude of different daylight indices have been used to study its effects on health, as for instance horizontal irradiance, intensity, or spectral composition. Furthermore, it is also unknown whether biological effects are due to acute alerting and affective responses, or to its effects on circadian rhythm and sleep quality. Epidemiological studies have investigated both effects of exposure to sunlight and amount of green in the proximity. None of these studies, however, have used combined data sets to simultaneously investigate effects of sunlight and nature exposure on health while in at least some studies an interaction of these two phenomena can be expected.

1.7 General discussion: effects of nature and daylight on health

We have presented an overview of how both nature and daylight can positively influence health in a variety of ways. Although not providing a systematic review in the strict sense of the word, our aim was to provide an overview of the range of classes of health effects and mechanisms and to bring together empirical findings from different research fields. Results were reported not only from different research fields, but also on different levels of analysis. Effects were found on an individual level (e.g., Hartig & Staats, 2006; Kaida et al., 2007) as well as the community level (e.g., Maas et al. 2006, Straus et al., 2004). We have discussed effects on health directly, but also concepts closely related to health: stress, mood, and executive functioning and self-regulation. These phenomena do not exist in isolation but are all closely intertwined. For instance, stress can cause changes in mood, and executive functioning has also been related to stress (Williams, Suchy, & Rau, 2009) as well as changes in mood (Hagger, Wood, Stiff, & Chatzisarantis, 2010).

1.7.1 The overlap in salutogenic effects

Commonalities have particularly been found in effects of both phenomena on mood, activation of the parasympathetic nervous system, executive functioning, recovery and mental health. Higher light levels have been associated with better mood (Kaida et al., 2007; Kööts et al., 2011; Partonen & Lönnqvist, 2000; Rot et al., 2008) as have natural environments (van den Berg & Custers, 2010; Fredrickson & Levenson, 1998; Hartig et al., 2003). Furthermore, both bright light and natural environments have been found to increase vitality (Ryan et al., 2009; Smolders , de Kort, & van den Berg 2013; Partonen & Lönnqvist, 2000). Natural environments speed up cardiovascular recovery after stress induction (Fredrickson & Levenson, Laumann et al., 2003; Ulrich et al., 1991) whereas exposure to bright light appears to affect the cardiovascular system by improving heart rate variability (Rechlin et al., 1995). Furthermore, our cardiovascular system is highly dependent on our circadian rhythm. Viewing, or being in, a natural environment has been found to improve executive functioning (Berman et al., 2007; Hartig et al., 2003; Laumann et al., 2003) and first indications for effects of bright light on executive functioning have been found as well (Phipps-Nelson et al., 2003; Smolders et al., 2012). In a clinical setting, both natural views and more daylight entry affect recovery (Ulrich, 1984; Beauchemin, & Hays, 1998; Walch et al., 2005). Lastly, both an urban upbringing and lack of vitamin D during childhood were associated with an increased risk of developing schizophrenia (van Os et al., 2010; McGrath et al., 2010).

The substantial overlap in effects indicate a risk of focusing on only one of the two phenomena, because an effect of the other phenomenon cannot always be ruled out (van den Berg, 2005). For instance, in the study by Walch and colleagues (2005) investigating the effects of light exposure on patient recovery, dim rooms received less daylight because of an adjacent building, which may have also blocked the view of patients in these room. Similarly, in the study by Ulrich (1984), the patient rooms overlooking a brick wall probably received less daylight than the rooms overlooking nature. The same pertains to the epidemiological studies on nearby nature, as enjoying nature outdoors is likely to go hand in hand with daylight exposure, and better weather might also increase the propensity to visit nature outdoors, as the study by Hartig and colleagues (2007) illustrates. These examples indicate the complexity and interrelatedness of both phenomena.

Fortunately, many of the studies reported here have controlled for possible confounds to a certain degree, although not always deliberately. For instance, laboratory studies using pictures or videos of nature often rule out any effect of direct exposure to daylight and some studies have even reported keeping the weather conditions on the visual content the same. Furthermore, in some field studies participants in the nature and urban conditions have both walked outside in the same weather conditions. Similarly, laboratory experiments investigating the effects of bright light exposure have often ruled out effects of view content.

A challenge in comparing the effects of daylight and views to nature we encountered is that they are studied in separate research domains, resulting in the use of different research paradigms and different outcome variables. For research into the effects of view content, recovery is measured after induction of either stress or attention fatigue. For light research, however, effects are usually studied after mere exposure to either bright or dim light. In cross-sectional and epidemiological research, the effects of (day) light have been studied using a wide variety of predictors, including the amount of bright light (irrespective of it being natural or electric light) encountered during a certain period, amount of sunshine, latitude, or season. For nature, research usually looks at either the geographical size of the hometown (city / rural / etc.) or the amount of greenery in the environment. Light, furthermore, has been studied extensively as a therapeutic intervention, whereas nature does not seem to have reached this status yet.

1.7.2 Methodological issues

There are some methodological issues in both fields that impede drawing the causal inferences needed to establish them as a therapeutic intervention. First of all, there is a need for controlled randomized trials (Annerstedt & Währborg, 2011; Dijkstra, Pieterse, & Pruyn, 2006; Veitch & Galasiu, 2012). Secondly, clinical trials often include a placebo condition, which can be difficult to implement in research investigating effects of light and nature (Bowler et al., 2010; Veitch & Galasiu, 2012). It has been proposed that taking multiple measures including physiological measures can help overcome the absence of a placebo condition (Veitch & Galasiu, 2012). Furthermore, taking baseline measures can also help draw causal inferences (Bowler et al., 2010).

In studies testing whether natural environments are superior to urban environments in their health-protective effects, it is not always clear whether nature has health-protective effects or whether instead urban environments have detrimental effects on health. Moreover, especially urban environments used in research vary substantially in attractiveness and content displayed. If urban environments have detrimental effects on health, we need to be able to better identify specifically which elements cause these effects. Furthermore, the evolutionary basis for beneficial effects of nature on health has recently received criticism, mostly aimed at the relative lack of evidence for this claim (see Joye & van den Berg, 2011). The high level of segregation between research on effects of light and effects of nature on health and well-being. Furthermore, even within the field of lighting research the absence of multidisciplinary research (Veitch & Galasiu, 2012) counters an integrated research approach. The current plurality in light treatments differing in spectral composition, intensity, time-of-exposure, and baseline light exposure procedures makes drawing causal inferences difficult.

To be able to be conclusive about the hypothesized overlap in effects and underlying mechanisms of these two phenomena, more uniformity in research paradigms and dependent variables is needed. In both research areas, the focus of research is also slightly different. For daylight, a solid evidence base exists for effects on mood and on physical and mental health. Less extensively studied are stress-reducing effects and effects on diurnal executive functioning and self-regulation. For nature, most studies have focused on stress-reduction, mood-enhancement, and improvement of executive functioning and self-regulatory capacity. Direct effects on mental health and physical health are studied less extensively. Therefore, a lack of evidence for effects of one phenomenon in one of the fields does not necessarily imply that these effects are non-existent. Rather, it may have received less attention from researchers. This holds, for instance, for stress-reducing effects of daylight. For these reasons, in this dissertation the effects of daylight and nature will be investigated using similar research paradigms and outcome variables.

1.7.3 Dissertation outline

Two psychological theories exist proposing mechanisms through which nature affects health, whereas for daylight, the focus has mainly been on biological mechanisms as the biological clock and vitamin D production. For daylight, some psychological mechanisms have been hinted at (e.g., Boyce et al., 2003; Vandewalle et al., 2009; 2010), yet no theoretical basis for these effects exists as yet. Instead, if effects are found for daylight they are often -almost automatically- attributed to non-image forming pathways without considering psychological processes and sometimes even without knowing the exact underlying biological pathway. We believe here lies a challenge for the present thesis, as very similar effects of both phenomena have been found on mood, executive functioning, and the cardiovascular system. Therefore, the first objective addressed in this dissertation is to investigate possible underlying *psychological* mechanisms for the beneficial effects of daylight and natural environments and the commonalities herein. The focus will be on preference and the connotations that people have with nature and daylight as possible pathways.

The previous sections pointed at the considerable overlap in beneficial effects of daylight and natural environments. However, we also concluded that this hypothesized overlap should be explored further using uniform research paradigms with similar dependent variables. For this reason, the second objective of this dissertation is to test for beneficial effects of daylight and natural environments within similar experimental designs. Importantly, following up on our first objective, we mainly focus on testing effects evoked by psychological pathways running through preferences and connotations. In addition, as we also concluded that in some studies daylight and nature exposure were confounded, we test for effects of one phenomenon while controlling the other to establish the unique effects of daylight and natural environments.

Hence, the main research questions addressed in this dissertation are:

Do daylight and nature exhibit similar (unique) restorative effects when studied within the same research paradigm?

and

To what extent do restorative effects of daylight and nature share underlying psychological pathways?

The structure of the dissertation will follow the two main objectives. We will start with taking a closer look at the possible psychological underlying mechanisms. The first psychological pathway investigated concerns environmental preferences. Preferences are often thought to serve adaptive purposes, guiding us to approach healthy environments and to avoid detrimental environments. Therefore, in Chapter Two, a series of studies is conducted investigating both implicit and explicit preferences for photos of environments differing both in naturalness (natural versus urban environments) and in two dimensions related to the presence of daylight; weather type (sunny versus overcast) and brightness (light versus dark). Explicit preferences are investigated using both aesthetic ratings and the attitude toward spending one hour in the displayed environment, whereas implicit preferences are investigated using an affective priming paradigm. In this chapter, preference for daylight is measured with photos manipulated along two dimensions; weather type and brightness. As this comparison only investigates the *amount* of daylight present in the environment rather than the light *source*, we additionally tested for differences in preference ratings between daylight and its artificial counterpart in Chapters Four and Six.

Preference ratings of environments are -at least initially- based on the person’s existing associative patterns with these environments. Therefore, in the following two chapters we investigate the associations that people have with nature or daylight and compare the valence of their respective associations. Chapter Three will do this for the nature-urban comparison, showing photos of either natural or urban environments. In Chapter Four, daylight and electric light are compared via participants’ responses to images or descriptive words of the different light sources. In both chapters we not only test for differences in valence of the associations, but also explore how they are related to preference ratings and restorative outcomes. In both chapters, these restorative outcomes are tested after an initial stress induction.

Restorative outcomes are further tested in Chapters Five and Six. This time, effects are tested using a typical ego-depletion experimental design. In Chapter Five the environment type (natural versus urban) is manipulated whereas in Chapter Six the light source is manipulated (daylight versus electric light). The main outcome variables include self-regulation performance, mood, and physiology. Careful attention is given to controlling daylight parameters when testing for effects of naturalness and vice versa. In these studies, focal attention will be given to preference as the underlying psychological pathway. Chapter Seven, the last chapter, will discuss the outcomes of all studies and the implications from both a scientific and societal point of view.

Chapter 2

Let the sun shine!

Explicit and implicit preference for environments differing in naturalness, weather type and brightness[1]

On a stormy day
The clouds move too fast to see
The shapes they make
and how they wrap our little world right up

I'm in your garden but I want a forest
I'm in God's garden, I'll make it a forest
I'll make it a forest
(Editors - I want a forest)

[1] This chapter is based on: Beute, F., & de Kort, Y.A.W. (2013). Let the sun shine! Measuring explicit and implicit preference for environments differing in naturalness, weather type, and brightness. *Journal of Environmental Psychology, 36,* 162-178.

Abstract. Exposure to natural environments and daylight often coincides. From an evolutionary perspective on preference, both should be highly preferred as they were important components for survival. Furthermore, research has indicated that people generally have positive connotations with both daylight and nature. In this chapter we present three studies in which effects of naturalness and daylight characteristics on preference are studied simultaneously. We investigated both explicit and implicit preference, using direct ratings of the scenes and an affective priming task, respectively. The scenes were manipulated across three dimensions; naturalness (nature vs. urban), brightness (light vs. dark), and weather type (sunny vs. overcast). Consistently, we found explicit preferences for natural, bright, and sunny scenes. In contrast, no evidence was found for an implicit preference for nature, brightness, or sunlight.

2.1 Introduction

Daylight and greenery are both highly valued -and salutogenic- elements of nature. In daily life, exposure to natural environments often coincides with exposure to daylight, whether it is in images or videos or while actually being outdoors in nature. To all of us gardeners, bird watchers, and hikers this offers a clear win-win situation. Yet from a research perspective such concurrent exposure opens the door to confounds if we want to learn about the independent contribution of each of these elements. Therefore, in this chapter, we will investigate how preference ratings are affected by environment type and daylight characteristics.

Both natural phenomena have been intensively studied with respect to their potential for resource replenishment and health. Very little research has focused on investigating preference for view type and daylight characteristics (for instance brightness and weather type) simultaneously, while much can be said in favour of studying them together (see Chapter One). Apart from their frequent co-occurrence, both are an important part of our natural world in which we have evolved. Furthermore, the presence of one element may influence the appraisal of the other. For instance, as neighbourhood scenes are appraised differently under day and night time conditions (Hanyu, 1997; 2000), daylight characteristics such as the amount of shadows potentially affects preference ratings of environmental scenes (Ulrich, 2008), and the use of lighting directed toward natural elements during night time influences perceived restoration as well as preference ratings (Nikunen & Korpela, 2009; 2012). The current chapter therefore reports of studies in which the effects of nature, weather type, and brightness on preference ratings were considered simultaneously yet manipulated independently. This allowed us to investigate their independent contributions and how differences in one phenomenon influence preference ratings of the other. Furthermore, we considered preferences measured both on an explicit and implicit level.

Several viewpoints on the development and functionality of preferences exist. Some scholars view preferences from an evolutionary perspective, claiming that preferences serve adaptive needs (e.g., Kaplan, 1992b; Ulrich, 1983). Others pose that preferences are more likely to be learned and culturally based (e.g., Tuan, 1974). However, irrespective of whether preference is in our DNA or learned, preference is often assumed to (at least partly) have a functional origin and is therefore believed to reflect the restorative potential of environments (van den Berg et al., 2003).

2.1.1 Evolutionary bases of preference

From an evolutionary point of view, human emotion, behavior, and cognition have adapted to the past environments we lived in (Tooby & Cosmides, 1990). Environmental preference influences subsequent affect, behaviour, and cognition (Ulrich, 1983) as well as knowledge acquisition (Kaplan, 1992b). Throughout human history, preferences for certain environments may have served adaptive needs by inducing approach or avoidance, thus guiding human beings towards healthy environments and away from unsuitable environments (Kaplan, 1987; Ulrich, 1983). For instance, humans have evolved in natural environments, subject to the cycles of day and night.

For thousands of years, man learned to be active during the – relatively safe – day and rest and seek shelter during the dangerous, dark night. Light, therefore, also has evolutionary relevance and Ulrich (2008) argues that under certain circumstances, positive responses to nature may be enhanced by daylight. For instance, a sunny and well-lit environment signals less danger than an overcast environment or an environment with many shadows (Ulrich, 2008). Looking at the adaptive functionality of preferences, these findings are not completely surprising, as daylight has served a major adaptive role in developing our biological clock. Numerous physiological rhythms in our body have evolved based on this diurnal cycle (Millar-Graig et al., 1978; Rea et al., 2008; Ruger & Scheer, 2009). In fact, rhythms not only encompass diurnal cycles, but also seasonal ones related to the earth's solstice. These rhythms are engrained in our bodily make-up and DNA. The same can be said for environment type, as humans have evolved in natural - as opposed to urban - environments. It has been suggested that because humans have evolved with these natural environments, and diurnal and seasonal cycles, they are also preferred (Wohlwill, 1983).

Some state that environmental preferences are formed immediately based on the composition of a scene, like the presence of certain "preferenda" (Zajonc, 1980). Preferenda are features in an environment that can cause an affective response even without paying conscious attention to it. Examples of these features are for instance water elements and deflected vistas (Ulrich, 1983). Research has indicated that certain more global attributes of our environments as for instance refuge (Appleton, 1975; 1992), legibility (Kaplan, 1992a; Ulrich, 1983), and complexity (Kaplan, 1992a) influence preference. Preference judgments have also been proposed to rely on more cognitive processes comparable to decision making (Kaplan, 1992b), their outcome based on a complex weighing various attributes. Kaplan and Kaplan (1989) proposed an information-processing framework, the central premise of which is that environments that facilitate understanding and exploring are preferred over environments that do not fulfil human's basic hunger for knowledge (Knopf, 1987).

If preferences have an evolutionary basis, then these judgments should be universal. Indeed, research has indicated that people generally and consistently prefer natural over urban environments (see e.g., Hartig & Evans, 1993; Ulrich, 1983). Furthermore it is postulated that these effects can occur very rapidly and automatically. Evidence for preference on a pre-cognitive level of natural over urban environments has been found in a series of experiments Hietanen, Korpela and colleagues (Korpela et al., 2002; Hietanen, & Korpela, 2004; Hietanen et al., 2007). They employed an affective priming paradigm, in which pictures of natural or urban environments were followed by either emotional vocal expressions or emotional facial expressions.

The affective priming paradigm dictates that if natural environments initiate positive affect pre-cognitively, this should facilitate recognition of subsequent positive emotional stimuli because this response is congruent with their response to the natural environment. Conversely, recognition of negative stimuli after viewing a natural picture should become slower because this category is incongruent with their response to the natural environment. Indeed, they found different facilitation effects between natural and urban environments. Interestingly, an automatic affective response to blue light has also been suggested, based on brain imaging studies showing a very rapid activation of the hippocampus and amygdale after exposure to blue light (Vandewalle et al., 2009; Vandewalle et al., 2010).

The evolutionary perspective in restoration research has recently received criticism (Joye & van den Berg, 2011). Moreover, in general, the evolutionary basis of environmental psychology is debatable (Heft, 2013). It assumes a dichotomy between mind and environment, with the mind -and in this case preferences- being passively 'moulded' by the environments we have evolved in. However, the relation between environment and human beings has also been postulated to be more reciprocal than this, see for instance influential theories by Barker (1968) and Gibson (1979), with not only the environment itself being important, but also the actions people perform in these environments and the sociocultural structures (Heft, 2013).

2.1.2 Cultural, and learned bases of preference

In spite of indications that preferences may be partly encoded in our genes and/or neurological makeup, preferences also appear to be influenced by the personal experiences that people have had with certain environments and the values that society places on these environments, which better reflects the dynamic relation between humans and their environment. Within this framework a universal preference for natural over urban environments is contradicted by for instance the changing values of nature, which over the past centuries have ranged from being a place of evil to being a sanctuary (Knopf, 1987). Furthermore, it has been postulated that childhood experiences play an important role in the formation of values of environments (Tuan, 1977). In this respect, sunshine may have very different connotations for people living at high latitudes than for people living in a more Mediterranean climate.

Light and dark have very strong positive and negative connotations in daily life (Meier et al., 2004; 2007). People further show a strong preference for daylight in work environments (Markus, 1967), believe that daylight is superior in its effects over electric light on health, mood, and performance (Veitch & Gifford, 1996; Veitch et al., 1993), and believe it is better for the eyes of office employees (Wells, 1965). The basis behind these beliefs may be partly instrumental – daylight has important characteristics for health such as its full spectrum quality, intensity, and timing – but also ideological, as was noted by for instance Haans and Olijve (2012). They argued that a similar 'naturalness bias' exists for light as for other products that are perceived as more natural, including packages, food, and medication even when its synthetically produced counterpart is identical on the molecular level (e.g., DiBonaventura & Chapman, 2008; Rozin, 2005; Scholten & Midden, 1997).

Aesthetic judgments – often viewed as an important part of preferences - have also been found to rely on evolutionary-based influences (Berlyne, 1971) that can subsequently be affected or even changed by cultural influences (Jacobsen, 2010; Tomasello, 2000). One well-known biologically determined aesthetic liking is our preference for symmetry (Jacobsen, Schubotz, Höfel, & Cramon, 2005). Factors as for instance a persons' affective state have been found to influence aesthetic judgments as well (Konecni, 1979). Jacobsen (2010) suggests that aesthetic judgments are a complex interplay between the stimulus, the person, and the situation. Similarly, research has indicated that besides culturally and individually based differences, preference for certain environments can differ within a person, based on motivational needs. Indeed, a higher need for restoration results in higher preference for natural environments (Hartig & Staats, 2006; Staats, van Gemerden, & Hartig, 2010).

Porteous (1996) has further postulated that people base their preference judgment on the beliefs they possess on how the environment affects their health and wellbeing. From this perspective, it is not the evolutionary relevance of natural environments and natural light that would influence preference, but the values that people themselves have given to these two entities. For instance, research has indicated that people generally believe that natural light is better for health, performance, and mood (Veitch & Gifford, 1993; Veitch et al., 1993), and brightness (as opposed to darkness) is often associated with good (vs. bad; Lakens et al., 2012; Meier et al., 2007). People also often use weather type as a cue for their mood, with sunshine related to a more positive mood (Messner & Wänke, 2011; Schwarz & Clore, 1983). Similarly, natural environments are viewed as places for cognitive freedom and escape (Gifford, 2002; Kaplan, 1995). More generally speaking, evidence has been found for a certain 'naturalness bias' (Rozin, 2005) meaning that natural products are preferred over synthetically produced products even when they are exactly the same at a molecular level. In conclusion, preferences may have evolutionary, learned, cultural, and motivational bases.

2.1.3 Rationale

Nature and daylight have been two important contextual factors throughout the development of humankind. Seen from an evolutionary point of view, they should therefore both score high on preference, as humans "are best suited for acting in the environment that wrote the script" (Knopf, 1987, pp. 785). In addition, we saw that positive associations with nature and daylight may be acquired during life, via culturally determined values or personal experience. Moreover, preference has been found related to restorative potential and, in turn, nature and daylight have both been found to influence health and wellbeing beneficially.

Irrespective of the basis of preferences, evidence has been found that preference is related to the restorative potential of environments for human beings. In other words, environments that foster mental and physical health are likely to be preferred over environments that are detrimental for mental and physical health. In accordance to this, a consistent link between explicit preference - operationalized as ratings of scenic beauty and attitude towards being in the environment - and the restorative potential of environments has been reported (Hartig & Staats, 2006; van den Berg et al., 2003). Moreover, preference for a natural environment was suggested to depend largely on the restorative effect the displayed environments had on individuals' mood (Van den Berg et al., 2003). As noted in Chapter One, though, the causal direction of the link between preference and restorative potential is not yet clear.

There is a considerable overlap in effects found for both light and views to nature, although the underlying mechanisms to which they are ascribed differ. Beneficial effects of nature are generally attributed to psychological processes (Kaplan, 1995; Ulrich, 1983) whereas effects of light exposure have mostly been attributed to biological processes, although psychological mechanisms have also been proposed (Boyce et al., 2003). Similarly, reported effects of nature need not always have been purely psychological, as (day)light levels varied with the view or experience offered. In other words, studies of effects of daylight exposure may have been confounded with the effect of view content and vice versa. We expect that light – through its evolutionary significance, and its meaning, connotations and associations – can also impact wellbeing through non-biological mechanisms.

It is exactly this possible underlying psychological path that we aim to investigate in the present study. Therefore, we studied both phenomena simultaneously by investigating preference ratings of depicted environments differing in content (nature vs. urban), weather type (sunny vs. overcast), and brightness (light vs. dark) by means of both explicit and implicit preferences. We chose to use two different daylight manipulations, because both can be used to manipulate the perceived amount of daylight in the pictures but could possibly affect preferences differently, as they have different biological and psychological relevance for humans. Brightness of the environment is biologically relevant for entrainment of the biological clock, but on a psychological level it is often used as a metaphor of good (bright) versus bad (dark). Weather type may be used as an implicit cue for mood, but more sunshine also exhibits biological relevance via the production of vitamin D.

The current chapter reports of three studies. The first study investigated explicit preference ratings for scenes differing in environment type, weather type, and brightness. The second and third study extended these outcomes by investigating not only explicit preferences but also implicit preferences using an affective priming paradigm. For reasons listed above, we expected that natural, sunny, and light environments would be given higher preference ratings. Furthermore, we also expected that they would facilitate categorization responses towards a positive target in an affective priming paradigm.

2.2 Study One - Explicit preferences for bright and sunny nature

The first study was an experiment, which investigated whether natural, sunny, and light pictures indeed score higher on explicit preference than urban, overcast, and dark pictures.

2.2.1 Method

A within-participants design was employed with environment (natural vs. urban), weather (sunny vs. overcast) and brightness (light vs. dark) as within-subjects factors and explicit preference as dependent variable.

2.2.1.1 Participants
Twenty participants (8 females) participated in the study. Their mean age was 23 (*SD* = 2.93, ranging from 19 through 30). Participants were invited via our participant database, or recruited personally on the university premises. The majority of participants were students at the Eindhoven University of Technology or the Fontys Higher Education institute. All participants had normal or corrected to normal vision.

2.2.1.2 Stimuli & manipulations
In this study, we used a set of photos that was objectively manipulated (i.e., by categorical or numerical differences) along three dimensions; Environment type, Weather type, and Brightness.

Environment type. Photos of nine different views were used. Five photos depicted natural scenes and four depicted urban scenes. The photos were taken during springtime, in April. Natural photos were taken at the “Strabrechtse heide” and the “Genneper parken”. Both are natural areas around Eindhoven, the first containing primarily heath and woodland and the latter containing woodland, a creek and stretches of grass. The urban photos were all taken in the city of Eindhoven, excluding overly familiar places in the city centre.
Weather type. All nine views were photographed twice, once in overcast weather and once in sunny weather. Sunny weather was defined as a clear sky and overcast weather was

defined as a complete overcast sky but without any rain or signs of previous rain (no puddles).

Brightness. All 18 pictures were processed using Adobe Lightroom®, to create two sets objectively differing in brightness. One set was higher in brightness, while the other was lower on brightness. Within these two sets photos were matched in brightness, both by calculation in ImageJ® and by measurement of on-screen brightness by using a luminance camera. Correlation between both measures was high (r=.98, $p < .001$). The brightness difference between dark and light photos was tested and proved significant for both calculated brightness (measured in mean grey values; F (1,34) = 738.3, $p < .001$) and luminance (F(1,34) = 7423.5, $p < .001$). Light pictures (Mean grey value = 96.0, SE = 12.48; Mean Luminance 46,4 cd/m², SE = .14) were significantly brighter than dark pictures (Mean grey value = 143.9, SE = 12.48; Mean Luminance = 29.9 cd/m², SE = .14). No significant difference in brightness was found between urban and natural pictures (F (1,34) < .1, p = *NS*), or between sunny and overcast pictures (F(1,34) < .1, p = *NS*).

All photos were taken between 9:45 am and 3 pm. Example photos can be found in Figure 2.1. The displayed photos were 8 x 11.4 cm. Natural and urban scenes were visually matched on overall spatial structure (i.e., enclosure, composition) and on the amount of shadows and contrasts.

2.2.1.3 Procedure

After signing the informed consent form, participants started the experiment by reading the instructions on a notebook. During the experiment, participants viewed one photo at a time. They judged this photo consecutively on aesthetics, photo characteristics, attitude, and reported the perceived time of day and season. They were then presented with the next photo. Every participant viewed all 36 photos, in random order. At the end of the experiment, participants were thanked and paid for their participation. The experiment lasted approximately 25 minutes and participants received €5 compensation for their participation.

2.2.1.4 Measures

Preference was measured on two dimensions; aesthetics and attitude.

Aesthetics. Participants rated the aesthetic value of the scenes on three aspects (beautiful, appealing, pleasant) on a scale of 1 (not at all) to 7 (extremely) (Staats Kieviet, & Hartig, 2003). Internal consistency of the scale was very high (Cronbach’s alpha = .94).

Attitude. Attitude was measured by asking participants to indicate how [attractive, pleasant, positive, agreeable] it would be to spend an hour in the displayed environment (Staats et al., 2003), measured on a scale from 1 (not at all) to 7 (to a very high degree). Again, internal consistency was high (Cronbach’s alpha = .96).

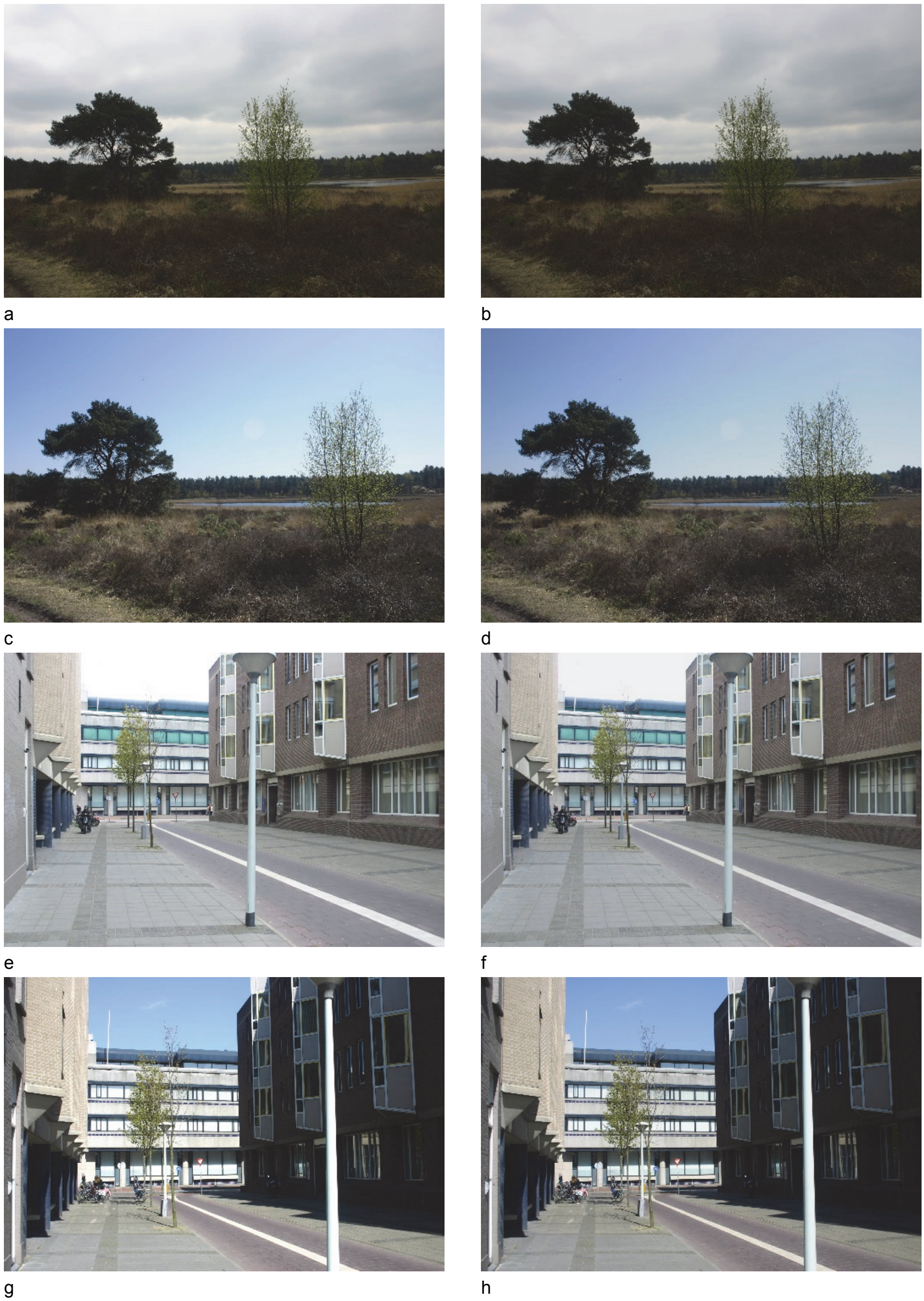


Figure 2.1 Example photos. (a = natural, overcast, light; b = natural, overcast, dark; c = natural, sunny, light; d = natural, sunny, dark; e = urban, overcast, light; f = urban, overcast, dark; g = urban, sunny, light; h = urban, sunny, dark).

Photo characteristics. Participants rated the pictures on a number of additional variables. These variables were not part of our central hypothesis, but were added to explore how the different manipulations affected ratings on a number of characteristics of the photos. Participants indicated how [light, rich in contrast, complex, fascinating, vast, familiar] they rated the environment, again on scales ranging from 1 (not at all) to 7 (extremely). Participants were also asked to indicate which time of day (8-10 am, 10-12 am, 12-2 pm, 3-4 pm, 4-6 pm) and which season (autumn, winter, spring, or summer) they felt it was when each picture was taken, to control for these variables as potential predictors of outcomes.

2.2.1.5 Data analysis

The mean ratings for all the items were calculated for each of the eight categories (nature sunny light / dark, nature overcast light / dark, urban sunny light / dark, urban overcast light / dark). Full-factorial repeated measures ANOVAs were performed with aesthetics and attitude as dependent variable and Environment, Weather type and Brightness as within-subjects variables.

2.2.2 Results

2.2.2.1 Explicit preference

Aesthetic evaluation

Significant main effects for all three manipulations were found on aesthetic evaluation; Environment ($F(1,19) = 55.15$, $p < .001$, $\eta_p^2 = .74$), Weather ($F(1,19) = 20.2$, $p < .001$, $\eta_p^2 = .52$), and Brightness ($F(1,19) = 9.7$, $p = .006$ $\eta_p^2 = .34$) all impacted aesthetic evaluation in the expected directions, see Figure 2.2. Natural environments ($M = 4.7$, $SE = .12$) scored significantly higher on aesthetic evaluation than urban environments ($M = 3.7$, $SE = .16$). Participants also rated sunny scenes ($M = 4.4$, $SE = .13$) higher than overcast scenes ($M = 4.0$, $SE = .13$) and light scenes ($M = 4.3$, $SE = .13$) higher than dark scenes ($M = 4.1$, $SE = .12$).

Furthermore, a significant interaction of Environment * Weather ($F(1,19) = 5.8$, $p = .026$, $\eta_p^2 = .23$) was found as well as a significant interaction of Weather * Brightness ($F(1,19) = 9.9$, $p = .005$, $\eta_p^2 = .35$). Effects of sunny weather appeared stronger for natural than urban scenes, and stronger for dark than light images. See Table 2.1 for means and standard deviations. The Environment * Brightness interaction was not significant ($F(1,19) = 1.3$, $p = .247$).

Table 2.1 Means and standard deviations for Environment * Weather and Weather * Lightness on aesthetics.

	Urban Environment M (SE)	Natural Environment M (SE)	Dark M (SE)	Light M (SE)
Overcast Weather	3.5 (.15)	4.5 (.15)	3.9 (.13)	4.2 (.14)
Sunny Weather	3.8 (.18)	5.0 (.11)	4.4 (.13)	4.4 (.14)

Attitude
A similar pattern was found for the attitude towards spending one hour in the displayed environment. Significant main effects were found for Environment (F(1,19) = 57.2, p < .001, η_p^2= .76), Weather (F(1,19) = 23.0, p < .001, η_p^2= .55), and Brightness (F(1,19) = 8.0, p = .011, η_p^2= .29), see Figure 2.3. Again, natural environments (M = 4.7, SE = .10) scored higher than urban environments (M = 3.4, SE = .16), sunny weather (M = 4.3, SE = .11) scored higher than overcast weather (M = 3.8, SE = .11) and light scenes (M = 4.2, SE = .10) scored higher than dark scenes (M = 4.0, SE = .11).

As for aesthetics, interaction effects were found for both Environment * Weather (F(1,19) = 8.4, p = .009, η_p^2=.30) and Weather * Brightness (F(1,19) = 15.8, p =.001, η_p^2=.45). Again, effects of sunny weather appeared stronger for natural than urban scenes, and stronger for dark than light images. One additional significant interaction of Environment * Brightness (F(1,19) = 6.0, p = .024, η_p^2=.24) was found, indicating that the effect of Brightness was stronger for natural than urban scenes. See Table 2.2 for means and standard deviations.

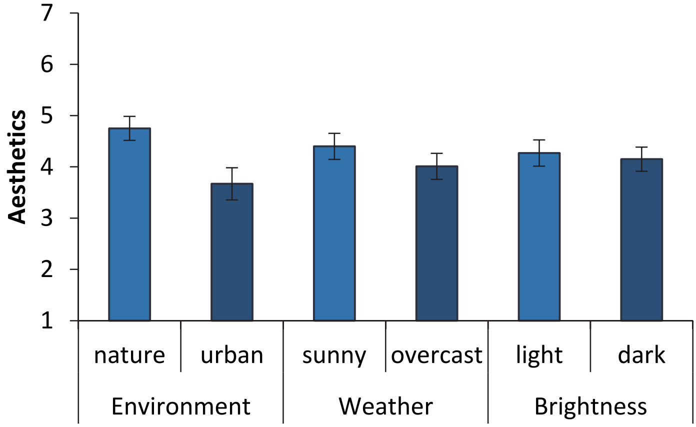


Figure 2.2 Main effects of environment, weather type, and brightness on aesthetics. Error bars represent 95% confidence intervals.

Table 2.2 Means and standard deviations for the Weather * Lightness, Environment * Weather, and Environment * Lightness interaction on attitude.

	Urban Environment M (SE)	Natural Environment M (SE)	Overcast Weather M (SE)	Sunny Weather M (SE)
Dark	3.4 (.17)	4.5 (.11)	3.6 (.13)	4.3 (.12)
Light	3.5 (.15)	4.8 (.20)	4.0 (.11)	4.3 (.11)
Overcast Weather	3.3 (.17)	4.4 (.13)		
Sunny Weather	3.6 (.16)	5.0 (.11)		

Photo characteristics
A series of full-factorial repeated measures ANOVAs was run with the photo characteristics as dependent variables, and Environment, Weather, and Brightness as within-subject variables.

Main effects of Environment type were found on complexity (F(1,19) = 17.7, p <.001, η_p^2=.48), fascination (F(1,19) = 17.7, p <.001, η_p^2=.48), familiarity (F(1,19) = 123.3, p < .001, η_p^2=.86), and time of day (F(1,19) = 7.8, p= .011, η_p^2=.29) but not on perceived lightness, contrast, or extent. Natural environments were rated higher on complexity (M = 4.8, SE = .09), fascination (M = 4.2, SE =.18), and familiarity (M = 4.7, SE = .12) than urban environments (M = 4.4, SE = .14; M = 3.4, SE = .18; and M = 2.7, SE = .13, resp.). Furthermore, time of day was estimated later in the natural (M = 3.4, SE = .09) than in the urban (M = 3.0, SE = .13) environments.

Main effects for Weather type were found on lightness (F(1,19) =5.2, p =.035, η_p^2=.21), perceived contrast (F(1,19) = 28.0, p <.001, η_p^2=.59), complexity (F(1,19) = 81.1, p <.001, η_p^2=.81), fascination (F(1,19) = 28.9, p <.001, η_p^2=.61), and extent (F (1,19) = 5.5, p = .03, η_p^2=.22). Sunny weather (M = 3.7, SE = .13) was perceived as lighter than overcast weather

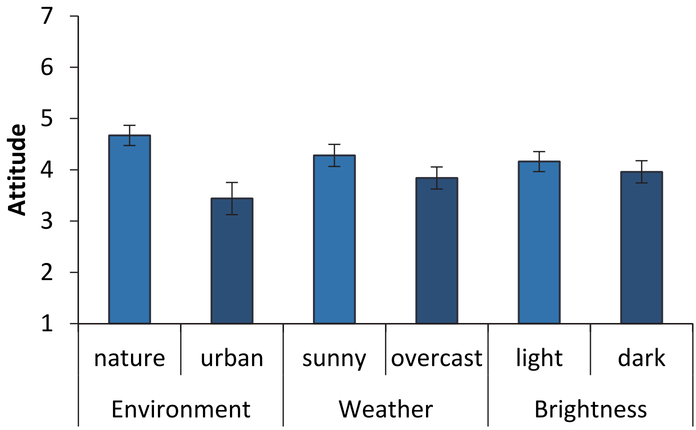


Figure 2.3 Main effects of environment, weather type, and brightness on attitude. Error bars represent 95% confidence intervals.

Table 2.3 Means and standard deviations for the Weather * Lightness interaction on contrast, complexity, fascination, and time of day.

		Contrast M (SE)	Complexity M (SE)	Fascination M (SE)	Time of day M (SE)
Overcast	Dark	3.6 (.13)	3.3 (.11)	3.5 (.17)	3.7 (.17)
weather	Light	3.9 (.13)	4.8 (.12)	3.7 (.15)	3.1 (.12)
Sunny	Dark	4.2 (.15)	4.7 (.15)	3.9 (.15)	3.0 (.12)
weather	Light	4.2 (.14)	5.5 (.15)	3.9 (.16)	2.9 (.12)

(M = 3.6, SE = .14); higher on contrast (M = 4.2, SE = .14 vs. M = 3.8, SE = .12); higher on complexity (M = 5.1, SE = .14 vs. M = 4.1, SE = 1.0); higher on fascination (M = 3.9, SE = .14 vs. M = 3.6, SE = .15); and slightly higher on extent (M = 4.4, SE = .16 vs. M = 4.3, SE = .15). Lastly, sunny scenes (M = 3.0, SE = .11) were perceived as being taken earlier on the day than overcast scenes (M =3.4, SE = .13; (F(1,19) = 11.2, p =.003, η_p^2=.37). No effects of Weather type were found for familiarity.

Surprisingly, no main effect of Brightness was found on perceived lightness of the scenes. Brightness did, however, affect perceived complexity (F(1,19) = 97.4, p <.001, η_p^2=.83), with light scenes (M = 5.1, SE = .12) scoring higher on complexity than dark scenes (M = 4.0, SE = .11). Furthermore, light scenes (M = 3.0, SE = .09) were perceived as being taken earlier on the day than dark scenes (M = 3.4, SE = .12; F(1,19) = 12.5, p =.002, η_p^2=.40). No main effects of Brightness were found for contrast, fascination, perceived extent, and familiarity.

Significant interaction effects were only found for the Weather * Brightness interaction, and only on contrast (F(1,19) = 7.1, p= .016, η_p^2=.27), complexity (F(1,19) = 38.2, p <.001, η_p^2=.67), fascination (F(1,19) = 5.0, p = .037, η_p^2=.21), and time of day (F(1,19) = 13.0, p= .002, η_p^2=.41), see Table 2.3 for means and standard deviations. In general, effects of Brightness were stronger for overcast than sunny images.

To test for differences in the season attributed to the scenes, chi-square tests were performed with Environment, Weather, and Brightness crossed with the frequency that each of the seasons was chosen. These tests revealed significant relations between Environment and season (χ^2 (3)= 17.2, p = .001) and between Weather and season (χ^2 (3)= 9.5, p = .024), but not between Brightness and season (χ^2 (3)= 5.9, p = .116).

2.2.3 Discussion

Results of Study One indicated a clear preference for natural, sunny, and bright environments when asked explicitly. Interaction effects suggest that effects of the brightness manipulation are more pronounced under an overcast sky than under a sunny sky. A large overlap in effects was found between aesthetics and attitude towards the environments. Interestingly, we found effects of brightness of the scenes on attitude and aesthetics even though we did not find differences in direct subjective lightness ratings. However, the difference in brightness between light and dark pictures was very subtle. Therefore, we increased the difference in brightness between light and dark pictures in Study Two. Fascination, an important factor within Attention Restoration Theory, was not only found to be higher for natural as compared to urban environments, but also for sunny as compared to overcast weather. Moreover, extent - a second important factor within ART- was found to differ between weather types, with sunny weather scoring higher on extent.

As both nature and daylight characteristics -captured in weather type and brightness- induced marked differences in terms of explicit preference in the current study, we performed a second study to replicate these effects with a new set of pictures and to test whether such differences would also appear in an (implicit) affective priming paradigm.

2.3 Study Two – Implicit and explicit preference for bright and sunny nature

In the second study participants completed an affective priming task, adapted from Hietanen and Korpela (2004). In addition, participants rated the pictures on explicit preference afterwards. Because of the considerable overlap in effects found for aesthetics and attitude, we only included measures of attitude in the second study. Furthermore, we added questions about how sunny and threatening participants perceived the scenes. We expected to find a replication of the findings of Study One for explicit preference.
Furthermore, we also expected to find an implicit preference for natural environments – replicating results reported by Hietanen and Korpela (2004) but also for sunny and light environments. More specifically, we expected faster responses to positive facial emotional expressions after displaying pictures of natural, sunny, and light environments than after displaying urban, overcast, and dark pictures and the opposite pattern for negative facial expressions.

2.3.1 Method

2.3.1.1 Design
Two within-participants experiments were run in parallel. In Study 2a target stimuli were happy and angry faces, in Study 2b target stimuli were happy and sad faces. Dependent variables were both explicit and implicit preference (reaction time). In both studies, pictures were manipulated across three dimensions (Environment, Weather type, Brightness) as in study One.

2.3.1.2 Participants
In Study 2a, 25 participants (10 females) participated. Their ages ranged from 19 to 33 (M= 22.0; SE= 3.7). In Study 2b, 25 participants (8 females) participated. Their ages ranged from 19 to 32 (M= 21.9; SE=2.7). Participants were recruited via our participant database. The majority studied at the Eindhoven University of Technology or the Fontys Higher Education Institute. All participants had normal or corrected to normal vision.

2.3.1.3 Procedure

Participants were seated in a cubicle behind a computer. After signing the informed consent form the experiment started. They first received instructions on the computer about the reaction time task. They were told that environments would appear briefly, followed by the faces. After the instruction, a practice round started (with environments and faces different from the ones in the experimental trials). After finishing the affective priming task, participants reported their mood and started with the second part of the experiment. In this part, participants rated all 24 pictures on the photo characteristics and attitude. After finishing the second part of the experiment, participants were thanked and paid for their participation. The experiment lasted approximately 50 minutes and participants received €10,- as compensation.

2.3.1.4 Stimuli

In this study, we again used a set of photos that was objectively manipulated (i.e., by categorical or numerical differences) along three dimensions; Environment type, Weather type, and Brightness.

Photos. The photos were taken during summertime, late August and September. All photos were taken between 12 am and 2 pm.

Environment type. Again, the nature photos were taken at the “Strabrechtse heide”, containing primarily heath and woodland. The urban photos were all taken in the center of the city of Eindhoven.

Weather type. Both the nature and urban scenes (three of each) were photographed twice, once in sunny, once in overcast conditions. Again, natural and urban scenes were visually matched on overall spatial structure (i.e., enclosure, composition) and on the amount of shadows and contrasts.

Brightness. For the brightness manipulation, the same procedure was used as in Study One, resulting in a set of 24 pictures distributed over eight experimental categories, see Figure 2.4.

Facial expressions.

For the emotional facial expressions, faces from the Radboud Faces Database (Langner, Dotsch, Bijlstra, Wigboldus, Hawk, & van Knippenberg, 2010) were chosen. In each study, emotional expressions from 2 males and 2 females were used.

2.3.1.5 Measures

Affective Priming Task. Affective priming paradigms consist of a ‘prime’ stimulus that is briefly shown to a participant (in our case a photo from the environmental stimuli set), and a subsequent ‘target’ stimulus, which participants are asked to categorize as quickly as possible. In the present study the targets were happy and angry (Study 2a) or happy and sad (Study 2b) facial expressions. Participants could familiarize themselves with the task during a practice round before the start of the experimental trials. Figure 2.5 provides a schematic overview of the affective priming task.

Figure 2.4 Example photos. (a = natural, overcast, light; b = natural, overcast, dark; c = natural, sunny, light; d = natural, sunny, dark; e = urban, overcast, light; f = urban, overcast, dark; g = urban, sunny, light; h = urban, sunny, dark).

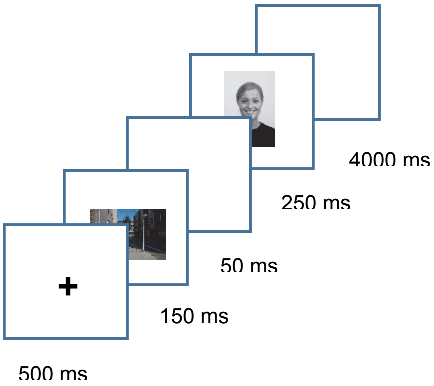


Figure 2.5 Scheme of affective priming task.

Each trial started with a fixation point at the centre of the screen, displayed for 500 ms, followed by a picture of the environment which was displayed for 150 ms. Subsequently a blank screen was displayed for 50 ms. followed by the display of the emotional facial expression for 250 ms. after which participants were given a response time of maximally 1500 ms. during which a blank screen was displayed. A trial was concluded with a blank screen displayed for 2500 ms.

They were instructed to pay attention to the environmental scenes, but they had to react as fast and correct as possible to the emotional faces (targets) displayed after the environments. Response keys used were the 'z' key on the left side of the keyboard and the '3' key on the numeric keypad on the right of the keyboard. Participants placed and kept their index fingers on these keys during the trials. The meaning of the response keys (angry/sad vs. happy) was counterbalanced between participants. Two emotional expressions of 2 male and 2 female faces were displayed as target. All combinations of the 24 pictures with the 8 faces were presented in random order, resulting in a total of 192 trials. *Mood.* Participants rated their mood by indicating how [tired, sad, tense, happy, bored, angry, irritable, relaxed] they felt on a scale ranging from 1 (not at all) to 7 (to a high degree). This part was added as a filler task between the affective priming session and the explicit ratings session and will therefore not be reported.

Photo characteristics. Participants rated all 24 scenes on the following items: rich in contrast, light, threatening, fascinating, vast, sunny, and complex on scales ranging from 1 (not at all) to 7 (to a high degree). Participants were also asked to indicate which time of day (8-10 am, 10-12 am, 12-2 pm, 3-4 pm, 4-6 pm) they thought each picture was taken.

Preference: Attitude. As in Study One, attitude was measured with three items asking how [pleasant, positive, attractive] it would be to spend an hour in the displayed environment (Staats et al., 2003), measured on a scale from 1 (not at all) to 7 (to a very high degree).

2.3.1.6 Data analysis

To investigate the effects of the three manipulations on attitude and photo characteristics, data from both studies were collapsed into one (no significant differences were found between Studies 2a and 2b). A series of full-factorial repeated-measures ANOVA's were run with attitude and photo characteristics as dependent variables, and Environment, Weather, and Brightness as within-subjects variables.

Before data analysis of the implicit preference measures, all incorrect responses and reaction times deviating more than 2 standard deviations from the mean were removed. Mean reaction time scores were calculated for each of the eight categories, for each valence. A full-factorial Repeated measures ANOVA was again run. This time with reaction time score as dependent variable and Environment, Weather type, Brightness, and Valence as independent factors.

2.3.2 Results

We will first report effects found for explicit preference, followed by the results for the photo characteristics. Second, we will report effects found for environment, weather type, and brightness on implicit preference.

2.3.2.1 Explicit measures

Explicit preference: Attitude

As in Study 1, significant main effects were found for all three manipulations in the expected direction, Environment ($F(1,49) = 82.1$, $p < .001$, $\eta_p^2=.62$), Weather ($F(1,49) = 172.8$, $p < .001$, $\eta_p^2=.77$), and Brightness ($F(1,49) = 14.1$, $p < .001$, $\eta_p^2=.22$), see Figure 2.6. Natural environments ($M = 4.8$, $SE = .11$) scored higher than urban environments ($M = 3.4$, $SE = .10$), sunny scenes ($M = 4.6$, $SE = .09$) scored higher than overcast scenes ($M = 3.6$, $SE = .09$) and light scenes ($M = 4.2$, $SE = .08$) scored higher than dark scenes ($M = 4.0$, $SE = .08$). Contrary to the results in Study One, no significant interaction effects were found.

Photo characteristics

Main effects of Environment were found on perceived lightness ($F(1,49) = 28.0$, $p < .001$, $\eta_p^2=.36$), extent ($F(1,49) = 127.5$, $p < .001$, $\eta_p^2=.72$), and fascination ($F(1,49) = 69.0$, $p < .001$, $\eta_p^2=.58$). Natural environments scored higher on lightness ($M = 4.5$, $SE = .09$), extent ($M = 5.0$, $SE = .14$) and fascination ($M = 4.2$, $SE = .13$) than urban scenes ($M = 4.0$,

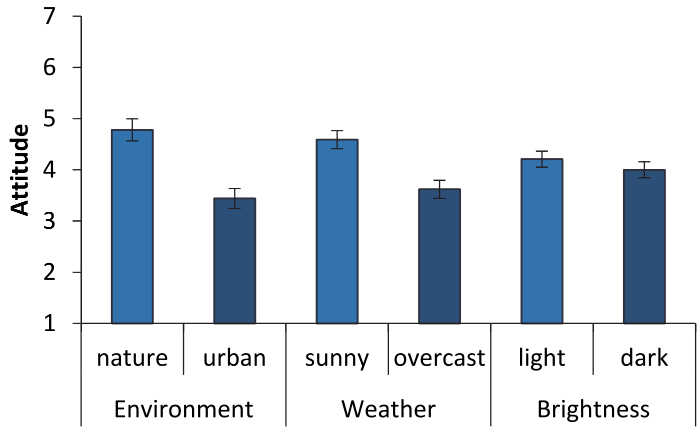


Figure 2.6 Main effects of environment, weather type, and brightness on attitude. Error bars represent 95% confidence intervals.

SE = .08; *M* = 2.8, *SE* = .13; *M* = 3.0, *SE* = .10, resp.). Furthermore, Environment type also significantly affected scores on the two new items: 'sunny' ($F(1,49) = 22.1$, $p < .001$, $\eta_p^2=.31$) and perceived threat ($F(1,49) = 5.4$, $p = .024$, $\eta_p^2=.10$). Natural environments (*M* = 4.2, *SE* = .09) were perceived as being sunnier than urban environments (*M* = 3.7, *SE* = .08), while urban environments (*M* = 2.5, *SE* = .12) were perceived as more threatening than natural environments (*M* = 2.3, *SE* = .12).

Main effects of Weather type were found on perceived lightness ($F(1,49) = 480.5$, $p < .001$, $\eta_p^2=.90$), contrast ($F(1,49) = 104.1$, $p < .001$, $\eta_p^2=.67$), extent ($F(1,49) = 21.4$, $p < .001$, $\eta_p^2=.30$), fascination ($F(1,49) = 99.9$, $p < .001$, $\eta_p^2=.67$), and time of day ($F\ (1,49) = 5.9$, $p = .019$, $\eta_p^2=.11$). As in Study One the scores on lightness, contrast, extent, and fascination were higher for Sunny weather than for Overcast weather, see Table 2.4 for means and standard errors. Furthermore, as could be expected, Weather type significantly affected the score on the item 'sunny' ($F(1,49) = 417.5$, $p < .001$, $\eta_p^2=.90$). Sunny weather (*M* = 5.3, *SE* = .09) scored significantly higher than Overcast weather (*M* = 2.7, *SE* = .10). Lastly, Overcast scenes (*M* = 2.6, *SE* = .12) were perceived as more threatening than Sunny scenes (*M* = 2.2, *SE* = .10; $F(1,49) = 28.3$, $p < .001$, $\eta_p^2=.37$).

Table 2.4 Means and standard errors of lightness, contrast, extent, fascination, and time of day.

	Lightness M (SE)	Contrast M (SE)	Extent M (SE)	Fascination M (SE)	Time of day M (SE)
Overcast	3.4 (.09)	3.3 (.10)	3.7 (.09)	3.2 (.10)	3.3 (.08)
Sunny	5.2 (.08)	4.7 (.11)	4.1 (.10)	4.0 (.10)	3.0 (.05)

Table 2.5 Means and standard errors for lightness, contrast, and perceived threat.

		Lightness M (SE)	Contrast M (SE)	Perceived threat M (SE)
Overcast	Dark	2.9 (.10)	3.2 (.11)	2.9 (.15)
	Light	3.9 (.10)	3.5 (.10)	2.3 (.11)
Sunny	Dark	4.8 (.09)	4.7 (.12)	2.3 (.12)
	Light	5.5 (.09)	4.7 (.12)	2.1 (.10)

Table 2.6 Means and standard errors for the environment * lightness interaction for contrast and the environment * weather interaction for fascination.

	Contrast		Fascination	
	Dark M (SE)	Light M (SE)	Overcast M (SE)	Sunny M (SE)
Natural	4.1 (.11)	4.0 (.13)	3.7 (.14)	4.7 (.14)
Urban	3.8 (.11)	4.2 (.10)	2.6 (.11)	3.3 (.12)

Brightness of the scenes significantly affected scores on perceived lightness ($F(1,49) = 19.1$, $p < .001$, $\eta_p^2=.28$), extent ($F(1,49) = 5.6$, $p = .022$, $\eta_p^2=.10$), and time of day ($F\ (1,49) = 13.2$, $p = .001$, $\eta_p^2=.21$). As expected, bright scenes ($M = 4.7$, $SE = .08$) scored higher on lightness than dark scenes ($M = 3.9$, $SE = .09$). Furthermore bright scenes ($M = 4.0$, $SE = .10$) also were rated higher on extent than dark scenes ($M = 3.8$, $SE = .10$). Time of day in bright scenes ($M = 3.0$, $SE = .05$) was rated as significantly earlier than for dark scenes ($M = 3.3$, $SE = .06$). Bright scenes ($M = 4.3$, $SE = .08$) also scored higher on the item 'sunny' than dark scenes ($M = 3.7$, $SE = .08$; $F(1,49) = 79.7$, $p < .001$, $\eta_p^2=.62$). Lastly, dark scenes ($M = 2.6$, $SE = .12$) were perceived as more threatening than the bright scenes ($M = 2.2$, $SE = .10$; $F(1,49) =52.6$ $p < .001$, $\eta_p^2=.52$).

Besides main effects, a number of interaction effects were found. A significant interaction of Weather * Brightness was found on lightness ($F(1,49) = 115.0$, $p < .001$, $\eta_p^2=.71$), contrast ($F(1,49) = 5.2$, $p = .027$), and perceived threat ($F(1,49) = 14.6$, $p < .001$, $\eta_p^2=.23$), see Table 2.5. As in Study One, effects of Brightness were generally stronger for overcast than sunny images. An Environment * Brightness ($F(1,49) = 17.1$, $p < .001$, $\eta_p^2=.26$) interaction was found for contrast, see Table 2.6. For fascination a significant interaction of Environment * Weather ($F(1,49) = 13.3$, $p = .001$, $\eta_p^2=.21$) appeared, see Table 2.6. Perceived contrasts were impacted by Brightness, but more so in urban than in nature scenes. Fascination was positively impacted by sunny weather, but more so for natural than urban scenes.

Mediation of lightness and amount of sunshine on preference

In the previous section, we saw that perceived lightness varied not only with the brightness manipulation, but also with environment type and weather type. Similarly, perceived amount of sunshine not only varied with weather type, but also with environment type and brightness. To investigate to what extent these changes in perceived lightness and sunshine explain effects on preferences, we ran additional mediation analyses. Because single-level models of nested data generally underestimate the standard errors (Krull, & MacKinnon,

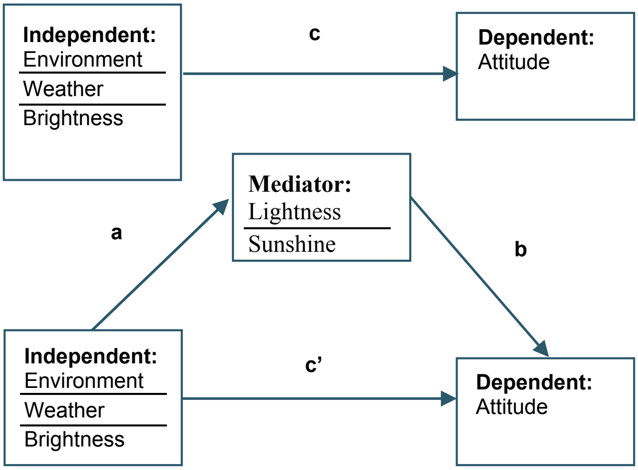


Figure 2.7 Graphical representation of the mediation analyses

2001), multilevel models were used with participant as nesting variable. Mediation effects were calculated based on Bauer, Preacher, & Gil (2006) and are presented in Figure 2.7 and Table 2.7.

The effect of weather type on attitude was significantly mediated by perceived lightness and amount of sunshine. Furthermore, the effect of the brightness manipulation on attitude was fully mediated by weather type and partially mediated by lightness. Interestingly, the effect of

Table 2.7 Mediation analyses for the effects of environment and weather type on attitude, mediated through lightness and amount of sunshine.

Independent	Mediator	a (SE)	b (SE)	c (SE)	c' (SE)	Indirect effects (ab)	Confidence Interval
Environment	Lightness	-.32** (.08)	.44** (.02)	-1.15** (.12)	-1.02** (.02)	-.17* (.01)	(-.19) - (-.15)
	Sunshine	-.32* (.10)	.43** (.03)	-1.15** (.12)	-1.02** (.10)	-.27** (.02)	(-.30) - (-.24)
Weather	Lightness	1.75** (.09)	.53** (.03)	1.06** (.07)	.21 (.14)	.86** (.14)	.82 - .90
	Sunshine	2.71** (.15)	.46** (.03)	1.06** (.07)	-.28 (.20)	1.42** (.04)	1.35 - 1.49
Brightness	Lightness	.75** (.09)	.42** (.05)	.19** (.05)	-.23* (.10)	.43** (.02)	.40 - .46
	Sunshine	.54** (.06)	.56** (.07)	.19** (.05)	-.11 (.10)	.30** (.02)	.27 - .33

** p < .05, **p < .001*

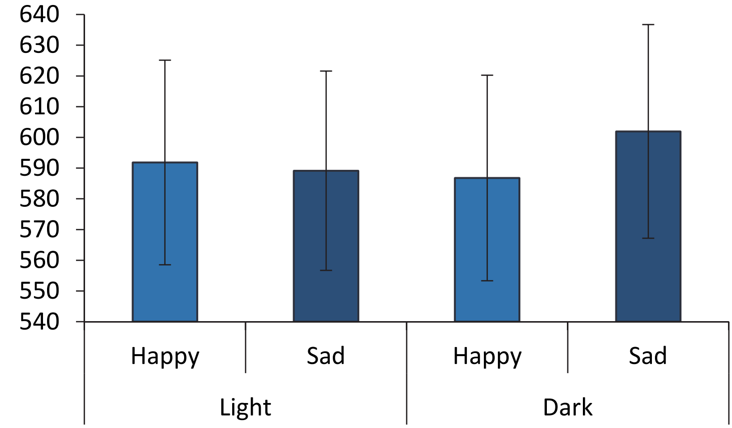


Figure 2.8 The Valence * Brightness interaction. Error bars represent the 95% confidence intervals.

environment on attitude was also partially mediated by both perceived lightness and amount of sunshine.

2.3.2.2 Implicit measures: the Affective Priming Task

Study 2a Happy versus Angry expressions

Counter to our expectations, no main effects or interaction effects were found for Environment, Weather type, Brightness, or Valence ($F(1,24) < 2.6$, $p > .117$).

Study 2a Happy versus Sad expressions

No main effects were found for Environment, Weather type, Brightness, or Valence (all $F(1,24) < 2.6$, $p > .119$). One significant interaction effect of Valence * Brightness was found ($F(1,24) = 5.0$, $p = .034$, $\eta_p^2 = .18$), see Figure 2.8. No further interaction effects were found ($F(1,24) < 3.0$, $p > .094$).

Contrary to our expectations, after dark scenes participants responded faster to happy emotional expressions than to sad emotional expressions, while reaction times were approximately equal after light scenes.

2.3.3 Discussion

In Study Two, we replicated our findings for explicit preference from Study One, indicating a clear preference for natural, sunny, and bright environments. Again, this was largely in line with our expectations. In contrast however, we did not find any of the expected effects for the implicit preferences, whether we contrasted happy with angry targets (Study 2a), or happy with sad targets (Study 2b). In fact, the only effect we did find in the latter experiment (Brightness * Valence) showed a direction opposite to the hypothesis.

Investigation of perceived photo characteristics illustrated that all three manipulations of the scenes affected a range of characteristics. This included components of restorativeness such as fascination and extent, but also perceptions of contrast, lightness, and amount of sunshine. The latter series of effects indicates a certain level of spill-over in the effects of the three manipulations. Changing one dimension can thus also affect perception on other seemingly unrelated variables, which indicates the complexity of environmental scene perception.

In an additional mediation analysis we explored how perceived amount of sunshine and perceived lightness influenced preference ratings. Here, we found clear indications that the difference in preference between light and dark pictures had everything to do with differences in perceived lightness and perceived amount of sunshine. Moreover, differences between sunny and overcast pictures were partly mediated by perceived lightness and fully mediated by perceived amount of sunshine. These results indicate that our manipulations were successful and that perceptions of lightness and sunshine contribute significantly to environmental preference. Surprisingly, we also found that perceived lightness and amount of sunshine in the natural versus urban scenes (even though they were objectively matched on these manipulations) partially mediated differences in preference ratings between natural and urban scenes.

The effects on explicit preference found were in line with what we expected, again corroborating the successfulness of the manipulations of naturalness, brightness and weather type, and their effectiveness in inducing more positively valenced explicit judgments. The question that arises is why this was not reflected in the implicit affect measures. After all, whether such effects would arise for light and sunny scenes had not been tested before, but for natural vs. urban scenes Hietanen and Korpela (2004) did establish affective prime effectiveness. We therefore explored methodological explanations for the absence of effects.

In the current study we employed exposure durations and targets types similar to those used by Hietanen en Korpela (2004). There is however one important distinction between their and our studies: the number of dimensions along which the primes differ. The assumption underlying affective priming paradigms is that a prime will facilitate or inhibit the recognition of the target when prime and target are affectively congruent or incongruent respectively. Such evaluations should be less sensitive to cognitive biases and intentional distortion, and instead of being governed by conceptual or verbal representations of events, implicit affective responses are ‘likely to depend on associations individuals form between events and affective responses’ (Quirin, Kazen, Rohrman, & Kuhl, 2009; Strack, & Deutsch, 2004). To tap into these pre-cognitive responses, primes are only flashed briefly (150 ms) before the target appears. Within this brief exposure period, participants do however have to recognize and categorize the depicted object or environment before an affective response emerges. In the current study we included all three manipulations in one affective priming paradigm. It is possible that by adding these three dimensions simultaneously, immediate categorization of the scenes is more difficult than when scenes vary along only one dimension (e.g., nature versus urban). Therefore, we decided to run a third study in which the three dimensions were manipulated separately.

2.4 Study Three – Implicit and explicit preferences for bright and sunny nature

In the third study we conducted a series of experiments in parallel. In each experiment only one of the three dimensions (Environment, Weather, or Brightness) was manipulated at a time, keeping the other two dimensions constant. In the first experiment (Study 3a), environment type was manipulated. All pictures were taken in sunny weather and brightness was matched. In the second experiment, weather type was manipulated. We conducted two separate experiments, one with natural scenes (Study 3b) and one with urban scenes (Study 3c). Again, brightness was kept constant. In the fourth and last experiment, brightness was manipulated (Study 3d). All pictures in this experiment were urban scenes with a partially overcast sky. One additional methodological change from Study Two concerned the type of targets. In the current study the targets were positive and negative words instead of facial expressions. As in Study Two, all participants first completed an affective priming paradigm and afterwards rated all pictures on several characteristics.

2.4.1 Method

2.4.1.1 Design
Four within-subjects experiments were run in parallel, investigating the effects of Environment (3a; sunny nature vs sunny urban), Weather for natural scenes (3b; sunny nature vs. overcast nature), Weather for urban scenes (3c; sunny urban vs. overcast urban), and Brightness (3d; urban; light vs. dark). Dependent variables were both explicit (attitude) and implicit preference (reaction time).

Study 3c and 3d were combined into one experiment, for which participants first completed the first study (affective priming task followed by the explicit rating of the pictures) before starting the second study. The order of studies (3c / 3d) was counterbalanced and results were checked for possible order effects. This combined experiment lasted approximately 30 minutes and participants received €5,- compensation.

2.4.1.2 Participants
In total 122 participants (64 females) participated in the study. In study 3a (Environment) 33 participants (17 females) participated. Their mean age was 20.9 (*SD*=2.3). Thirty three participants (17 females) completed Study 3b (Weather, Nature scenes) with a mean age of 20.8 (*SD*=2.3). Twenty-seven participants (14 females) participated in Study 3c (Weather, Urban scenes), their mean age was 22.1 (*SD*=2.1). Lastly, Study 3d (Brightness, Urban scenes) had 29 participants (16 females), of which 2 participants completed only the Brightness condition. Their mean age was 21.7 (*SD*=2.2). The majority of participants were

student. Recruiting participants was done face-to-face and via emails to respondents in our database. All participants had normal or corrected to normal vision.

2.4.1.3 Procedure

Participants were seated in a cubicle behind a computer. After signing the informed consent form the experiment started. They first received instructions on the computer about the reaction time task. They were told that environments would appear briefly, followed by the display of words. After the instruction, a practice round started with environments and words different from those in the actual experiment. After the affective priming task, participants reported their mood and started with the second part of the experiment. In this part, participants rated all 6 pictures on the general aspects and attitude. After finishing the second part of the experiment, participants were thanked and paid for their participation. The experiment lasted approximately 15 minutes and participants received €3,- as compensation.

2.4.1.4 Stimuli

All photos originated from the same photoset as was used in Study Two. Compared to Study Two, additional photos – as for instance the partially overcast scenes - were needed. These photos were chosen from the larger pool of photos acquired for Study Two. Instead of emotional facial expressions, we used Dutch translations of positive and negative words adapted from Meier and Robinson (2004). Examples of positive words were loyal, love, sweet, and gifted. Examples of negative words were divorce, illness, sour, and rude. The chosen words were unrelated to any of the manipulations.

2.4.1.5 Measures

Affective Priming Task. During the Affective Priming Task, the environmental scenes served as priming stimuli and the positive and negative words served as targets. Each trial started with a fixation point at the center of the screen, displayed for 2000 ms, followed by a picture of the environment which was displayed for 150 ms. This prime was followed by a blank screen for 150 ms. after which either a positive or negative word was displayed for 2000 ms. In each study three different scenes were used per condition (e.g. 3 natural and 3 urban pictures in Study 3a). Each scene was combined with six positive and six negative words, resulting in a total of 72 trials. For the remainder of the task, the same procedure was used as in Study Two.

Mood. Participants rated their mood by indicating how [tired, sad, tense, happy, bored, angry, irritable, relaxed] they felt on a scale ranging from 1 (not at all) to 7 (to a high degree). Again, this questionnaire mainly served as a filler between tasks and will not be reported here.

Photo characteristics. Participants were asked to indicate how [rich in contrast, light, threatening, fascinating, vast, sunny] they rated the environment, again on scales ranging from 1 (not at all) to 7 (to a high degree). Participants were also asked to indicate which time of day (8-10 am, 10-12 am, 12-2 pm, 3-4 pm, 4-6 pm) they thought each picture was taken.

Attitude. Attitude was measured by asking participants to indicate how [pleasant, positive, agreeable] it would be to spend one hour in the displayed environment (Staats et al., 2003), measured on a scale from 1 (not at all) to 7 (to a very high degree).

2.4.1.6 Data analysis
For explicit preference, full-factorial repeated measures ANOVAs were conducted with attitude as and photo-characteristics dependent variables and manipulation (Environment, Weather, Brightness) as independent variables.

Before analysing the implicit preference data, all incorrect responses and reaction times deviating more than 2 standard deviations from the mean were removed. Mean reaction time scores were calculated for each category, for each valence. For each study, a full-factorial repeated measures ANOVA was run with reaction time score as dependent variable and the manipulation (Environment, Weather, or Brightness) and Valence as independent factors.

2.4.2 Results

We will first report effects found for explicit preference, followed by the results for the photo characteristics. Lastly, we will report effects found for implicit preference. Effects will be reported for each experiment separately.

2.4.2.1 Explicit measures

Explicit preference (attitude)
Study 3a Environment
A significant main effect of environment was found (F (1,28) = 136.8, p < .001, η_p^2=.83). As expected, natural environments (M = 5.5, SE = .16) scored significantly higher on preference than urban environments (M = 3.0, SE = .19).

Study 3b and c Weather (nature & urban)
First, two separate repeated measures ANOVA's (in natural /urban environment) were conducted with attitude as dependent variable and Weather type as within-subjects variable. Main effects of Weather on attitude were found both for the natural scenes (F(1,26) =69.1 , p < .001, η_p^2=.72) as well as the urban scenes (F(1,32) = 30.4, p < .001, η_p^2=.49). For both types of environment, sunny weather scenes (nature: M = 5.3, SE = .18, urban: M = 3.9, SE = .16) scored higher on attitude than overcast scenes (nature: M = 3.9, SE = .17, urban: M = 3.2, SE = .14).

Study 3d Brightness
A significant main effect of brightness was found ($F(1,32) = 27.1$, $p < .001$, $\eta_p^2=.46$). Light environments ($M = 3.8$, $SE = .19$) scored higher on preference than dark environments ($M = 3.0$, $SE = .15$).

Photo characteristics
The analyses of the photo characteristics yielded similar results as in Study One and Two and will only briefly be discussed here.

Study 3a Environment
Natural environments were perceived as significantly sunnier than urban environments ($F(1,28) = 45.2$, $p < .001$, $\eta_p^2=.62$) and scored higher on perceived lightness ($F(1,28) = 58.9$, $p < .001$, $\eta_p^2=.67$), extent ($F(1,28) = 173.4$, $p < .001$, $\eta_p^2=.86$), and fascination ($F(1,28) = 45.5$, $p < .001$, $\eta_p^2=.62$). Lastly, urban environments were perceived to be more threatening than natural environments ($F(1,28) = 8.7$, $p = .006$, $\eta_p^2=.24$). No effects were found on complexity, contrast, or perceived time of day ($F(1,26) < 1.8$, $p > .187$).

Study 3b Weather Nature
Sunny weather was rated as sunnier ($F(1,26) = 172.7$, $p < .001$, $\eta_p^2=.86$) and also scored higher on perceived lightness ($F(1,26) = 74.7$, $p < .001$, $\eta_p^2=.74$), extent ($F(1,26) = 8.1$, $p = .008$, $\eta_p^2=.24$), and fascination ($F(1,26) = 45.9$, $p < .001$, $\eta_p^2=.64$). Surprisingly, overcast weather ($M = 5.1$, $SE = .17$) scored higher on contrast than sunny weather ($M = 3.6$, $SE = .16$; ($F(1,26) = 61.3$, $p < .001$, $\eta_p^2=.71$). There were no differences in complexity and perceived time of day between the two Weather types. Lastly, overcast scenes were perceived as significantly more threatening than sunny scenes ($F(1,26) = 18.7$, $p < .001$, $\eta_p^2=.42$).

Study 3c Weather Urban
Again, not surprisingly, sunny scenes were perceived as sunnier than overcast scenes ($F(1,32) = 72.7$, $p < .001$, $\eta_p^2=.69$) and sunny scenes were also perceived as lighter than overcast scenes ($F(1,32) = 74.7$, $p < .001$, $\eta_p^2=.71$). There was no difference in complexity between the two Weather types, but we did find, as with the natural environment, a main effect of Weather type on perceived extent ($F(1,32) = 5.0$, $p = .033$, $\eta_p^2=.14$). No significant differences were found on fascination. For the urban environment, the same unexpected difference between weather types was found ($F(1,32) = 12.6$, $p = .001$, $\eta_p^2=.28$) with overcast scenes ($M = 4.5$, $SE = .17$) scoring higher on perceived contrast than sunny scenes ($M = 3.7$, $SE = .17$). As with the natural environment, overcast scenes were perceived as significantly more threatening than sunny scenes ($F(1,32) = 16.1$, $p < .001$, $\eta_p^2=.34$). Furthermore, sunny pictures were perceived to be taken significantly earlier in the day ($M = 2.8$, $SE = .11$) than overcast pictures ($M = 3.2$, $SE = .13$; $F(1,32) = 4.2$, $p = .048$, $\eta_p^2=.12$).

Study 3d Brightness

Light pictures were perceived as significantly sunnier ($F(1,32) = 65.4$, $p < .001$, $\eta_p^2=.67$) and lighter ($F(1,32) = 57.5$, $p < .001$, $\eta_p^2=.64$) than dark pictures. As in the earlier studies, we did not find a difference in rated complexity. We did find an effect of Brightness on extent ($F(1,32) = 7.8$, $p = .009$, $\eta_p^2=.19$ and fascination ($F(1,32) = 9.7$, $p = .004$, $\eta_p^2=.23$). No differences in contrast or perceived time of day were found. Lastly, we also found a significant effect of Brightness on perceived threat ($F(1,32) = 26.6$, $p < .001$, $\eta_p^2=.45$).

Mediation analysis

As with Study Two, we post-hoc decided to run additional mediation analyses. However, Mixed Linear models were not used to calculate mediation as no sufficient level-one and level-two units were present to reliably estimate coefficients and covariance parameters. Therefore, a single-level model was used with preference as dependent variable, the three manipulations (environment, weather, and brightness) as independent variables, and perceived lightness and amount of sunshine as mediators. As a consequence of discarding the nested nature of the measurements, standard errors for the coefficients could me slightly underestimated (Krull & MacKinnon, 1999). See Figure 2.9 for a schematic overview of the mediation analyses.

Similar to Study Two, the beneficial effect of natural environments on preference were partially mediated by perceived lightness and amount of sunshine. The effect of the brightness manipulation on preference was fully mediated by both mediators, whereas effects of weather type was fully mediated by amount of sunshine and partially mediated by perceived lightness. The mediation analyses are summarized in Table 2.8.

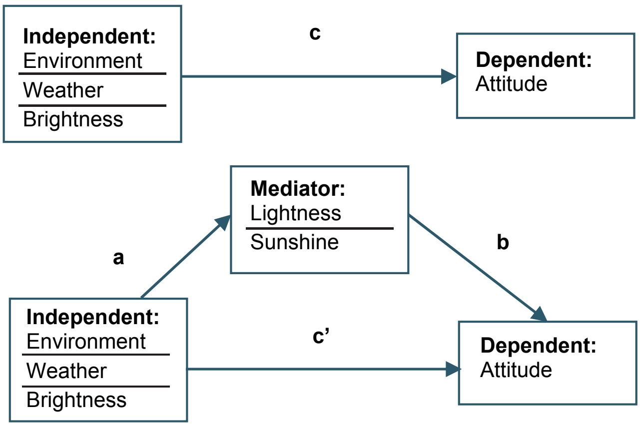


Figure 2.9 Graphical representation of the mediation analyses

Table 2.8 Mediation analyses for the effects of environment and weather type on attitude, mediated through lightness and amount of sunshine.

Independent	Mediator[2]	a (SE)	b (SE)	c (SE)	c' (SE)	Indirect[1] effects (ab)	95% Confidence Interval[1]	Sobel (Z)
Environment (Study 3a)	Light	-1.02** (.19)	.29** (.07)	-2.53** (.17)	-2.24** (.18)	-.30 (.09)	(-.50) - (-.14)	-3.42**
	Sun	-.97** (.18)	.29** (.07)	-2.53** (.17)	-2.25** (.18)	-.28 (.10)	(-.48) - (-.11)	-3.30**
Weather Study (3b/c)	Light	-1.64** (.14)	.41** (.04)	-.99** (.13)	-.32* (.14)	-.67 (.09)	(-.88) - (-.51)	-7.29**
	Sun	-2.63** (.14)	.42** (.04)	-.99** (.13)	.12 (.16)	-1.12 (.13)	(-1.40) - (-.87)	-8.58**
Brightness Study (3d)	Light	-1.57** (.18)	.29** (.06)	-.71** (.16)	-.26 (.18)	-.44 (.11)	(-.67) - (-.25)	-4.29**
	Sun	-1.80** (.19)	.36** (.05)	-.71** (.16)	-.06 (.17)	-.65 (.12)	(-.90) - (-.45)	-5.63**

** p < .05, **p < .001.*

[1]No significance for the ab path is calculated. Confidence intervals are calculated using bootstrapping.

[2] Light = Lightness, Sun = Sunshine

2.4.2.2 Implicit measures: Affective priming Task

Study 3a Environment

A significant main effect was found for Valence ($F(1,28) = 4.6$, $p = .041$, $\eta_p^2 = .14$), with faster reaction times to positive words ($M = 729$, $SE = 19.8$) than to negative words ($M = 751$, $SE = 18.6$). No main effect for Environment, nor an interaction of Environment * Valence was found ($F(1,28) < 1.8$, $p > .187$).

Study 3b Weather (nature)

Only a non-significant trend emerged for Valence ($F(1,32) = 3.8$, $p = .063$). No main effect of weather type or interaction effect of Weather * Valence was found in the experiment with natural scenes ($F(1,32) < 2.2$, $p = .148$).

Study 3c Weather (urban)

A significant main effect of Valence was found ($F(1,32) = 7.0$, $p = .013$, $\eta_p^2 = .18$), again with faster reaction times to positive words ($M = 702$, $SE = 18.2$) than to negative words ($M = 727$, $SE = 18.5$). More importantly, no main or interaction effects were found of Weather in the experiment with urban scenes ($F(1,32) < .8$, $p > .371$).

Study 3d Brightness

Only one significant main effect of Valence was found ($F(1,32) = 30.9$, $p < .001$, $\eta_p^2 = .49$). No main or interaction effects emerged for Brightness ($F(1,32) < .2$, $p > .650$).

In three of the four studies reported above, a main effect of valence was found. For this reason, analyses were repeated with centred variables, adjusted for the group mean per valence category. These analyses yielded similar results as the ones reported above.

2.4.3 Discussion

In Study Three we ran four separate experiments, isolating all three manipulations under investigation in this manuscript. For explicit preferences, we were able to replicate the findings of Studies One and Two. Moreover, we also saw great similarity in results found for the photo characteristics.

However, separating the manipulations into different experiments did not yield the facilitation or inhibition effects expected in the affective priming tasks. Moreover, the one significant result we did find was opposite to our hypothesis namely a facilitating effect of urban environments -as opposed to natural environments- on recognition of positive words for males. In other words, again we found no evidence for more positive implicit preferences for natural, sunny, or light scenes.

2.5 General discussion

In this chapter, we investigated whether people have a preference for sunny, bright, and natural environments. For this, we used two different paradigms that have previously been employed in restoration literature, one targeting explicit preference, the other implicit preference. With both paradigms, preference for natural environments had been demonstrated in earlier research (Van den Berg et al., 2003; Korpela et al., 2002; Hietanen, & Korpela, 2004). In our research, we extended these studies by adding additional manipulations to the original designs contrasting not only natural versus urban scenes, but also sunny versus overcast, and brighter versus darker scenes.

2.5.1 Explicit preferences

In three studies, we found clear and consistent explicit preferences for bright and sunny nature. Earlier research had already indicated that people generally prefer natural to urban scenes (e.g., Van den Berg et al., 2003), and daylight over artificial light (Veitch & Gifford, 1993; Veitch et al., 1993). We have further shown that people also prefer light scenes to darker scenes, and sunny scenes to overcast scenes. The latter two manipulations intended to capture different daylight conditions in the pictures. The findings thus suggest that individuals prefer conditions with more intense (day)light to less intense (day)light. The findings on explicit preference are corroborated by the additional assessments of the pictures made by participants.

The images we used were matched on brightness (within brightness conditions), general composition, and amount of enclosure across weather type and scene content. Notably, even though pictures were matched on objective brightness, they were not always perceived as equal in lightness. This implies that besides overall luminance, weather type and sometimes scene type are used as cues in the estimation of lightness. Part of the explanation for this effect might stem from the fact that the human eye is highly adaptive. Therefore, we are not equipped to perceive and judge absolute brightness. Rather, lightness judgments are partly inferred from scene content. For instance, a blue and sunny sky might signal that the scene is lighter than an overcast sky. Furthermore, participants may have resolved to judge lightness via differences in contrast between the sky and the ground within the scene. Similarly, photos of sunny scenes were more likely to be seen as photos taken during spring or summer than overcast photos, even though both pictures were taken at the same spot and within the same week.

Interestingly, even though natural and urban scenes were objectively matched on brightness and weather type they were rated differently by our participants on lightness and amount of sunshine. This difference, in turn, partially mediated the difference in preference ratings between natural and urban environments. Possibly, inherent features of urban versus natural environments pertaining to the distribution of shadows and contrasts can explain a small portion of the difference in preference ratings between these two environments, with urban environments often characterized by more pronounced shadows and contrast relative to natural environments.

Mediation analyses further showed that the perceived differences in lightness and amount of sunshine (partially) mediated the effects of weather type and brightness manipulations on preference. This indicates that differences in preference indeed are due to differences in daylight characteristics. Furthermore, the fact that weather type and brightness influenced perceived lightness and amount of sunshine similarly suggests that perceived lightness and amount of sunshine were perceived as the same concept by respondents. Correlation analyses indeed show a substantial, though not complete correlation between the two variables. On the other hand, it may also be that weather type and brightness manipulations affected ratings in the same way, because both manipulations are intended to affect the same concept: perceived amount of daylight.

Respondents' scores on extent and fascination -two concepts important for restorative environments (Kaplan, 1995)- point to the restorative potential of both daylight and nature. We consistently found that nature scenes and sunny weather scored higher on both characteristics than urban scenes and overcast weather respectively, and in some cases the same pattern emerged for lighter versus darker pictures (the light manipulation was also the most subtle one).

2.5.2 Implicit preferences

In contrast to our hypotheses, we did not find evidence for an automatic affective response towards natural, sunny or light scenes. We were not able to replicate findings by Hietanen, Korpela and colleagues of facilitating effects of nature on responses to positive emotions, in spite of the fact that we performed multiple experiments and used very similar experimental designs in terms of duration of exposure, stimulus presentation and targets used. Whereas they reported automatic positive affective responses towards natural environments, we found no such effects for lighter (vs. darker) scenes, sunnier (vs. overcast) scenes, or natural (vs. urban) scenes. Worse yet, an interaction effect in Study Three suggested the opposite effect for male respondents: facilitation of positive word recognition after priming by urban scenes.

Several factors must be considered in discussing the absence of automatic affective responses towards the environmental scenes in the current study. First, among the pictures in the urban set of Hietanen, Korpela and colleagues were images of deserted parking lots. In the present study we explicitly chose to avoid using aesthetically unappealing urban photos, possibly resulting in less extreme differences between urban and natural photos. However, if evolutionary based automatic affective responses towards nature underlie the effects found by Hietanen, Korpela and colleagues, we should find similar effects since the photos clearly represent scenes from either the natural or urban categories. Moreover, we did find a clear distinction between explicit preferences of urban and natural environments.

Another consideration could be that perhaps more distinct implicit preferences for natural over urban environments only emerge under relatively high need for restoration. On the other hand, Hietanen, Korpela and colleagues also did not induce such a need during their experiment, and we did find the expected results for the explicit preference. As a last issue, we would like to note that although three earlier publications do report of successful implicit affective priming with nature scenes, all three experiments were performed by the same group, leaving open the possibility that certain (implicit) idiosyncratic design choices or sampling strategies in our or their group determine the differential findings. Moreover, the three studies by Hietanen, Korpela and colleagues are not fully consistent in the effects they find, sometimes reporting facilitating effects of nature, sometimes inhibitory effects of urban scenes instead. The question remains whether implicit, pre-cognitive affective responses to nature indeed do exist, or whether instead preferences for nature rely on other -more cognitive- processes as for instance informational components (Kaplan, 1987).

2.5.3 Psychological pathways for effects of daylight

Effects of daylight on health and wellbeing are often attributed to biological pathways. In this study, however, we were able to show that differences in amount of daylight also have psychological relevance by influencing preference ratings. Considering the adaptive function of environmental preference and its link to the restorative potential of an environment (Hartig & Staats, 2006; Van den Berg et al., 2003) our findings provide a first indication for restorative effects of daylight through psychological pathways. Weather type and scene brightness should be taken into account when studying preference for -and restorative potential of- natural environments. Moreover, our results indicate that psychological effects of daylight should be taken seriously in studying salutogenic effects of daylight.

2.5.4 Conclusion

To conclude, we were able to show clear explicit preferences for bright scenes, sunny weather, and natural environments. We did not find any evidence for an automatic affective response to sunny weather and bright pictures. The results of this chapter further showed that even though we objectively manipulated brightness and weather type, natural and urban scenes sometimes still differed in perceived lightness and amount of sunshine. For this reason, we will not only look at restorative effects of images differing in daylight characteristics (i.e., weather type and brightness) during the remainder of this dissertation, but also at daylight versus its' artificial counterpart; electric light.

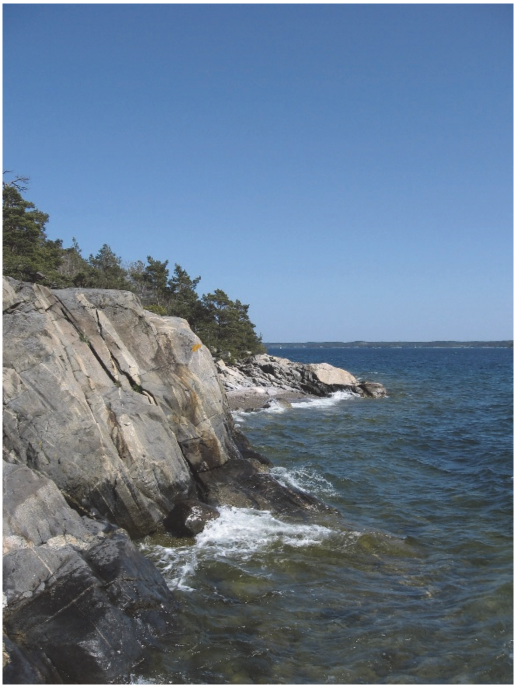
Learned connotations and associations with environments have been proposed to influence preference ratings. This possible pathway is investigated for natural as opposed to urban environments in the next chapter. Subsequently, Chapter Four will explore learned associations with daylight as opposed to electric light.

Chapter 3

Thinking of Nature.

The role of associative patterns in preference formation and restorative outcomes[1]

Let's stay awake
and listen to the dark
before the birds
before they all wake up
it's the ending of a play
and soon begins another
hear the leaves applaud the wind
(Emiliana Torrini - Birds)



[1] This Chapter is based on:
Beute, F. & de Kort, Y.A.W. (submitted). The role of associative patterns in preference formation for pictures differing in naturalness and weather type.
Beute, F. & de Kort, Y.A.W. (in preparation). Natural thoughts: Associations with natural environments and their role in preference formation and restorative outcomes.

Abstract. People generally prefer natural over urban environments. In the previous chapter, we saw this reflected in consistently higher explicit preference ratings for natural environments, but no evidence was found for higher implicit preferences. Associations play an important role in the formation of both implicit and explicit preferences. Moreover, learned associations with natural environments have been postulated as an underlying pathway for the positive effects of nature on health and wellbeing. Therefore, in this chapter, we investigated the associations that participants had with natural as opposed to urban environments and how they were related to preference formation and restorative effects of natural environments. In three studies we consistently found that when participants could freely associate, their associations with natural environment were more positive than with urban environments. Furthermore, the valence of associations partially mediated the effect of environment type on preference. No evidence was found for restorative effects of natural environments on mood and performance. Possibly, the association-generation task interfered with restorative effects of nature. Not only were participants associating freely with natural or urban environments, in two studies we also instructed them to generate either only positive or only negative associations. In these two studies, we consistently found that generating positive associations improved hedonic tone. These results provide evidence for restorative effects of positive associations and indirectly imply that the positive associations that people have with nature could form an underlying pathway of its restorative effects.

3.1 Introduction

Nature visits or wilderness experience often leave pleasurable memories; the song of birds, the smell of pine trees, or a picnic in the grass. In the previous chapter, we consistently saw higher explicit preference ratings for natural environments than for urban environments. In contrast, no evidence was found for implicit preference. In social psychology, the distinction between implicit and explicit evaluations has been studied extensively (e.g., see: Nosek, 2005; Strack, & Deutsch, 2004; Wilson, Lindsey, & Schooler, 2000). Some studies, for instance investigating stereotypes, have found differential outcomes for implicit versus explicit evaluations as well (Blair, 2002). Associative patterns are an important component in theories explaining the mechanisms behind the formation of implicit and explicit evaluations. Furthermore, learned associations have been proposed to underlie beneficial effects of nature (Tuan, 1974). Therefore, this chapter will focus on the role of associations in preference formation and the creation of restorative outcomes. In the next section, the relation between implicit and explicit evaluations as well as the role of associations in evaluations will be discussed, after which we will look at the implications for implicit and explicit evaluations in nature restoration research.

3.1.1. Associative and propositional processes in evaluations

A distinction has been made between associative and propositional processes in evaluation (Gawronski, & Bodenhausen, 2006; Strack, & Deutsch, 2004). Associative patterns highly affect implicit evaluations, which, in turn, form the base for further evaluative actions. These associative patterns are transferred to what Strack and Deutsch (2004) refer to as the reflective system. The reflective system forms relational schemata to derive propositions as *'I like this environment'*. As opposed to implicit evaluations, their explicit counterparts are dependent on 'truth values' and are adjusted accordingly. Depending on the gap between the associative and propositional outcomes, implicit and explicit evaluations can be similar but also dissimilar (Gawronski, & Bodenhausen, 2006). Moderators have been proposed to explain differences between explicit and implicit measures, as for instance self-representation, evaluative strength, dimensionality, and distinctiveness (Nosek, 2005). For example, implicit evaluations may reflect socially unacceptable prejudices that are overruled in explicit reports.

Implicit and explicit evaluations do not necessarily reflect distinct constructs. Rather, Fazio and Olson (2003) claimed that the only difference between implicit and explicit evaluations is the method of measurement. Implicit evaluations are said to depend on automatically activated associative processes, independent of 'truth values'. In explicit evaluations, more controlled cognitive processes have taken place allowing for adjusting the evaluation to 'truth values'. To illustrate this model, let's look at the biophobia hypothesis (see e.g., Ulrich, 1991). According to this hypothesis, people are biologically prepared to dislike snakes. In the model presented above, automatic associative processes may result in a negative implicit evaluation of snakes. However, if you are a herpetologist, the proposition 'I dislike snakes' is likely to be inconsistent with other propositional evaluations or 'truth vales' you have regarding snakes (e.g., 'snakes are beautiful'). In this case, the explicit evaluation of snakes might be the exact opposite of the implicit evaluation. A distinction between automatic and more controlled evaluations is also reflected in the theories explaining restorative effects of nature, as will be discussed in the next section.

3.1.3. Implicit and explicit evaluations in nature restoration

Within restoration theories, implicit evaluations are often thought to reflect evolutionary based affective responses, based on gross structures in the environment labelled preferenda (Ulrich, 1983; Zajonc, 1980). This assertion builds on the adaptive functionality of affective responses to environments, eliciting approach or avoidance behaviour (Ulrich, 1983; Zajonc, 1980). Other approaches, however, stress the significance of more cognitively controlled responses to nature (Kaplan, 1995).

The popular notion appears to be that implicit evaluations distinguish themselves from explicit evaluations by reflecting more stable and long-term underlying processes, but these claims have recently has been challenged (Gawronski & Bodenhausen, 2006). Some studies have in fact found explicit attitudes to be more stable than implicit attitudes (Blair, 2002; Duffy, & Verges, 2010). Duffy and Verges (2010), for instance, found that explicit connectedness to nature was stable throughout the year, whereas implicit connectedness to nature differed between seasons and weather conditions.

Whereas most theories stress positive evaluations of nature, evidence for negative associations with nature -more specifically with wilderness- has been reported as well (Koole, & van den Berg, 2005). Koole and van den Berg postulated that overcoming these negative associations requires self-regulation. This claim was illustrated by the fact that participants with better self-regulatory capacity (measured in terms of their self-regulation orientation) rated wilderness photos more positively.

3.1.4 Rationale

In the previous sections, we have seen that associative patterns form the basis for evaluations. In the remainder of this chapter, we will study the relation between associative patterns and preference for -and restorative effects of- natural over urban environments.

Learned associations have been proposed to underlie beneficial effects of nature on wellbeing (Tuan, 1974; Ulrich, 1983). However, counter to the role of associative patterns assumed in social psychology (e.g., Gawronski & Bodenhausen, 2006; Strack & Deutsch, 2004), Ulrich (1983) proposed that learned associations mostly affect explicit preferences. The question addressed in this chapter is whether associative patterns differ between natural versus urban environments and how they are related to preference for the respective scenes. As no evidence was found for implicit preference for natural over urban environments in the previous chapter, the focus in the studies will be on explicit preferences.

Associative evaluations can be defined as *"automatic affective reactions resulting from particular associations that are activated automatically when one encounters a relevant stimulus"* (Gawronski, & Bodenhausen, 2006; pp.693). Which association is activated depends on how associative networks are represented in the brain. In a series of three studies, we investigated (1) whether associations toward natural versus urban environments differ in their valence and (2) how these associative patterns are related to explicit preference and restorative potential.

Study One was conducted to explore whether natural environments indeed generate more positive associations than urban environments. Having ensured this, Studies Two and Three investigated whether the valence of associations mediated restorative outcomes. To this end, participants were either asked to freely produce associations with our stimuli, or they were instructed to generate either only positive or negative associations. This way, we could investigate whether the valence of associations mediated restorative outcomes.

To measure the valence of the associations, all participants rated their own associations post-hoc on valence. Not only did this enable testing mediating effects of valence of the associations, it also helped establishing the meanings of the verbal or written responses (Osgood, 1957).

The activation of an associative pattern depends on the context (Gawronski, & Bodenhausen, 2006). For this reason both within (Study One) and between-subjects designs (Studies Two and Three) were employed. The first offering an explicit contrast between natural vs. urban environment, the second offering only environments within one category.

We expect that natural environments produce more positive associations than urban environments. Furthermore, if beneficial effects of nature run (partly) through these more positively valenced associative pathways, we expected that all positive associations should be able to induce higher preference ratings as well as restorative effects irrespective of the environments that evoked these associations. In other words, generating positive associations with urban environments might result in beneficial effects as well. In a similar fashion, negative associations should result in a decrease in restorative outcomes, irrespective of whether these associations were generated for natural or urban environments.

As a note of caution, Koole and van den Berg (2005) found that altering associations requires self-regulation, therefore we expected that generating only negative (or positive) associations would require self-regulation to suppress the positive (or negative) associations. This could result in lower restorativeness experiences in the instruction conditions as opposed to the free-association conditions (hypothesis 3). However, if associations with nature are inherently more positive, then this effect would only emerge in the negative-association condition, and similarly the same effect would only emerge in the positive-association condition for urban environments.

3.2 Study One

In Study One, the associations that people have regarding different types of environments were investigated. Besides environment type (natural vs. urban), weather type was also manipulated (as in Chapter Two). Participants were asked to generate associations with different environmental scenes and rated these associations on valence. The environmental scenes, in turn, were scored on two dimensions of preference; aesthetics and attitude. We expected that natural environments would generate more positive associations as well as received higher preference ratings. We further expected that valence of associations mediated the effect of environment type on preference ratings.

3.2.1 Method

3.2.1.1 Design

In this experiment participants generated and then evaluated associations with photographs of various scenes. They also gave preference ratings for each photo. A within-subjects design was employed. Each subject viewed 12 pictures (4 filler photos). The experimental photos differed in Environment type (Natural vs. Urban scenes) and Weather type (Sunny vs. Overcast).

3.2.1.2 Participants

Thirty-eight participants (21 female) completed the study. Their mean age ranged between 19 and 56 years old (M = 23.29, SD = 5.82). Participants were recruited through an email invitation via our JFS database. The majority of participants were students of the Eindhoven University of Technology or Fontys Higher Education Institute. The duration of the experiment was approximately 30 minutes and participants received €5.00 compensation.

3.2.1.3 Procedure

The experiment started after participants had read and signed the informed consent form. Twelve photos were presented on screen in random order and participants filled in their associations with each photo, after which they rated their associations on valence. Then, they rated the photos on preference after which the experiment was finished. Participants were then thanked and paid for their effort.

3.2.1.4 Manipulation - Photos

The stimulus set consisted of twelve photographs. Four photos depicted natural environments and four depicted urban environments; all eight photos were taken in and around Eindhoven (selected from photos used in Chapter One). For each environment, two photos were taken in sunny weather and two in overcast weather. To not disclose the contrast between urban and nature scenes as our core interest, four additional filler photos were added. They depicted holiday related environments: a city in a tropical country, a tropical city park, a mountain top, and a busy beach. See Figure 3.1 for example photos.

3.2.1.5 Manipulation - Association generation

Participants were asked to view the photos and write down all associations that came to their mind, even if they were strange or unusual. Furthermore, they were assured that associations are personal and therefore their answers were neither right nor wrong. They were told that the associations could be single words or a sentence. The associations could be typed in text fields below the photo. A minimum of five associations was required and a maximum of ten associations per photo were allowed. Table 3.1 displays a number of example associations per category.

Table 3.1 Example associations per category

	Example associations
Nature Sunny	*'Summer' 'Deer' 'hiking' 'Far away from the inhabited world' 'Army base' 'Adventure' 'Biology' 'Running' 'Prickly bushes' 'Mowing the lawn' 'Holiday' 'Gloomy'*
Nature Overcast	*'Family' 'Hay fever' 'drowsy weather' 'Feeling free' 'The sound of animals' 'Cows' 'Birds' 'Scooters' 'Wanting to go home' 'Field'*
Urban Sunny	*'Eating ice cream' 'Lots of sun' 'Work' 'Road' 'Shadow' 'Boring' 'On the bench enjoying the sun' 'Have to go to hairdresser' 'Rush' 'There should have been more trees'*
Urban Overcast	*'Traffic' 'Noise' 'No fresh air' 'Culture' 'high buildings' 'People spending most of their day in the office' 'Housemates who study Architecture' 'Rain coming'*

Figure 3.1 Examples of the photos used; natural environments (top) and urban environments (bottom); sunny environments (left) and overcast environments (right).

3.2.1.6 Measures

Association Valence. Participants were asked to rate each association on valence, using a scale from 1 (very negative) to 7 (very positive). For clarity, the photo for which the associations were generated was displayed on the screen as well.

Preference. Participants viewed each photo in random order and preference ratings for each picture were obtained on two dimensions: Aesthetics and Attitude. The same items were used as in Chapter Two, see Section 2.2.1.4 for a description. Reliability of both dimensions was good (α ranging between .89 and .96 for Attitude and between .83 and .94 for Aesthetics).

3.2.1.7 Data analysis

For each category (Nature Sunny vs. Nature Overcast vs. Urban Sunny vs. Urban Overcast) the mean scores for preference and association valence were calculated. Subsequently, effects of Environment and Weather type were investigated using Repeated Measures ANOVA’s, with Environment and Weather type as within-subjects variables.

3.2.2 Results

First, results for the valence ratings of the associations will be discussed, followed by effects of weather and environment on preference. This section will end with mediation analyses, investigating mediating effects of the valence of associations on the preference for the images that produced these associations.

3.2.2.1 Valence of the associations

On average, participants generated a total of 42.68 (*SD* = 2.62) associations for the eight photos. Participants formed slightly more associations for the sunny photos (*M* = 21.84, *SD* = .32) than for the overcast photos (*M* = 20.84, *SD* = .20; $F(1,37)=9.9$, $p = .003$, $\eta_p^2=.21$).

Significant main effects of Environment ($F(1,37)=23.9$, $p < .001$, $\eta_p^2=.39$) and Weather type ($F(1,37)=34.5$, $p < .001$, $\eta_p^2=.48$) on the valence of the associations were found. The interaction of Environment * Weather was not significant ($F(1,37)=2.3$, $p = .139$). As we expected, the Natural scenes (*M* = 4.96, *SE* = .13) induced more positive associations than the Urban (*M* = 3.98, *SE* = .13) scenes, and the Sunny scenes (*M* = 4.81, *SE* = .11) generated more positive associations than the Overcast scenes (*M* = 4.13, *SE* = .10), see Figure 3.2.

3.2.2.2 Preference

Preference scores were obtained on two dimensions; aesthetics and attitude. Both Environment ($F(1,37)=86.4$, $p < .001$, $\eta_p^2=.70$) and Weather type ($F(1,37)=15.1$, $p < .001$, $\eta_p^2=.29$) significantly affected attitude levels. Natural and Sunny environments scored higher on Attitude than Urban and Overcast environments, respectively. Furthermore, a significant

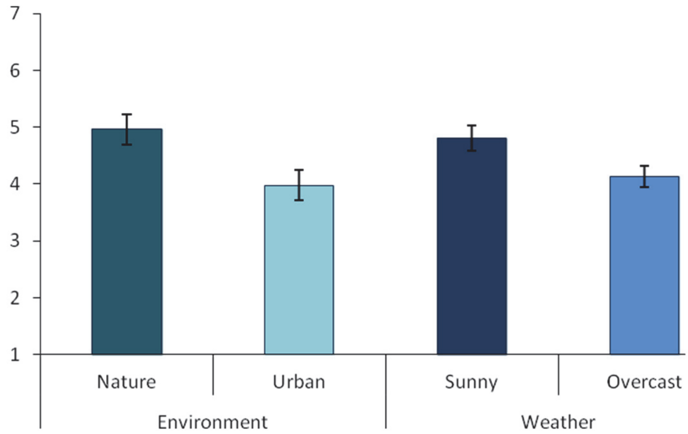


Figure 3.2 Mean Valence scores for Environment and Weather type, bars represent 95% confidence intervals.

interaction of Environment * Weather type was found ($F(1,37)=18.2$, $p < .001$, $\eta_p^2=.33$), with more pronounced effects of Weather type on attitude for natural environments than for urban environments.

A very similar pattern was found for aesthetic preference, with significant main effects of Environment ($F(1,37)=88.6$, $p < .001$, $\eta_p^2=.71$) and Weather type ($F(1,37)=30.9$, $p < .001$, $\eta_p^2=.46$), as well as a significant interaction of Environment * Weather type ($F(1,37)=19.0$, $p < .001$, $\eta_p^2=.34$). Similar to attitude scores, we found that effects of weather type on aesthetic preference was more pronounced for natural environments than for urban environments. Table 3.2 displays the means and standard errors for Attitude and Aesthetics.

Together, these outcomes confirm our hypothesis concerning the effects of environment type on preference ratings as both attitude and aesthetics scores were higher for natural than for urban environments.

Table 3.2 Means and standard errors for Attitude and Aesthetics

		Natural scenes M (SE)	Urban scenes M (SE)
Attitude	Sunny Weather	5.27 (.17)^{a,c}	2.92 (.13)^{b,c}
	Overcast Weather	4.60 (.17)^{a,d}	2.93 (.14)^{b,d}
Aesthetics	Sunny Weather	5.37 (.13)^{a,c}	3.27 (.15)^{b,c}
	Overcast Weather	4.55 (.16)^{a,d}	3.12 (.13)^{b,d}

Means with the same superscript letter are significantly different

3.2.2.3 Mediation of preference through associations

Having established that natural scenes elicit more positively valenced associations as well as produce higher preference ratings, we further investigated whether the valence of associations mediated the effect of environment type on preference ratings.

In this study we employed a within-subjects design, with nested data (i.e., four different categories of photos for each participant). Because single-level models of nested data generally underestimate the standard errors (Krull, & MacKinnon, 2001), multilevel models were used with participant as nesting variable. Mediation effects were calculated based on Bauer, Preacher, & Gil (2006). The results for all analyses are displayed in Table 3.3. In this table**,** the ***a*-**path reflects the effect of the independent variable (Weather or Environment) on the mediator (Valence of associations), *b* the effect of the mediator (Valence of association) on the dependent variable (Attitude or Aesthetics). The direct effect of the independent variable on the dependent variable is represented by the *c* (without mediator) and *c'* (with mediator) paths, see Figure 3.3 for a graphical representation. The indirect effect (ab path) column represents the measure for the amount of mediation. The analyses revealed that Valence of associations significantly mediated the effects (partially) of both Environment and Weather type on aesthetics and attitude.

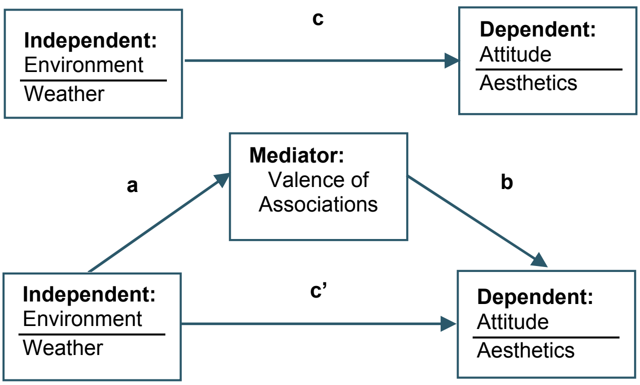


Figure 3.3 Graphical overview of the mediation analyses

Table 3.3 Mediation coefficients for the mediation of the effects of Weather and Environment on preference through valence of the associations.

Dependent Independent	a (SE)	b (SE)	c (SE)	c' (SE)	ab Indirect effect (SE)	95% Confidence Interval Indirect effect
Attitude	.99**	.47 **	2.01**	1.90**	.09*	.08 - .10
Environment	(.20)	(.04)	(.22)	(.20)	(.002)	
Weather	.71**	.47**	.33**	.14	.23*	.20 - .26
	(.11)	(.04)	(.09)	(.09)	(.02)	
Aesthetics	.99**	.39**	1.77**	1.58**	.19*	.17 - .21
Environment	(.20)	(.03)	(.19)	(.16)	(.01)	
Weather	.71**	.39**	.48**	.29*	.21**	.19 - .23
	(.11)	(.03)	(.09)	(.08)	(.008)	

** $p < .05$, **$p < .001$*

3.2.3 Discussion

In this study, we found that participants generated more positive associations with natural environments than with urban environments. Similarly, more positive associations were reported for photos with sunny than with overcast weather. A very similar pattern of effects emerged for preference: again natural scenes were preferred over urban and sunny scenes were preferred over overcast scenes. This corroborates the findings reported in Chapter Two.

Mediation analyses were performed to see whether the valence of associations significantly mediated the effects of both environment and weather type on explicit preference. These analyses showed that valence of associations indeed (partially) mediated effects of environment and weather type on attitude and aesthetics. Having established a significant difference in valence of free associations with natural versus urban environments, the influence of association valence on restoration outcomes was studied in the next two studies.

As a side note, contrary to Chapter Two, different environmental scenes were used in the overcast and sunny weather conditions to avoid that participants had to generate associations for the same environments. Therefore, effects of Weather type could also be partly due to differences between the environmental scenes.

3.3 Study Two

The results of Study One indicated that people generate more positive associations with natural as opposed to urban environments. Furthermore, the valence of associations partially mediated the effect of environment on preference formation. Thus, preference for natural versus urban environments may -at least partly- run through associative pathways. Therefore, in Study Two, we wanted to extend these outcomes and investigate whether associative pathways also play a role in the restorative effects of natural environments. To this end, we measured restorative effects of natural versus urban environments on mood and performance after inducing stress.

While viewing either natural or urban environments, participants were instructed to produce associations. The instructions were also manipulated between groups: some were allowed to freely associate, while others were instructed to either generate only positive or negative associations, suppressing the oppositely valenced associations. Guiding the valence of instructions allowed us to test the causal direction of the relation between valence of associations and respectively preference and restorative outcomes. If positive associations with natural environments underlie the restorative effects of these environments, we expected that generating positive associations with any environment would produce restorative effects. Similarly, producing negative associations with natural and urban environments would both result in hampered restorative outcomes.

3.3.1 Method

3.3.1.1 Design
Study Two consisted of a 2 (Environment; natural vs. urban) by 3 (valence instruction; free vs. positive vs. negative) between-subjects design.

3.3.1.2 Participants
In total, 120 participants (45 female) entered in this experiment. Their age ranged between 18 and 38, with a mean age of M = 23.31 (SD = 3.15). Participants were recruited through an email invitation via our JFS database and through personal contacts of the researcher. The majority of participants were students of the Eindhoven University of Technology or Fontys Higher Education Institute. The experiment lasted approximately 45 minutes and participants received €7.50 compensation for their effort.

3.3.1.3 Procedure
After signing the consent form, participants were seated behind a desktop and ECG electrodes were attached. Before the experiment started, the experimenter explained the Necker Cube task and practiced the task together with the participant. When the instructions of the Necker Cube task (see Section 3.3.1.7) were clear to participants, the experiment leader left the room. During a baseline period of 5 minutes (for physiological measures not

reported in this dissertation), participants filled in the baseline mood questionnaire (baseline; t_0). After the initial 5 minutes, participants performed the Necker Cube task (NC; baseline; t_0) for the first time, after which the stressor task (MPA) started. After finishing the stressor task, participants filled in the mood questionnaire for the second time (post stressor; t_1), followed by the second Necker Cube task (t_1). Then, they viewed the environmental scenes and generated associations, after which the mood questionnaire was filled in for the third time (post manipulation; t_2), followed by the third Necker Cube task (NC; post manipulation; t_2). They then answered some questions concerning the generation of associations (i.e., difficulty, effort) and rated the associations on valence. After rating all photos on preference, the participant was ready and was thanked and paid for his or her effort. Figure 3.4 displays an overview of the experimental set-up.

3.3.1.4 Stress induction: Markus & Peters Arithmetic test (MPA test)

The MPA test (Peters, et al., 1998) consists of arithmetic problems that need to be solved in a number of consecutive steps, with each step being displayed on consecutive screens. It started with the most difficult arithmetic problem (e.g., 27 * 14), followed by two easier ones (e.g., + 3). After three arithmetic transformations, four multiple-choice answers were displayed. During the task, participants were wearing headphones on which industrial noise was played, with different noise levels (low, medium, and high). The arithmetic problems had to be solved within a time limit and in each round a certain criterion (amount of correctly solved arithmetic problems) had to be met. If the criterion was not met, they were not allowed to choose the noise level for the next round. Because not all trials contained the right answer, participants oftentimes could not control the noise level (in 14 of the 16 trials). Due to the combination of high task demand and low controllability, this task induces stress (Peters et al., 1998).

3.3.1.5 Manipulation – Photos

In each condition, either four natural (Nature conditions) or four urban (Urban conditions) photos were used. These photos were a subset of the photoset of Chapter One and were all taken in sunny weather. Different photos were used than in Study One, to corroborate the differences in valence of associations were not due to the particular photoset used. The photos were displayed on the notebook.

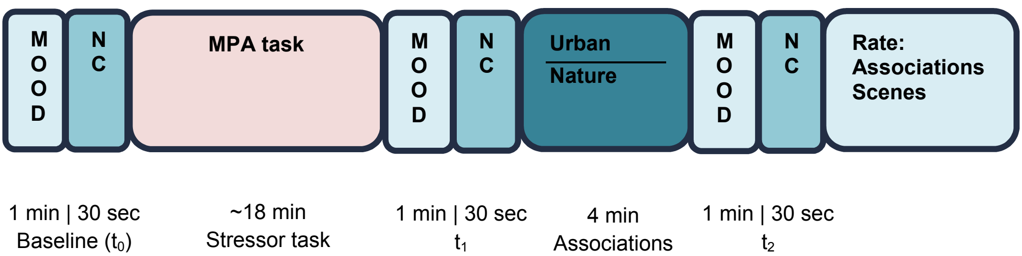


Figure 3.4 Overview of the experimental set-up

3.3.1.6 Manipulation – Association generation
Participants were asked to write their associations down on a paper placed in front of them. This paper was folded and also contained the rating scales for valence on the backside. However, these scales were not visible for the participants during the Association-generation stage. For each photo, they were allowed 1 minute to write down all associations that came to mind. No minimum number of associations was indicated, but the fields were limited to a maximum of 10 associations per photo. After 60 seconds the next photo appeared automatically and a beep sounded, indicating the appearance of a new photo.

In the free-association conditions, participants received instructions similar to Study One. In the guided-association conditions, however, participants were instructed to generate either only positive or only negative associations and to suppress the oppositely valenced associations, i.e. to suppress positive associations in the negative condition and vice versa. Table 3.4 displays some example associations for each category.

3.3.1.7 Measures
Association generation & valence. Similar to Study One, participants rated their own associations on valence, see Section 3.2.1.6. Furthermore, one item measured how much effort participants felt they had put into the generation of associations (effort) and one measured how difficult participants rated generating the associations (difficulty), both on a scale of 1 (not at all) to 7 (very much). In the guided-association conditions, participants were asked how often they suppressed oppositely valenced associations (suppression) on a scale ranging from 1 (never) to 7 (very often).

Table 3.4 Example associations per category.

	Nature	Urban
Free associations	*'Nature' 'Hiking' 'Holiday' 'Sun' 'Quiet' 'Summer' 'Family' 'Life' Holding hands' 'Relaxing' 'Picnic' 'Dry' 'Eating chips' 'Throwing stones in the water' 'Deserted' 'No humans'*	*'Cycling' 'Modern housing' 'Not seeing trees and forest anymore' 'Nice weather' Rules regarding behaviour' 'Pizza' 'Ferrari' 'Busy environment' 'Artificial / unnatural' 'Feeling small'*
Positive associations	*'Tranquil' 'Hiking' 'Green' 'Happy' 'Clean air' 'Relaxation' 'Peaceful' 'Whistling birds' 'Freedom' 'Nice weather' 'Family' 'Exercising' 'Laying in the grass' 'Privacy / being alone'*	*'Summer' 'Sun' 'Quiet' 'Ice cream' 'Paris' 'No litter' 'Shopping' 'Nice party' 'Embracing' 'Protected' 'Freedom' 'Artist' 'Music' 'Theatre' 'Nice to live here' 'Christmas'*
Negative associations	*'Animals' 'Insects' 'Allergy' 'Thirsty' 'Murder' 'Danger in the dark' 'Scary men' 'Lost' 'No way out' 'Fire' 'No overview' 'Lonely' 'Dead people' 'Frustration' 'Nature destroyed'*	*'Scooters' 'Traffic accidents' 'Noise' 'Boring' 'Robbery' 'Waiting for bus' 'Anxious' 'Bad for environment' 'Dark' 'Annoying people' 'Littering' 'Blocked sun' 'Too many cyclists'*

Preference. Preference was rated on two dimensions; aesthetics and attitude, identical to Study One, see Section 3.2.1.6.

Mood. Mood was measured along three dimensions; tension, energy, and hedonic tone. For tension and energy items were derived from the Activation-Deactivation adjective Checklist (Thayer, 1989). This scale measures mood along two axes; tiredness – energy and calm – tension. Seven items were used to measure tension (tense, placid, at rest, nervous, jittery, calm, quiet) and for this dimension the Cronbach's alpha ranged from .71 to .82 at the three different time points. Eight items measured energy (energetic, sleepy, wakeful, lack of energy, tired, vital, wide awake, exhausted) with Cronbach's alpha ranging from .86 to .87. Hedonic tone was constructed from a selection of items of the UWIST Mood Adjective Checklist (Matthews, Jones, & Chamberlain, 1990). Five items were selected, namely sad, depressed, happy, content, and enthusiastic with a reliability ranging between $\alpha = .77$ and $\alpha = .79$.

Sustained attention – Necker Cube Pattern Reversal Task. The Necker Cube (see Figure 3.5) is a cube that can be seen from two perspectives. When looking at the cube, these perspectives can change automatically (pattern reversals). It requires sustained attention (i.e., directed attention, see Section 1.2.1) to hold on to one perspective of the Necker Cube (Orbach, Ehrlich, & Heath, 1963).

The Necker Cube was presented on the computer screen and participants were asked to hold the perspective for as long as possible during a 30 second period. Whenever the pattern reversed, they were asked to press the spacebar and to subsequently hold this perspective for as long as possible. The number of pattern reversals reflects Necker Cube performance, with higher scores indicating lower ability to sustain attention.

Participants performed the Necker Cube task four times. The first time was a practice round, and participants practiced it with the experimenter present to ensure instructions were understood correctly. During the three experimental Necker Cube tasks, the experimenter was not present.

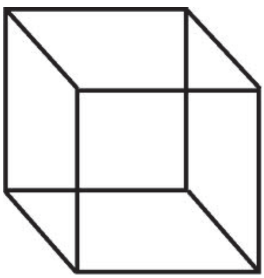


Figure 3.5 The Necker Cube

3.3.1.9 Physiology

Physiological measures (Heart Rate and Skin Conductance) were conducted throughout the experiment, but will not be reported in this dissertation because no physiological measures were recorded during any of the other studies investigating the relation between associations and restorative outcomes of nature and daylight. Therefore, no comparison between physiological responses to daylight and nature could be made.

3.3.1.10 Data analysis

For mood and Necker Cube performance, change scores were calculated. Residualised change scores were used to overcome problems associated with raw change scores such as regression towards the mean (Streiner & Norman, 1995) and systematic correlation with measurement error (Cronbach & Furby, 1970). Residualised scores were calculated by running a regression with the measurement of interest as dependent variable and the preceding measurement of the same variable as predictor - for instance, the pre-test baseline mood measure as predictor variable and the post-test mood measure as dependent variable. By subtracting the predicted score from the actual score, the part of the posttest score that could be predicted based on the pretest score is removed (Cronbach & Furby, 1970). Thus, residualised change scores indicate who recovered better than expected and who recovered worse than expected.

Preference and valence of association scores were calculated by computing the mean of all four photos in a category. ANOVA's were run with Environment and Valence instruction as independent variables and residualised change scores (mood, performance), preference, and valence of association as dependent variables.

3.3.2 Results

The results section will consist of three parts. In part one the effects of Environment and Valence instruction on valence of the associations will be presented. In part two, effects on preference will be presented, followed in part three by an analysis of the role of associations in restorative processes.

3.3.2.1 Associations, preference ratings, and mediation of preference through associative pathways

Association valence & generation

The valence of associations was compared between conditions. This analysis revealed a significant main effect of Valence instruction ($F(5,114) = 319.6$, $p < .001$, $\eta_p^2 = .86$). Planned contrasts for Valence instruction revealed a significant difference between the free-association and positive-association condition, between the free-association and negative-association condition, and between the positive-association and negative-association condition (p < .001). These result indicate that our Valence instruction manipulation was successful in guiding the valence of associations.

Significant effects of Environment ($F(5,114) = 20.7$, $p < .001$, $\eta_p^2 = .16$) and Environment * Valence instructions ($F(5,114) = 9.9$, $p < .001$, $\eta_p^2 = .16$) emerged as well. In the free-association condition, a significant difference was found between natural and urban environments, with natural environments generating more positive associations than urban environments ($p < .001$). Guiding valence of the associations resulted in overall more positive associations in the positive-association conditions than in the negative-association conditions ($p < .001$) and Environment type no longer affected the valence of associations ($p > .446$). Thus, guiding the valence of associations not only affected valence of the associations, this effect also occurred independent of environment type. These results further corroborate that our Valence instruction manipulation was successful in guiding the valence of associations, irrespective of the environments with which the associations were generated. Table 3.5 displays the means and standard errors for the association generation and valence outcomes and Figure 3.6 displays the mean valence of associations for all conditions.

The total number of associations that participants generated for the four photos ranged between 4 and 40. The mean number of associations generated was 20.52 (SD = 8.15). The number of associations was affected by Valence instruction ($F(5,114) = 12.0$, $p < .001$, $\eta_p^2 = .17$). Planned contrasts revealed that the number of associations differed between all three Valence instructions (*all* $p < .016$). The highest number of associations was generated in the free-association condition (M = 24.60*,* SE = 1.18), followed by the positive-association condition (M = 20.53 ,SE = 1.18). The fewest associations were generated in the negative-association condition (M = 16.43*,* SE = 1.18). No significant effects for Environment or Environment * Valence instruction were found (F < 1.9, $p > .161$).

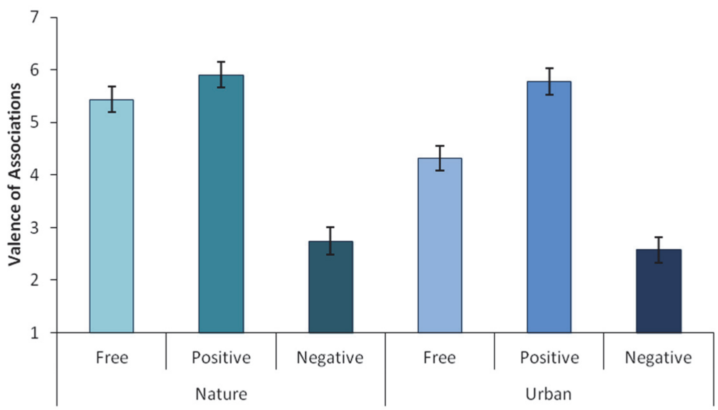


Figure 3.6 Valence of the associations for all conditions, error bars represent 95 % confidence intervals.

A number of questions were included to investigate how participants rated the association-generation task. First of all, participants were asked to indicate how much effort they had put into the generation of associations. The amount of effort exerted appeared unaffected by Valence instruction or the interaction of Environment * Valence instruction ($F < .6$, $p > .551$). However, one non-significant trend was found for Environment ($F(5,114) = 3.1$, $p = .079$, $\eta_p^2 = .03$), with slightly more effort exerted in the urban conditions than in the nature conditions, see Table 3.5.

On the other hand, generating associations was not perceived as equally difficult in all conditions, which is in line with our expectations. A main effect was found for Valence instruction ($F(5,114) = 16.4$, $p < .001$, $\eta_p^2 = .22$), as well as an interaction of Environment * Valence instruction ($F(5,114) = 5.2$, $p = .007$, $\eta_p^2 = .08$), whereas Environment, as a main effect, did not significantly affect perceived difficulty ($F(5,114) = 3.3$, $p = .070$), see Figure 3.7. Planned contrasts revealed significant differences in perceived difficulty between all three Valence instructions (*all* $p < .006$). Generating free associations was perceived as least difficult ($M = 3.35$, $SE = .21$), followed by the positive-association condition ($M = 4.20$, $SE = .21$). Generating negative associations was perceived as most difficult ($M = 5.08$, $SE = .21$). Table 3.5 shows that guiding associations led to an increase in perceived difficulty for the urban environments, irrespective of whether these associations had to be positive or negative. For the natural environments only the negative associations were perceived to be more difficult to generate than the positive and free associations. Furthermore, generating positive associations was perceived to be more difficult in the urban condition than in the nature condition.

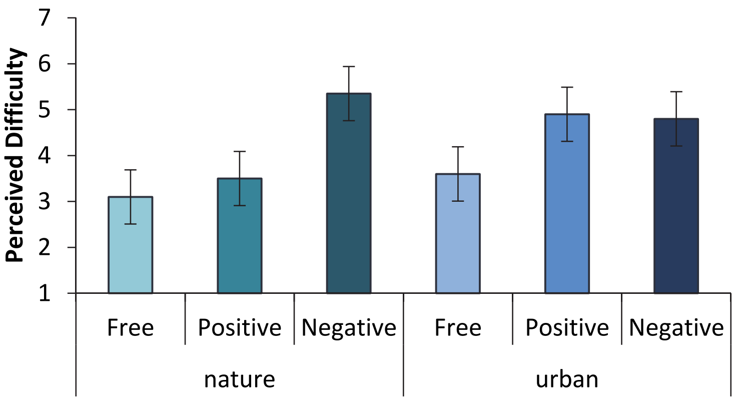


Figure 3.7 Perceived difficulty of the association generation for all conditions. Error bars represent the 95 % confidence interval.

Table 3.5 Means and standard errors for difficulty, effort, suppression, and valence of associations.

		Free Mean (SE)	Positive Mean (SE)	Negative Mean (SE)
Valence	Nature	6.38 (.47)[a,c]	5.91 (.10)[a]	2.75 (.11)[a]
	Urban	5.93 (.46)[b,c]	5.78 (.11)[b]	2.57 (.10)[b]
Number	Nature	25.50 (1.89)[a]	22.45 (1.63)[b]	15.20 (1.74)[a,b]
	Urban	23.70 (1.85)[c,d]	18.60 (1.27)[c]	17.65 (1.53)[d]
Effort	Nature	4.65 (.26)	5.00 (.22)	4.75 (.22)
	Urban	5.00 (.28)	5.15 (.22)	5.30 (.22)
Difficulty	Nature	4.90 (.28) [a]	3.50 (.29)[b,e]	5.35 (.29) [a,b]
	Urban	4.40 (.37) [c,d]	4.90 (.29) [c,e]	4.80 (.29) [d]
Suppress	Nature	-	1.60 (.30)[a,b]	5.80 (.30)[a,c]
	Urban	-	4.45 (.30)[b]	3.85 (.30)[c]

Means with the same superscript letter are significantly different

In the guided-association conditions, participants were further asked to what extent they had suppressed oppositely valenced associations. Again, no main effect of Environment was found ($F(1,76) = 2.2$, $p = .142$). However, a main effect of Valence instruction was found on suppression ($F(1,76) = 35.3$, $p < .001$, $\eta_p^2 = .32$), as well as an interaction of Environment * Valence instruction ($F(1,76) = 62.8$, $p < .001$, $\eta_p^2 = .45$). Participants in the urban conditions had to suppress roughly equal amounts of associations in the positive and negative conditions, whereas participants in the natural conditions reported having suppressed more associations in the negative than in the positive condition, see Figure 3.8. Thus, participants who were asked to generate negative associations to nature had to suppress many positive associations, whereas those that were asked to generate positive associations with nature had to suppress only a few negative associations. Furthermore, participants had to suppress more negative associations and less positive associations for natural environments than for urban environments.

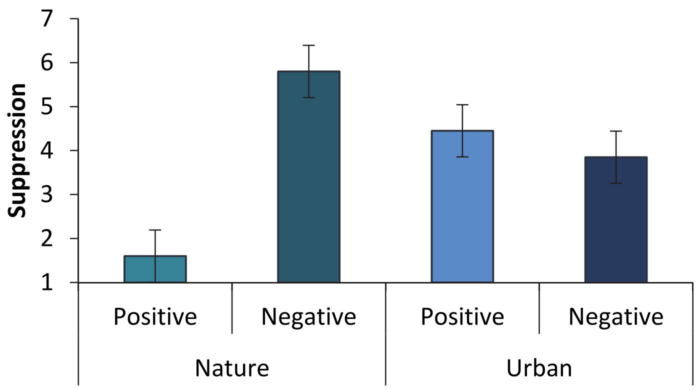


Figure 3.8 Suppression of oppositely valenced associations, error bars represent 95 % confidence intervals.*Preference*

Preference was measured on two dimensions; aesthetics and attitude. For aesthetics, a significant main effect of Environment was found ($F(5,114) = 173.5$, $p < .001$, $\eta_p^2 = .60$), see Table 3.6. Aesthetics ratings were not affected by Valence instruction nor did they show an interaction of Environment * Valence instruction ($F < 1.4$, $p > .240$). Attitudes, on the other hand, were affected by both Environment ($F(5,114) = 182.5$, $p < .001$, $\eta_p^2 = .62$) and Valence instruction ($F(5,114) = 3.8$, $p = .026$, $\eta_p^2 = .06$), see Figure 3.9. Planned contrasts revealed a significant difference between the positive and negative association conditions ($p = .009$), with a higher attitude score in the positive than in the negative association condition. No interaction of Environment * Valence instruction was found ($F(5,114) = .8$, $p = .442$). Table 3.6 displays the means and standard errors for preference.

Correlation analyses further indicated that even though Valence instruction did not consistently affect preference ratings, the valence of the generated associations was significantly correlated with both the preference ratings aesthetics ($r = .27$, $p = .004$) and attitude ($r = .34$, $p < .001$). When controlling for environment type, the correlation remained significant for attitude ($r = .30$, $p = .002$) but became nearly significant for aesthetics ($r = .19$, $p = .051$). These results indicate that environments scored higher on preference when more positive associations were generated with these environments and these effects occurred irrespective of the environment.

Table 3.6 Means and standard errors for Aesthetics and Attitude

		Free Mean (SE)	Positive Mean (SE)	Negative Mean (SE)
Aesthetics	Nature	5.08 (.24)^{b}	5.33 (.15)^{c}	5.22 (.15)^{d}
	Urban	3.50 (.18)^{b}	3.53 (.15)^{a,c}	3.06 (.15)^{a,d}
Attitude	Nature	5.27 (.16)^{b}	5.27 (.15)^{c}	5.05 (.15)^{d}
	Urban	3.55 (.15)^{b}	3.78 (.15)^{a,c}	3.18 (.15)^{a,d}

Means with the same superscript letter are significantly different

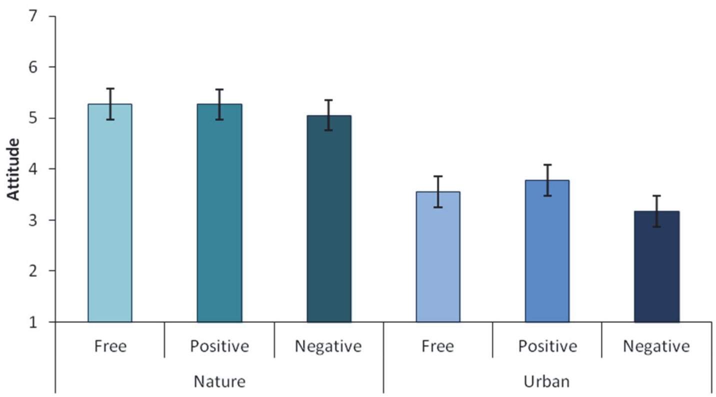


Figure 3.9 Attitude scores for all conditions, error bars represent 95% confidence intervals.

Does the valence of associations mediate preference?

In the previous sections, we saw that in the free-association conditions participants generated more positively valenced associations with natural environments than with urban environments. Furthermore, natural environments also scored higher on preference than urban environments. Similar to Study One, we wanted to test whether the valence of associations mediate the effects of environment on preference ratings. We only ran this mediation analysis for the free-association conditions, as we explicitly guided the valence of associations in the guided-associations conditions. The results of the mediation analyses are displayed in Table 3.7 and Figure 3.10. In the free-association conditions, valence of associations partially mediated the effect of environment on both attitude and aesthetics.

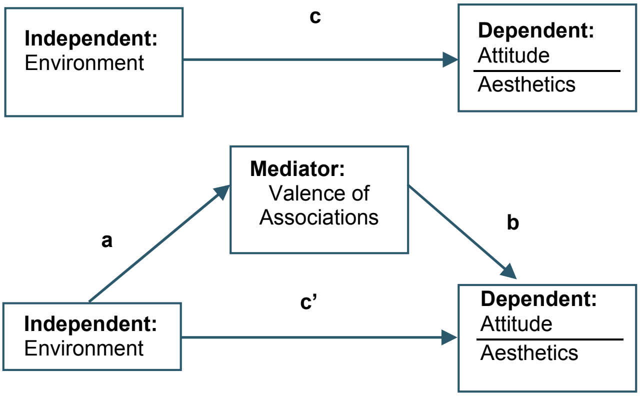


Figure 3.10 Graphical overview of the mediation analyses

Table 3.7 Mediation coefficients for the mediation of the effects of Environment on preference through valence of the associations for the Free-association condition

Dependent	a (SE)	b (SE)	c (SE)	c' (SE)	ab (indirect effects) (SE)	95 % Confidence Interval Indirect effect	Sobel (Z)
Attitude	1.11** (.22)	.56** (.14)	1.72** (.22)	1.09** (.24)	.63 (.19)	.31 – 1.09	3.24*
Aesthetics	1.11** (.22)	.71** (.19)	1.58** (.30)	.79* (.33)	.78 (.26)	.34 – 1.39	3.08*

** p < .05, ** p < .001 Note: the ab path is calculated using bootstrapping and no significance is indicated*

3.3.2.2 Restorative outcomes and mediation through associative pathways

After analysing the relation between environment type, association valence, and preference we will now report the effects of Environment and Valence instruction on restorative outcomes. Restoration was measured on two dimensions; recovery of mood and Necker Cube performance after stress induction.

Mood

A series of ANOVA's were conducted to investigate the influence of Environment and Valence instruction on the three mood dimensions; tension, hedonic tone, and energy. Table 3.8 displays the outcomes of these analyses and the means (raw scores) and standard errors for each condition. No baseline differences were found on any of the mood dimensions.

No restorative effects of Environment were found on any of the mood dimensions, neither did a significant interaction of Environment * Valence instruction emerge. As can be seen in Table 3.8 and Figure 3.11, counter to our expectations no evidence for restorative effects on mood of natural as opposed to urban environments was found in the free-association condition.

Table 3.8 Statistics, means, and standard errors for the effects of Environment and Valence on mood.

		Mean (SE)						Environ-ment		Valence		Env. * Valence	
		Nature			Urban								
		Free	Pos	Neg	Free	Pos	Neg	F	η_p^2	F	η_p^2	F	η_p^2
Tension													
	t_0[1]	2.30 (.09)	2.33 (.10)	2.42 (.11)	2.27 (.11)	2.24 (.11)	2.20 (.10)	1.8	-	<.1	-	.4	-
	t_1[2]	3.19 (.18)	2.95 (.14)	3.10 (.13)	2.95 (.12)	3.16 (.12)	3.00 (.13	<.1	-	<.1	-	1.6	-
	t_2[2]	2.36 (.08)	2.29 (.12)	2.58 (.12)	2.41 (.11)	2.40 (.11)	2.43 (.11)	<.1	-	1.6	-	.9	-
Hedonic tone													
	t_0[1]	3.90 (.17)	3.91 (.10)	3,87 (.11)	3.89 (.09)	3.94 (.10)	3.91 (.09)	<.1	-	<.1	-	<.1	-
	t_1[2]	3.02 (.20)	3.03 (.11)	3.13 (.14)	2.99 (.15)	2.97 (.15)	3.11 (.14)	.1	-	.5	-	<.1	-
	t_2[2]	3.63 (.13)	3.76[a] (.12)	3.43[a] (.11)	3.61[b] (.11)	3.65[c] (.12)	3.33[b,c] (.11)	.6	-	7.8**	.12	.1	-
Energy													
	t_0[1]	3.58 (.15)	3.79 (.12)	3.62 (.11)	3.54 (.14)	3.70 (.14)	3.49 (.12)	.6	-	1.4	-	.9	-
	t_1[2]	3.42 (.19)	3.67 (.14)	3.44 (.13)	3.38 (.16)	3.56 (.17)	3.23 (.14)	.4	-	.7	-	.1	-
	t_2[2]	3.50 (.13)	3.79 (.12)	3.46 (.13)	3.43 (.15)	3.51 (.15)	3.23 (.13)	2.5	-	.9	-	.5	-

*[1] the F-values represent baseline differences, [2] the f-values represent differences in residualised changes compared to the previous segment. Means with the same superscript letter are significantly different. ** p < .001*

A significant main effect was found for Valence instruction on hedonic tone at t_2 (after the association-generation phase). Planned contrasts revealed a significant difference between the free and the negative-association conditions (p = .004) as well as between the positive and negative-association conditions (p < .001). Hedonic tone increased more in the positive and free-association condition than in the negative-association condition, see Figure 3.11. Please note that this figure displays residualised change scores. Therefore, a negative score for the negative conditions does not represent a decline in positive affect. Rather, in this case a negative value indicates a smaller increase in hedonic tone compared to the other conditions. No remaining effects of Valence instruction were found on tension or energy.

Necker Cube performance

No baseline differences in Necker Cube performance were found (F < 2.1, p >.124). Only a non-significant trend was found for Environment ($F(5,112) = 3.2$, p < .077, $\eta_p^2 = .03$), with a slightly higher number of Necker Cube reversals in the urban conditions than in the nature conditions. See Table 3.9 for means and standard errors. In this table, it can be seen that, again counter to our expectations, besides the non-significant trend reported above no evidence for restorative effects of natural environments on Necker Cube performance was found at t_2. No significant effects were found of Valence instruction or Environment * Valence instruction on performance on the Necker Cube (F < .7, p > .819).

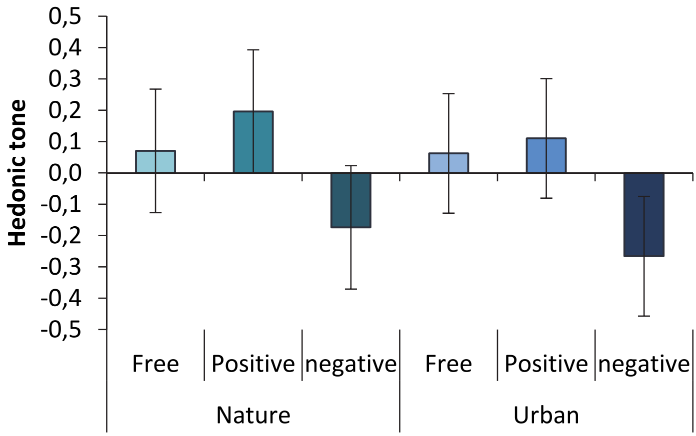


Figure 3.11 Residualised change scores for hedonic tone during the association-generation phase for the three different valence instructions, error bars represent 95% confidence intervals.

Table 3.9 Means and standard errors for number of Necker Cube Reversals.

		Mean (SE)					
		Nature			Urban		
		Free	Positive	Negative	Free	Positive	Negative
Necker	t_0	5.20	4.45	4.35	5.75	4.40	4.45
Cube		(.76)	(.50)	(.56)	(.75)	(.45)	(.47)
Reversals	t_1	5.50	4.60	3.85	5.40	4.50	5.00
		(.95)	(.52)	(.59)	(.74)	(.74)	(.63)
	t_2	5.15	4.11	3.45	5.40	4.60	4.60
		(.88)	(.57)	(.54)	(.54)	(.58)	(.58)

Mediation of restorative outcomes through associative pathways
As no evidence was found for restorative effects of Environment on mood or Necker Cube performance, no mediation analyses were performed. Correlation analyses did reveal significant correlations between the valence of associations and mood recovery for tension (r = -.26, p = .006), energy (r = .20, p = .037), and hedonic tone (r = .39, p < .001), but not between valence of associations and Necker Cube performance (r = -.18, p = .263).

3.3.3 Discussion

In this study, the results of Study One were replicated in a between-subjects design; natural environments again rendered more positive associations than urban environments. For the free-association conditions, valence of the associations partially mediated the effect of environment on aesthetics and attitude, further corroborating the potential role of associations in preference formation. Compared to Study One, four additional conditions were added in which participants were instructed to generate only negative or positive associations.

These valence instructions were added to further investigate whether valence of associations mediate restorative outcomes. If restorative effects of nature run through positive associations with these environments, it was to be expected that when participants are instructed to generate positive associations this should render restorative outcomes as well, independent of the environment with which these associations are generated. Looking at the valence of associations, we can conclude that the valence instruction manipulation was successful in guiding participants to generate only positive or negative associations. That is, more positive associations were generated in the positive condition than in the free and negative condition.

In all three valence instruction conditions, higher preference scores were found for natural environments than for urban environments. Guiding the valence of associations affected attitude scores, but not aesthetic scores. Looking at the correlations between preference ratings and valence of associations, these results indicated that participants who formulated more positive associations with the displayed environments also scored these environments higher on preference. These effects seemed to occur irrespective of environment type. Restorative outcomes were not affected by environment type, not even in the free-association conditions. However, valence instructions significantly affected the improvement of hedonic tone during the association-generation phase, with a higher improvement of hedonic tone for participants in the free and positive-association conditions than for those instructed to generate only negative associations.

Participants in all conditions reported an equal amount of effort put into generating associations, therefore effects could not be due to differences in motivation. Perceived difficulty was, however, affected by our valence instruction manipulation. Generating associations was perceived least difficult in the free-association condition, followed by the positive-association condition and generating negative associations was perceived as most difficult. The difference in difficulty between positive and negative associations was more pronounced for natural environments than for urban environments, with generating only negative associations being perceived as much more difficult than generating only positive associations with natural environments. Similarly, more positive associations had to suppressed when generating negative associations in the natural environment than in all other conditions.

The lack of restorative effects of natural environments could be due to the fact that participants were writing down their associations and therefore paid too little attention to the actual nature images for it to exhibit restorative effects. For this reason, the study was repeated with a different association-generation protocol.

3.4 Study Three

Study Three presents a replication of Study Two, with a slightly adapted version of the association-generation protocol. In the present study, instead of asking participants to write down the associations, they were asked to verbally report their associations. This way, they were able to take in the displayed environments while forming the associations. In order to increase the restorative influence of the photos even more, participants were instructed to view the photo for 15 seconds without generating associations. To further enhance restorative experience, larger photos were displayed on a television screen (see e.g., de Kort, Meijnders, Sponselee, & IJsselsteijn, 2006). In addition, besides preference ratings, participants were also asked to rate the photos on two characteristics of perceived restorativeness; fascination and being away.

3.4.1 Method

3.4.1.1 Design

Again, a 2 (Environment; natural vs. urban) by 3 (valence instruction; free vs. positive vs. negative) between-subjects design was employed.

3.4.1.2 Participants

In total 178 participants (67 females) participated in the study. Their mean age ranged between 18 and 43, with a mean of 22.07 (*SD* = 3.06). They were recruited via the researcher's personal network, face-to-face on the campus premises, and via our database. The duration of the experiment was approximately 45 minutes and participants received €7.50 compensation.

3.4.1.3 Procedure

After signing the informed consent form, participants took place behind a desk with a laptop. They first filled in a baseline mood questionnaire (baseline; t_0), followed by the baseline measure of the Sustained Attention to Response Task (SART1; performance task, see Section 3.4.1.7 for a description). After finishing the baseline measures, the stress induction task (Retail task, see Section 3.4.1.6) was started. After this task, participants completed the SART task for the second time (SART2), followed by the mood questionnaire (post induction; t_1). Then, after reading the instructions, the photos were displayed on the televisions and participants started naming their associations. Afterwards, participants filled in their mood for the third time (post manipulation; t_2), followed by the SART task (SART3). Upon completion of the SART task, participants reported how difficult it was to form the associations and started rating the displayed environments on preference and restorative qualities. They then called upon the experiment leader, who instructed them how to listen back their own associations, write them down and rate the associations on valence on a paper form provided to them by the experimenter. After finishing listing and rating their associations, the experiment was finished and participants were thanked and paid for their effort. Figure 3.12 displays an overview of the experimental set-up.

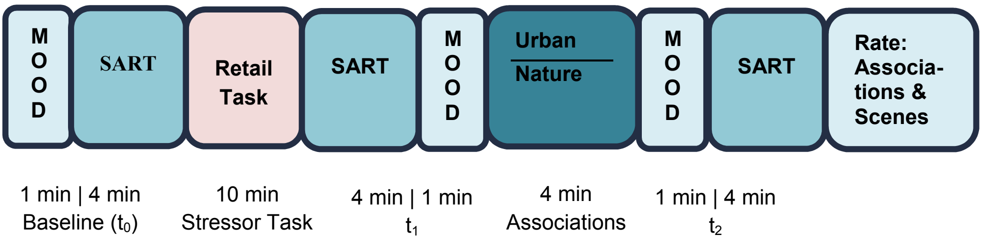


Figure 3.12 Overview of the experimental set-up

3.4.1.4 Manipulation – Photos

The eight photos in Study Three were taken in Heerlen and its surroundings. They were taken during sunny or half overcast days in spring and matched in brightness, see Figure 3.13. No humans were present in the nature photos and the presence of people in the foreground was avoided in the urban photos. The photos were presented on a wall-mounted television screen (32 inch).

3.4.1.5 Manipulation – Associations generation

Participants received valence instructions on the notebook, after which the photos were displayed on the television screen. They received the same instructions as in Study One and Two, except that they had to verbally express the associations. The associations were recorded via a microphone in the notebook in Audacity®. Furthermore, they were instructed to generate associations during 45 seconds, while the border around the photos was grey. After 45 seconds, the border turned white for 15 seconds and participants were instructed to look at the photos without expressing associations with the assignment to imagine being in the displayed environment.

If the participants remained quiet during the association-generation phase for longer than 5 seconds, he or she was encouraged to form new associations by a line of text appearing at the top of the screen. For example, they were asked to name the first thing that came to mind, or were asked whether there was anything else they could think of. Table 3.10 displays some examples of associations that participants reported.

Table 3.10 Example associations per category.

	Nature	Urban
Free associations	*'Making photos' 'Animals' 'Hiking shoes' 'Getting a tan' 'Picnic' 'Family' 'Hay fever' 'Holiday' 'Mountain bike' 'Open air' 'Harry Potter' 'Forest' 'Grass' 'The wind'*	*'Renovated' 'Reasonably quiet' 'Luxurious' 'Parties' 'Cycling' 'Inner city' 'Cafe' 'Alone' 'Grim' 'Empty' Deprived area' 'Dog' 'Low velocity' 'Playing children' 'Many inhabitants'*
Positive associations	*'Getting fresh air' 'Trees not really high' 'really in nature' 'Flowers' 'Discovering' 'Tranquillity' 'No cars' 'Being merry' 'Being active with friends' 'Hopping' 'Alone'*	*'Nice neighbourhood' 'Close to shops' 'Nice weather' 'Summer' 'People' 'Light' "Shops' 'Lively' 'Special beer' 'The Netherlands' 'Cinema' 'Architecture' 'Balcony' 'New t-shirt'*
Negative associations	*'Cold' 'Elderly' 'Allergy' 'Fire' 'Wounds' 'Rape' 'Alone' 'Boring' 'Molehill' 'Not bringing your picnic basket' 'Pretending nature is fun' 'Ruin your shoes' 'Guerrilla forces'*	*' Building looks unfinished' 'No clear function square' 'Shops closed' 'Boring' 'Deserted' 'Youngsters rioting' 'Cars in front of your house' 'Too little green' 'Death' 'Criminality'*

Figure 3.13 The photos used in Study Three with the natural (left) and urban (right) scenes.

3.4.1.6 Stress Induction – Retail task

In the present study, the retail task (adopted from: Häusser, Mojzisch, & Schulz-Hardt, 2011) - a workload task with low task control - was employed for stress induction. The retail task requires participants to compile a computer package existing of a PC, monitor, and printer for a client. During each trial, they were presented with a budget and one special wish (either a PC, monitor, or printer). Their task was to compile a package that would make maximum use of the budget, without exceeding it. The task consisted of 35 rounds, with a decreasing amount of time available per round. During the first 7 rounds, their time limit was 20 seconds, and each 7 next rounds the time decreased with 2 seconds. During the last 7 rounds, the time limit was 12 seconds. A clock was displayed on the screen to show the remaining time. Furthermore, at the bottom of the page the number of finished trials out of 34 was displayed. However, after finishing the 34th round there was one additional round to increase stress response. In addition, whenever a false answer was given, an alarm beep would sound. See Figure 3.14 for a screen shot.

3.4.1.7 Measures

Association valence & generation. Similar to Studies One and Two, participants rated their own associations on valence, see Section 3.2.1.6. Furthermore, Effort, Difficulty, and Suppression were measured for the generation of associations, see Section 3.3.1.8 for more detailed descriptions.

Preference and perceived restorativeness (being away and fascination). Preference was measured for each photo on one dimension; attitude. See Section 3.2.1.6 for a description. Cronbach's alpha for this variable was good (α ≈ .95).

Being away and Fascination were measured using the subscales for these dimensions of the Perceived Restorativeness Scale (Hartig, Kaiser, & Bowler, 1997). An example item for being away is: *"Being here is an escape experience"* and an example item for fascination is

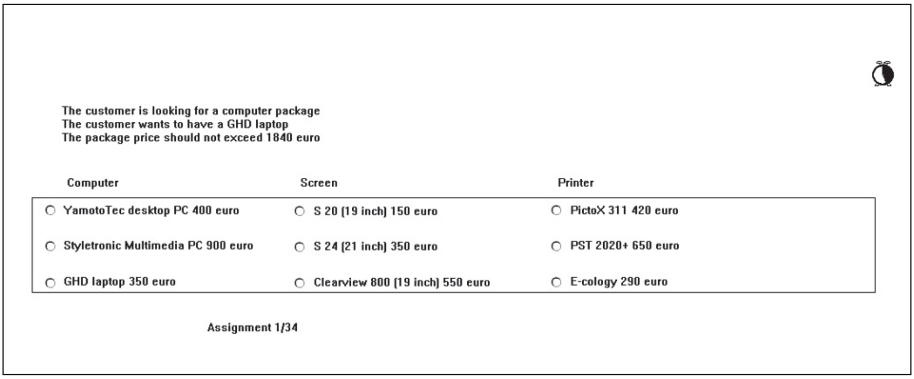


Figure 3.14 An example screen for the retail task

"This place has fascinating qualities". The response scale ranged from 1 (not at all) to 7 (completely).

Mood. Mood was measured along three dimensions; tension, energy, and hedonic tone, see Section 3.3.1.8. Reliability scores ranged between $\alpha = .85$ and $\alpha = .90$ for energy, between $\alpha = .72$ and $\alpha = .78$ for hedonic tone, and between $\alpha = .78$ and $\alpha = .86$ for tension.

Dependent task – Sustained Attention to Response Task. In the Sustained Attention to Response Task (SART), the digits 0 to 9 were displayed in random order on the computer screen. Participants were asked to respond to each digit by pressing the spacebar ('go' trials) as soon as possible, except when the digit was the number '6' ('no-go' trial). In this experiment, participants completed the SART three times. Each task consisted of 200 trials (20 targets; '6'). During each trial, the digit was displayed for 250 ms and followed by a blank screen for 900 ms. After the blank screen disappeared, the next trial would start automatically. During the baseline measurement, participants first completed 10 practice trials.

Dependent variables are the reaction times and two different types of scores; sensitivity (d') and bias (c') with formulas derived from signal detection theory (Snodgrass & Corwin, 1988).

Because the data had a logistic distribution, the following formulas were used to calculate d' and c':

$$\text{Sensitivity} = \ln \{[H(1-FA)]/[(1-H)FA]\}$$
$$\text{Bias} = 0.5\ [\ln\{[(1-FA)(1-H)] / [(H)(FA)]\}]$$

With H being the proportion of hits and FA representing the proportion of false alarms. Perfect scores (0 or 1) were adjusted by .0001.

In the SART task, sensitivity reflects the ability to discriminate between a go (any digit except '6') or no-go ('6') trial, whereas bias reflects the criterion that participants use to respond to the target. For instance, a participant might have the criterion to not want to miss any targets. This more lenient criterion results in more false alarms (not responding to a go trial), reflected in a lower bias score.

3.4.1.9 Data analysis

For mood and performance, residualised change scores were calculated between each time point, see Section 3.3.1.10 for the rationale. Preference, valence of associations, and perceived restorativeness scores were calculated by taking the mean of all four photos. ANOVA's were run with Environment and Valence instruction as independent variables and change scores (mood, performance), preference, perceived restorativeness, and valence of associations as dependent variables. For the performance parameters, scores deviating more than 2 standard deviations (reaction times; from the person mean - raw scores, 3 standard deviations for bias and sensitivity) were considered outliers and removed from the analysis.

3.4.2 Results

In this section, we will first report on the effects of Environment and Valence instruction in three parts. We will begin by reporting effects of our manipulations on the valence of associations, followed by the effects on preference and restorative potential. In the last part, we will report the effects of Environment and Valence instruction on recovery of mood and performance on the SART. For preference and restorative outcomes, we will further investigate whether the valence of associations mediates the effects of environment.

3.4.2.1 Associations, preference ratings, and mediation of preference through associative pathways

Association valence & generation

The valence of the generated associations was significantly affected by our manipulations, with main effects for both Environment ($F(5,116) = 7.8$, $p = .006$, $\eta_p^2 = .04$) and Valence instruction ($F(5,116) = 472.9$, $p < .001$, $\eta_p^2 = .85$). The interaction effect of Environment * Valence instruction was significant as well ($F(5,116) = 15.8$, $p < .001$, $\eta_p^2 = .16$), see Figure 3.15. Planned contrasts for Valence instruction revealed significant differences between all three valence conditions ($p < .001$). Valence was most positive in the positive-association conditions, followed by the free-association condition. Valence was most negative in the

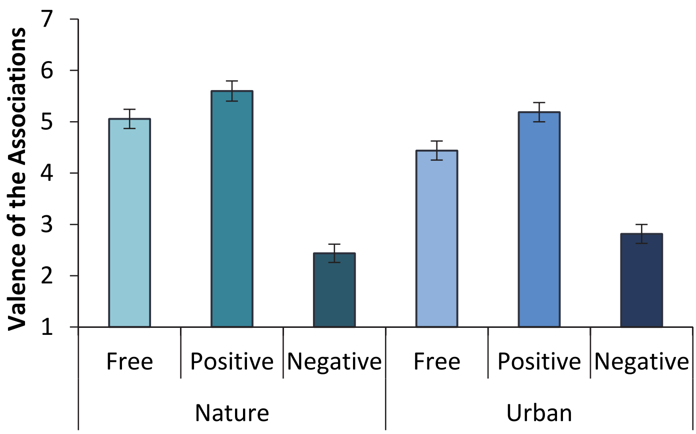


Figure 3.15 Means for the valence of associations for all conditions. Error bars represent 95 % confidence intervals.

negative-association conditions. Natural environments further generated more positive associations than urban environments in the free and positive condition, but generated more negative associations in the negative-association condition, see Table 3.11. Thus, the valence instruction was successful in generating either positive or negative associations. However, environment type also affected valence of the associations, not only in the free-association conditions, but also when associations were guided.

The number of associations participants generated with the four photos ranged substantially, between 4 and 73 (M = 28.30, SD = 12.46). Valence instruction significantly affected the number of associations generated ($F(5,169) = 19.4$, $p < .001$, $\eta_p^2 = .19$). Planned contrasts revealed significant differences between all valence conditions ($p < .004$). Most associations were generated in the free-association condition (M = 34.74, SE = 1.48), followed by the positive-association condition (M = 28.72, SE = 1.51), and the negative-association condition (M = 21.90, SE = 1.44). Environment did not significantly affect the number of associations (F (5.169) = .5, p = .484), whereas a non-significant trend was found for the interaction of Environment * Valence instruction ($F(5,169) = 2.4$, p = .096).
The amount of effort exerted was not affected by any of our manipulations ($F < 1.9$, $p >$ .147), indicating that participants in all conditions were equally motivated. Furthermore, all conditions were also perceived as equally difficult ($F < 2.0$, $p > .137$), see Figure 3.16.

Participants in the guided-association conditions were also asked to what extent they had suppressed oppositely valenced associations. This analysis revealed that the number of associations that needed to be suppressed was affected by our manipulation, with main effects of Environment ($F(5,116) = 6.5$, $p = .012$, $\eta_p^2 = .05$) and Valence instruction ($F(5,169)$ = 37.8, $p < .001$, $\eta_p^2 = .25$), as well as an interaction effect of Environment * Valence

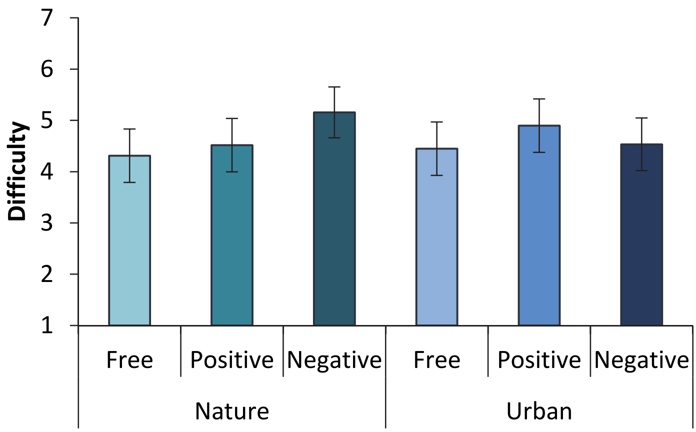


Figure 3.16 Difficulty of the association generation. Error bars represent 95% confidence intervals.

Table 3.11 Means and standard errors for difficulty, effort, suppression, and valence of associations.

		Free Mean (SE)	Positive Mean (SE)	Negative Mean (SE)
Number	Nature	33.34 (2.09)[a]	31.78 (2.17)[b,c]	22.13 (2.02)[a,b]
	Urban	36.24 (2.09)[a,b]	25.66 (2.09)[a,c]	21.67 (2.06)[b]
Effort	Nature	4.93 (.18)	5.24 (.18)	5.03 (.17)
	Urban	5.14 (.18)	4.86 (.18)	5.27 (.17)
Difficulty	Nature	4.31 (.27)	4.52 (.27)	5.16 (.25)
	Urban	4.45 (.27)	4.90 (.27)	4.53 (.26)
Suppress	Nature	-	2.59 (.27)[a,b]	5.59 (.26)[a]
	Urban	-	4.62 (.27)[b]	4.93 (.27)
Valence	Nature	5.06 (.10)[a,c]	5.60 (.10)[a,d]	2.44 (.09)[a,e]
	Urban	4.44 (.10)[b,c]	5.19 (.10)[b,d]	2.82 (.09)[b,e]

Means with the same superscript letter are significantly different.

instruction ($F(5,169) = 24.9$, $p < .001$, $\eta_p^2 = .18$), see Figure 3.17. Just as in Study Two, participants in the urban conditions had to suppress as many negative as positive associations, whereas participants in the nature conditions had to suppress more positive than negative associations. Furthermore, participants in the positive conditions had to suppress more negative associations for natural environments than for urban environments, see Table 3.11.

Preference and restorative potential

Preference was measured on one dimension; attitude. Attitude was affected by Environment (F (5,171) = 164.4, $p < .001$, $\eta_p^2 = .49$), but not by Valence instruction (F (5,171) = .7, p = .504). Furthermore a significant interaction of Environment * Valence instruction was found (F (5,171) = 3.1, $p = .050$, $\eta_p^2 = .04$), see Figure 3.18.

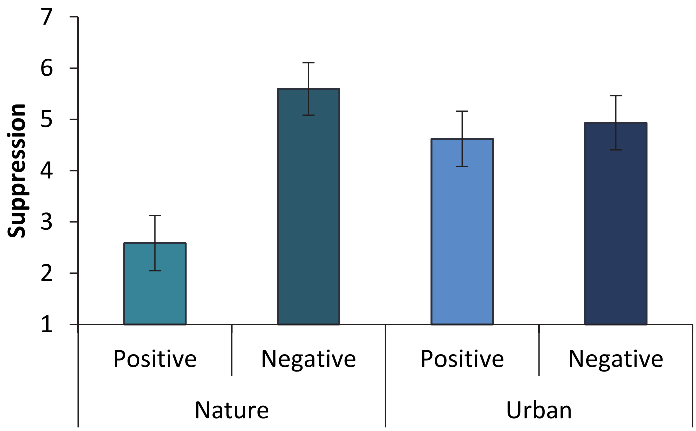


Figure 3.17 Suppression of oppositely valenced associations in the guided-association conditions. Error bars represent 95 % confidence intervals

Table 3.12 Means and standard errors for Attitude

		Free Mean (SE)	Positive Mean (SE)	Negative Mean (SE)
Attitude	Nature	5.11 (.15)[a]	5.02 (.15)[b]	5.22 (.14)[c]
	Urban	3.72 (.15)[a,d]	3.78 (.15)[b,e]	3.31 (.15)[c,d,e]
Fascination	Nature	4.46 (.15)[a]	4.39 (.15)[b]	4.54 (.14)[c]
	Urban	3.60 (.15)[a]	3.60 (.15)[b]	3.29 (.15)[c]
Being Away	Nature	4.83 (.15)[a]	4.93 (.15)[b]	5.21 (.15)[c]
	Urban	3.46 (.15)[a,d]	3.56 (.15)[b,e]	2.97 (.15)[c,d,e]

Means with the same superscript letter are significantly different.

Natural environments scored higher on attitude than urban environments in all conditions. Furthermore, valence instruction affected attitude scores for urban but not for natural environments. For the urban environments, attitude scores were lower in the negative-association condition compared to the free and positive-association condition, see Table 3.12. Counter to our expectations, no significant correlation was found between valence of association and attitude scores (r = .10, p = .171).

In this study, the relation between valence of associations and restorative potential was investigated in addition to preference. Analyses revealed a significant main effect of Environment on both fascination (F (5,171) = 62.1, p < .001, η_p^2 = .27) and being away (F (5,171) = 181.7, p < .001, η_p^2 = .52). Moreover, a significant interaction of Environment * Valence instruction was found for being away (F (5,171) = 5.7, p = .004, η_p^2 = .06). Table 3.12 displays the means and standard errors.

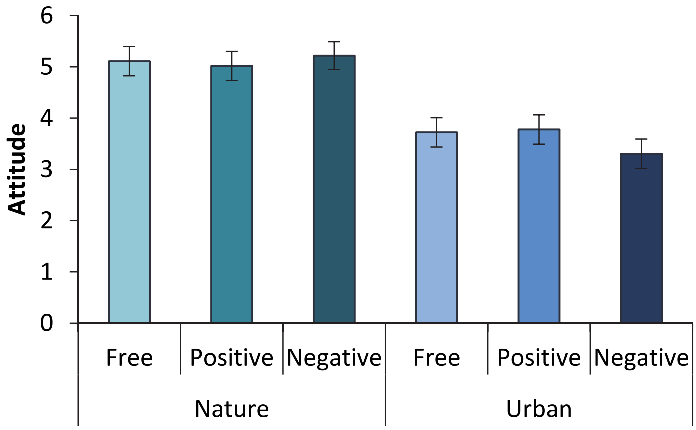


Figure 3.18 Attitude scores for all conditions, error bars represent 95% confidence intervals.

Similar to attitude, being away was affected by the valence instructions but only in the urban condition. Correlation analyses further revealed that –again counter to our expectations- valence of associations was not correlated with being away or fascination ($r < .11$, $p > .166$).

Does the valence of associations mediate preference and restorative potential?
Environment type significantly affected the valence of associations on the one hand and preference and perceived restorativeness ratings on the other in the free association conditions. As in Study Two, we wanted to test whether valence of the associations mediated the effect of environment on preference. In addition, we tested whether valence of associations also mediated the effect of environment on restorative potential, measured in terms of fascination and being away. Results of these analyses are presented in Table 3.13 and the mediation is graphically displayed in Figure 3.19. As in Study One and Two, valence of the associations partially mediated the effect of environment on attitude. In addition, valence of associations partially mediated the effect of environment on fascination scores.

3.4.2.2 Restorative outcomes and mediation through associative pathways
After analysing the relation between environment, association valence, and preference we will now report the effects of Environment and Valence instruction on mood and on performance on the SART Task.

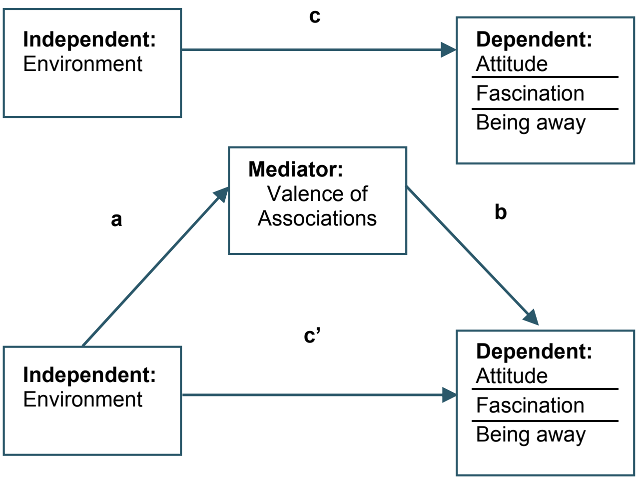


Figure 3.19 Graphical overview of the mediation analyses

Table 3.13 Mediation coefficients for the mediation of the effects of Environment on preference through valence of the associations for the Free-association condition.

Dependent	a (SE)	b (SE)	c (SE)	c' (SE)	ab (indirect effects) (SE)	95 % Confidence Interval Indirect effect	Sobel (Z)
Attitude	.62** (.12)	.59** (.17)	1.39** (.17)	1.02** (.18)	.38 (.13)	.15 - .67	2,97*
Fascination	.62** (.12)	.66** (.19)	.86** (.19)	.46* (.21)	.42 (.16)	.15 - .83	2.92*
Being away	.62** (.12)	.26 (.17)	1.36** (.16)	1.20** (.19)	-	-	-

Note: the ab path is calculated using bootstrapping and no significance is indicated.
** p < .05, ** p < .001*

Mood
A series of ANOVA's were conducted to investigate the influence of Environment and Valence instruction on the three mood dimensions; tension, hedonic tone, and energy. Table 3.14 displays the outcomes of these analyses and the means (raw scores) and standard errors for each condition. No significant baseline differences were found on any of the mood dimensions, and the induction task also did not affect the groups differently ($F < 2.9$, $p > .093$).

Analyses comparing mood before and after the association generation task revealed no main or interaction effects for Valence instruction and Environment type ($F < 2.3$, $p > .103$). One non-significant trend for Environment on hedonic tone was found (F (5,171) = 2.8, p = .095, $\eta_p^2 = .02$). Planned contrasts further revealed a significant difference in hedonic tone for the negative compared to the positive-association conditions (p = .040), see Figure 3.20.

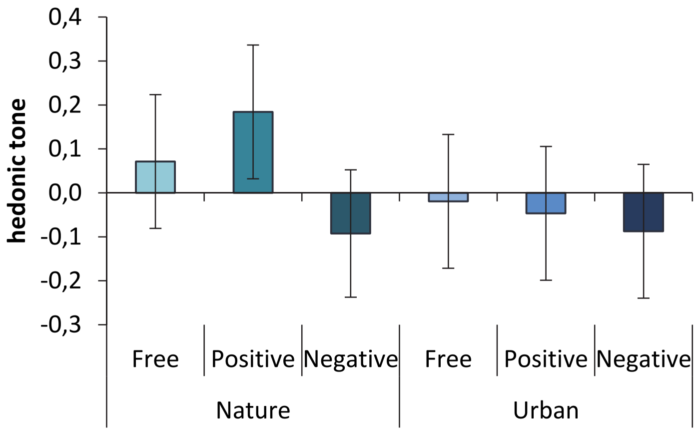


Figure 3.20 Residualised change score for hedonic tone during the association-generation phase for the three different valence instructions, error bars represent 95% confidence intervals.

Table 3.14 Statistics, means, and standard errors for the effects of Environment and Valence on mood

		Mean (SE)						Env	Val	Env * Val
		Nature			Urban					
		Free	Pos	Neg	Free	Pos	Neg	F (5,171)	F (5,171)	F (5,171)
Tension	t_0^1	2.11 (.09)	2.16 (.09)	2.18 (.09)	2.14 (.09)	2.15 (.09)	2.18 (.09)	<.1	.2	<.1
	t_1^2	2.62 (.14)	2.79 (.11)	2.57 (.10)	2.84 (.12)	2.66 (.11)	2.85 (.14)	2.1	.2	2.1
	t_2^2	2.24 (.10)	2.26 (.07)	2.32 (.10)	2.41 (.08)	2.36 (.11)	2.40 (.10)	1.0	.3	1.1
Hedonic tone	t_0^1	3.88 (.09)	3.97 (.09)	4.00 (.08)	3.95 (.09)	3.95 (.09)	3.83 (.09)	.3	.2	1.0
	t_1^2	3.18 (.13)	3.35 (.10)	3.36 (.10)	3.39 (.09)	3.32 (.12)	3.21 (.11)	.2	<.1	.7
	t_2^2	3.59 (.10)	$3.79^{a,b}$ (.08)	3.52^{b} (.10)	3.61 (.07)	3.54^{a} (.09)	3.45 (.12)	2.8	2.3	1.2
energy	t_0^1	3.70 (.10)	3.72 (.10)	3.88 (.10)	3.64 (.10)	3.50 (.10)	3.73 (.10)	2.9	1.9	.3
	t_1^2	3.22 (.14)	3.38 (.11)	3.46 (.11)	3.31 (.13)	3.19 (.16)	3.19 (.11)	1.0	.4	1.0
	t_2^2	3.50 (.12)	3.58 (.07)	3.58 (.09)	3.43 (.12)	3.49 (.11)	3.53 (.08)	<.1	.4	.9

*[1] the F-values represent baseline differences, [2] the f-values represent differences in residualised changes compared to the previous segment. Means with the same superscript letter are significantly different. * p < .05, ** p < .001*

During the association-generation phase, hedonic tone increased more in the nature positive condition than in the urban positive condition and nature negative condition, see Table 3.14. Similar to Study Two, we again did not find any evidence for restorative effects of natural as opposed to urban environments in the free-association conditions.

SART performance

First of all, no baseline differences in reaction times, bias, or sensitivity were found ($F < .7$, $p > .512$). However, residualised change scores in reaction times of the SART after the retail task compared to the baseline SART revealed a significant interaction of Environment * Valence instruction (F (5,171) = 3.9, $p = .022$, $\eta_p^2 = .04$). Thus, before generating associations with natural or urban environments participants differed in how the retail task affected their SART performance, see Table 3.15. However, no differences were found in bias or sensitivity ($F < 1.9$, $p > .149$).

Comparing the residualised change score of performance on the SART task before and after generating associations revealed no effects of Environment or Valence instruction on reaction times, bias, or sensitivity ($F < 1.7$, $p > .192$). See Table 3.15 for means and standard errors. Again, no evidence was found for beneficial effects of natural versus urban environments on performance in the free-association conditions.

Table 3.15 Means and standard errors for reaction times, bias, and sensitivity for the SART task.

		Mean (SE)					
		Nature			Urban		
		Free	Pos	Neg	Free	Pos	Neg
Reaction times	t_0	280.25 (5.20)	280.10 (7.24)	287.19 (5.45)	276.97 (5.72)	283.64 (7.29)	284.39 (5.99)
	t_1	273.17 (7.52)	275.72[a] (7.69)	278.56 (8.43)	273.43[b] (6.42)	260.01[a,b] (9.88)	281.23 (8.23)
	t_2	272.66 (9.12)	273.49 (9.09)	281.67 (12.64)	268.73 (7.47)	268.88 (12.04)	285.89 (10.87)
Sensitivity	t_0	.52 (.18)	.45 (.20)	.41 (.13)	.57 (.18)	.32 (.18)	.51 (.18)
	t_1	.58 (.18)	.62 (.18)	.40 (.18)	.45 (.20)	.85 (.18)	.70 (.17)
	t_2	.89 (.18)	.45 (.16)	.65 (.21)	.40 (.16)	.73 (.21)	.85 (.18)
Bias	t_0	-.35 (.07)	-.31 (.08)	-.33 (.05)	-.31 (.06)	-.35 (.08)	-.29 (.06)
	t_1	-.36 (.05)	-.29 (.08)	-.34 (.07)	-.35 (.06)	-.29 (.05)	-.29 (.06)
	t_2	-.34 (.06)	-.30 (.07)	-.31 (.08)	-.35 (.06)	-.30 (.07)	-.21 (.06)

Means with the same superscript letter are significantly different.
** $p < .05$, ** $p < .001$*

Mediation of restorative outcomes through associative pathways
As no evidence was found for restorative effects of Environment on mood or SART performance, no mediation analyses were performed.

3.4.3 Discussion

In this study, we again investigated whether natural environments generated more positive associations than urban environments and whether restorative outcomes of nature were mediated by the valence of associations. In Study Two, no evidence was found for restorative effects of nature on mood and cognitive performance in the free-association conditions. We hypothesized that the association-generation task might have lowered restorative potential of the natural environments as participants were writing their associations down and as a consequence paid less attention to the photos. Therefore, the design of Study Three was altered to enable more interaction with the displayed environments by verbally expressing associations rather than writing them down. However, in the present study, again, we did not find any evidence for restorative effects of natural environments on mood and performance.

Findings of Study One and Two regarding the valence of associations and the role of the valence of associations in preference ratings were replicated in the present study. First of all, natural environments again rendered more positive associations than urban environments. However, in this study natural environments also rendered more positive associations in the guided-association conditions. Contrary to Study Two, this indicated that even though valence instructions were successful in guiding participants to generate more positive or more negative associations, the valence of associations were still also affected by environment type.

Similar to Study Two, attitude toward natural environments was consistently higher than for urban environments, irrespective of valence instruction. Moreover, again, valence instruction affected preference ratings for urban environments. In Study Two, attitude toward urban environments was significantly higher for the positive-association condition than for the negative-association condition. In Study Three, attitude toward urban environments was not only higher for the positive-association condition, but also for the free-association condition compared to the negative-association condition. A third outcome replicated in this study was that valence of associations partially mediated the effect of environment on preference in the free-association conditions.

In the present study, in addition to effects on preference we also investigated whether the valence of associations influenced restorative potential measured on the dimensions fascination and being away. Natural environments scored higher on both fascination and being away in all valence-instruction conditions. Moreover, similar to attitude, valence instruction affected being away ratings for the urban environments but not the natural environments. Being away was scored higher for urban environments when participants associated freely or were instructed to generate positive associations than when they were instructed to generate negative associations. Mediation analyses revealed that in the free-association conditions, fascination scores were partially mediated by the valence of associations whereas the scores for being away were not.

Even though no restorative effects of natural environments were found in the free-association conditions, we did replicate the effect of Valence instruction on hedonic tone, with a higher increase in hedonic tone for the positive-association conditions than for the negative-association conditions. We did find some indications of restorative effects of nature, as the increase in hedonic tone in the positive-association conditions was higher for natural than for urban environments. Moreover, a difference between the negative and positive-association conditions was only found for the natural environments.

No effects on performance on the SART were found, just as no effects of environment or valence of associations were found on Necker Cube performance in Study Two. However, the retail task appeared to have affected participants differently in the guided-association conditions. This effect was relatively small and only for reaction times (not for bias and sensitivity) and because no effects of environment on SART performance were found in the free-association conditions, we expect this difference did not affect outcomes.

3.5 General Discussion

In this chapter, the role of associations in preference formation as well as restorative effects of nature were investigated in three consecutive studies. Participants were not only allowed to freely associate, but were sometimes also instructed to generate either only negative or positive associations. These conditions -in which association valence was guided- were added to help establish whether the valence of associations can be seen as a psychological pathway through which nature helps restore mood and performance. More specifically, these guided associations should enable establishing a causal direction of the relation between associations and preference and restorative outcomes.

3.5.1 Valence of the associations and preference

Consistently across all three studies, we found that natural environments elicited more positive associations than urban environments. These findings are in line with previous assertions made in restoration theories concerning learned associations with nature (Tuan, 1974; Ulrich, 1983). Furthermore, in Study One a similar outcome was found for weather type, with more positive associations generated for sunny than overcast weather.
In Study Two and Three, valence of associations was experimentally manipulated by instructing participants to generate either only positive or negative associations. In both studies, these manipulations were successful in guiding the valence of associations made. Moreover, in both studies we replicated the finding of Study One that when participants were freely associating, their associations with natural environments were more positive than with urban environments. In Study Three, besides valence instruction, environment type also significantly affected valence ratings of the associations in the guided association conditions. Even though participants were instructed to generate positive or negative associations, associations with nature turned out to be more positive in the positive-association condition than associations with urban environments. However, these findings do not signal a generally more positive associative pattern with natural than urban environments, since the opposite effect was found in the negative condition, with nature generating more negative associations than urban environments. That natural environments scored more negative than urban environments in the negative condition is especially striking as participants also reported suppressing more positive associations in the nature negative condition than in the urban negative condition. Because these effects were not found in Study Two, they could be due to the specific photographs used in Study Three with the natural environments possibly eliciting more extreme associations, both positively and negatively.

In the previous chapter, we consistently found higher preference ratings for natural environments over urban environments. These were replicated in this chapter, with again higher preference ratings for natural scenes as opposed to urban scenes (and higher preference for sunny vs. overcast weather). These findings are also in line with the general consensus in preference research in restoration literature (e.g., Hartig, & Staats, 2006; van den Berg et al., 2003). In all three studies, the valence of (free) associations with natural versus urban environments significantly mediated the effects of environment on preference. Similar effects for weather type as for environment on preference were found in Study One. These findings indicate a significant role of associations in preference formation, but do not indicate the causal direction of this relation, just as we do not know the causal direction of the relation between preference and restorative potential yet (van den Berg et al., 2003). It could be that people prefer natural environments and therefore generate more positive associations. However, the opposite might also hold; people have more positive associations with natural environments and therefore prefer these environments.

The guided-association conditions were added to shed more light on the causal direction of this relation. The results from the valence manipulation rendered mixed results for natural and urban environments. For natural environments, even when participants were instructed to generate negative associations, preference remained unaffected. In other words, even when participants were instructed to think of negative associations with nature they still scored the natural environments equally high on preference as when they were instructed to generate positive associations or to freely associate. Interestingly, preference ratings were affected by valence instruction for the urban environments in both Studies Two and Three, with lower preference scores after generating negative associations compared to preference after generating positive associations. These outcomes seem to suggest that people prefer natural environments and therefore generate more positive associations with nature, whereas a different mechanism might be at play for the urban environments. For urban environments, it seemed that the valence of associations generated did determine preference ratings.

On the other hand, the fact that we guided the associations does not automatically mean that their pre-existing associative patterns were overruled by this manipulation. In spite of the instructions, participants still may have activated these existing associative patterns when making the explicit evaluation. In that case, the negative associations with urban environment might have been closer to the pre-existing associative patterns that participants had regarding urban environments, whereas negative associations with natural environments were less salient. Additional support for this claim could be found by examining how participants rated the association-generation assignment. In Study Two, generating negative associations in the Natural environment was perceived as more difficult than generating positive associations with nature, but also more difficult than generating negative associations with urban environments. Furthermore, in Studies Two and Three, participants reported suppressing the highest number of associations in the nature negative condition. For natural environments, the positive associations appeared to be more salient than negative associations, whereas urban environments elicited both positive and negative associations.

The preference outcomes partly provided further evidence for the relatively stable character of explicit preferences, as also found in previous research (Blair, 2002; Duffy, & Verges, 2010), but only for the natural environments.

3.5.2 Associations and restorative outcomes

In addition to preference, in Studies Two and Three, the influence of the valence of associations on restorative outcomes was investigated as well. Little evidence was found for restorative effects of natural environments. In Study Two, a non-significant trend of environment on the number of Necker Cube reversals was found, with slightly better performance (less reversals) after associating with natural environments than after urban environments, irrespective of valence instruction. In Study Three, a non-significant trend of environment on hedonic tone was found. Contrasts revealed significant differences between the nature positive and urban positive conditions. The lack of consistent and significant effects of nature on recovery could be due to an additional cognitive load posed on participants due to the association-generation assignment. Generating associations could also have lowered restorative outcomes by distracting attention from the displayed environments in Study Two, where participants wrote down their associations and were therefore possibly less aware of the content of the photos. In Study Three, participants were asked to verbally express their associations, which some participants might have experienced as slightly awkward, thereby inducing some stress which may have diminished any possible restorative effects. No conclusive outcomes were found for the role of associations in restorative potential due to the lack of restorative effects found for nature.

Consistent effects were found for valence instruction. Both in Study Two and Three, we found that valence instruction affected recovery of hedonic tone, with higher hedonic tone in the positive-association conditions. In Study Two this effect occurred irrespective of whether participants were associating with natural or urban environments. However, in Study Three environment type also affected recovery of hedonic tone with a higher increase in hedonic tone for the nature positive condition than for the urban positive condition. Thus, it appears that thinking of positive associations with environments can recover mood. Some preliminary evidence showed that thinking positive associations with nature was more restorative than with urban environments. However, a superior effect of natural environments was only found when participants were instructed to think of positive associations with the displayed environments, but not in the free association condition. These results are in line with the finding of Duvall (2010) showing that cognitive engagement strategies can enhance restorative experiences of nature. Thinking of the positive aspects of nature affected it’s restorative potential. This raises the question of what exactly the valence instruction manipulation induced, did it really just guide the valence of associations or did it alter the way people thought about the displayed environments?

3.5.3 Guided associations or thought experiment?

In this chapter, we discussed the effect of –what we labelled- guided associations. These associations obviously did not represent 'true' associations as no natural flow of association formation was allowed. The associations that people generated in these conditions may not always have represented the associations that participants would have formed when allowed to associate freely. Therefore, this manipulation could also be considered some sort of 'thought experiment', guiding the cognitive appraisal of the displayed environments.

In a therapeutic context, thinking of stressful or anxious situations (also known as in sensu therapy) has been used to induce anxious mental states, for instance in cognitive-behavioral therapy for anxiety disorders (see e.g., Hoyer, Beesdo, Gloster, Runge, Höfler, & Becker, 2009). Likewise, we found that thinking positive thoughts with natural and urban environments also helped improve hedonic feelings. These findings are in line with positive psychology, where positive emotions are postulated to overcome negative emotions and stressors (Fredrickson, & Levenson, 1998; Fredrickson et al., 2000) as well as to help built resources to increase stress-resiliency (Broaden-and-Built Theory; Fredrickson, & Joiner, 2002; Fredrickson, 2004).

3.5.4 Conclusion

In this chapter we saw that natural environments elicited more positive associations than urban environments. The valence of associations mediated the effect of environment on environmental preference. Little evidence was found for restorative effects of nature on mood or cognitive performance. However, when participants were instructed to generate positive associations, they also reported feeling happier after the association-generation phase and in one study the effects of valence instruction on hedonic tone appeared more pronounced for natural environments. Together, these findings provide preliminary evidence for the importance of associations in the restorative effects of natural as opposed to urban environments. Nature generally elicits more positive associations. In turn, having happy thoughts -with nature- proved to be restorative. In the next chapter, we will investigate whether the same holds for daylight versus artificial light.

Chapter 4

Enlightened thoughts.
Are associations with daylight versus electric light related to preference and restoration?[1]

bakvið skýjaból vaknar sól úr dvala
svalar sér við kalda dropa regnsins
leikur sér við heita loga eldsins
býr til regnboga
(Sigur rós - hafssól (the sun's sea))

behind a vessel of clouds, the sun wakes up
refreshes itself with cold raindrops
plays with the hot flames of fire
creates a rainbow

[1] This chapter is based on: Beute, F. & de Kort, Y.A.W. (in preparation). Enlightened thoughts: Associations with daylight versus electric light and preference and restoration.

Abstract. The valence of associations with natural as opposed to urban environments proved to influence preference formation as well as some restorative outcomes in the previous chapter. In this chapter, we investigated associations with daylight versus electric light. Associations with daylight and electric light were compared on valence, but also on health, energy, and relaxation ratings. Furthermore, the influence of these association ratings on preference formation and restorative outcomes was investigated. No evidence was found for restorative effects of associating with daylight as opposed to electric light was found. And even though daylight evoked significantly more positive associations on all four dimensions (valence, health, energy, and relaxation) and preference was higher for daylight than for electric light, the effect of light source on preference was not mediated by the associations. Thus, contrary to the findings for natural versus urban environments in the previous chapter, associations with light could not explain higher preference ratings. Preliminarily, this indicates that beneficial effects of daylight run through different (psychological) pathways than beneficial effects of nature.

4.1 Introduction

Light evokes many associations and connotations. We use light versus dark as a metaphor for the good versus bad, we all know the phrase ‘always look on the bright side of life’ and speak of a bright or even brilliant person if we believe someone is intelligent. Not only are these phrases used in our everyday language, research has shown that associative patterns with light versus dark are deeply embedded in our cognitive system (see e.g., Lakens et al., 2012; Meier et al., 2004; 2007; Okubo, & Ishikawa, 2001). In this chapter, we investigated whether the source of light (i.e., daylight versus electric light) also affects the type and valence of associations evoked. Similar to the previous chapter, we investigated whether associations with daylight differed from associations with electric light and how these associations were related to both preference formation and restorative outcomes.

4.1.1 Light; associations, preference, and beliefs

People generally associate bright with positive and dark with negative. In a series of studies, Meier and colleagues (2007) found that words presented in a bright versus dark font were automatically associated with positive versus negative valence. This association was found to take place in the right hemisphere of the brain (Okubo, & Ishikawa, 2011). Other research has indicated that these associations between bright and good and dark and bad depend on the context in which they are presented (Lakens et al., 2012). More specifically, a contrast between bright and dark was needed to find these associative patterns with good versus bad.

In Chapter Two, we saw that people generally prefer sunny over overcast weather, and light over dark pictures. In Chapter Three, we also saw that sunny weather evokes more positive associations than overcast weather and that the valence of associations mediated the difference in preference between sunny and overcast weather. Research has also indicated that people generally prefer daylight over electric light, for instance in the workplace (Markus, 1967). In Chapter One, we already mentioned that more positive beliefs regarding effects of daylight versus electric light have been reported (Veitch, & Gifford, 1996; Veitch et al., 1993; Wells, 1965). These beliefs could be due to a naturalness bias (Haans, & Olijve, 2012), with natural light preferred over electric light because it is more natural. The more this natural light was altered by for instance reflective surfaces, the more perceived naturalness declined.

4.1.2 Associating daylight with restorative outcomes

Not only have preferences and beliefs with light been investigated, one study also investigated whether thinking of bright light exposure can be restorative (Richter et al., 1992). When investigating possible placebo effects of light therapy for Seasonal Affective Disorder, they tested whether patients who imagined receiving bright light while under hypnosis also showed remission of their depressive complaints. Indeed, they found that -on the short term- imagining exposure to bright light improved mood and lowered depression ratings.

Beliefs regarding restorative effects of daylight go back a long time. In the early 20th century, people acknowledged the importance of daylight exposure for physical health (e.g., in treating tuberculosis), resulting in the foundation of many sanatoriums.

4.1.3 Rationale

Beneficial effects of daylight are often attributed to biological mechanisms, but as the study by Richter and colleagues indicates, psychological mechanisms may be at play as well. The question is, do the psychological benefits of daylight run via the positive associations that people have with it?

Two studies were conducted to investigate whether associations with daylight versus electric light underlie beneficial effects of daylight. Study One tested the assumption that daylight produces more positive associations than electric light and whether associations are related to preference ratings. Study Two subsequently tested whether the valence of associations affected restorative outcomes. As in the previous chapter, we studied differences in association ratings in both a within and between-subjects study as associations have been found dependent on the context in which stimuli are presented (Gawronski & Bodenhausen, 2006).

Not only did we ask participants to rate associations on valence, we also asked them to rate the associations on health and two other mood dimensions (relaxation and energy). We added these three rating scales to be able to form a more complete picture of the nature of the associations and we based these rating scales on findings concerning the beliefs that people generally have with daylight and electric light (e.g., Haans, 2014; Veitch, & Gifford, 1996; Veitch et al., 1993). A challenge with light is that even though light is the main medium through which images are formed and perceived, it is often not consciously perceived in images. Therefore, in Study One we also investigated the best way of evoking associations with daylight versus electric light.

4.2 Study One

In Study One, the aim was to establish whether daylight evokes different associations than electric light. Whereas manipulating environment type with photos (as was done for natural versus urban environments) is easily achieved, eliciting daylight or electric light as the core concept in photos is more difficult. In this study, we included three different methods for the association generation phase.

We explicitly chose not to use real light exposure for two reasons. First of all, exposure to daylight automatically induces a possible confound due to differences in light intensity and colour temperature throughout the day and between different days. Second, in real-time light exposure the number of different light settings that can be presented is limited. We wanted participants to generate multiple associations and therefore needed to present more than one semantic differential to generate associations with. For these reasons we chose three different ways to evoke associations. The first method goes back to one of the more basic ways to evoke associative pathways, using words related to light. This approach has already been used extensively in earlier research concerning associations and meaning of concepts (e.g., see Osgood, 1957). We also tested effects of images with daylight or electric light, with two different types of instructions for the association generation (Implicit and Explicit) to test which instruction evoked most light related associations. To control for possible confounds due to differences in the content of the images, we used a virtual office environment, with two different types of instructions. In the implicit condition, participants were instructed to generate associations without any further specification, whereas in the explicit condition participants were specifically asked to generate associations with the light setting. Thus, a secondary aim of this study was to investigate which method worked best in generating light-related associations.

We hypothesized that daylight would generate more positive, energetic, relaxed, and healthy associations than electric light. We further expected that daylight would render more positive preference ratings and perceived restorativeness scores (fascination and being away) and that this beneficial effect of daylight on preference and perceived restorativeness would be mediated by the valence of association. We did not expect any differences between the three different methods for generating associations other than more pronounced light-related associations for the Text and Explicit Image conditions.

4.2.1 Method

4.2.1.1 Design

Associations with daylight versus electric light were investigated using a survey-based questionnaire. A 3 x 2 mixed design was employed, with Association Generation Method (Text vs. Image Explicit vs. Image Implicit) as between-subjects variable and Light source (daylight vs. electric light) as within-subjects variable.

4.2.1.2 Respondents & procedure

In total, 67 respondents completed the survey (30 females). Their age ranged between 18 and 52, with a mean of 25.24 (*SD* = 4.19). They were contacted by email (personal contacts of researcher) and through social media. The place of residence of the majority of respondents was the Netherlands (83.6 %). However, respondents living in different countries responded as well (i.e., Germany, Ireland, Russia, Italy, UK, Sweden, Spain, Finland, India, China, and Estonia)[2]. Filling in the survey was on a voluntary basis; respondents received no compensation.

4.2.1.3 Manipulation – Daylight versus Electric light

Three different methods were used to evoke associations with daylight versus electric light. Two methods included images of virtual office environments (Image environments). Using a virtual environment enabled us to use the same environment for daylight as for electric light, with only light source differing between the pictures. The virtual office environment, light sources, and light patterns were created using DIALUX®, a software package designed to simulate light. The images in the daylight and electric light category were matched in brightness. Two different environments were created and they were both presented with daylight and with electric light, see Figure 4.1.

The difference between the two Image methods were the association instructions given to the respondents, not the images. In the Image Implicit condition, respondents were asked to generate associations with the images, whereas in the Image Explicit condition respondents were specifically instructed to generate associations with the light setting in the images.
In the Text condition, respondents were asked to generate associations with words. The following words were used; ‘sunlight’ and ‘daylight’ for daylight; ‘lamp’ and ‘electric light’ for electric light.

[2] We ran analyses with only residents from the Netherlands and with residents from all other countries included. No differential effects were found. The reported results include all participants (residing in the Netherlands and in other countries)

Figure 4.1 Virtual environments used in the daylight (left) and electric light (right) conditions.

4.2.1.4 Manipulation – Association generation

Similar instructions for the generation of associations were used as in Study One of the previous chapter (Section 3.2.1.5). Respondents could enter the association below the image or text displayed on the screen. For each text or image, respondents could generate between three and five associations. Table 4.1 displays some example associations for each condition and light source.

4.2.1.5 Measures

Association generation and ratings. Respondents were asked to rate their associations on four dimensions; valence, energy, relaxation, and health on a 7-point scale ranging from 1 (very [positive, energetic, calm, healthy]) to 7 (very [negative, tired, tense, unhealthy]). As not all associations could be related to energy, relaxation, and health, for these items an option 'not applicable' was added. For analyses, the items were all reverse coded so that higher scores represented more positive ratings.

Preference. Preference was measured on one dimension; attitude. See Section 2.2.1.4 for a description. Reliability of the attitude measure was good with α = .98.

Table 4.1 Example associations per condition and light source.

	Daylight	Electric Light
Image Implicit	*'Open' 'Clear' 'Workshop' 'Sun' 'Good work environment' 'Fun' 'Daylight' 'Someone important may work here' 'Computer' 'Outside'*	*'Cellar' 'Locked up' 'Meeting' 'Tree' 'Silence and perfection' 'Suicide' 'Claustrophobic area' 'Future murder' 'Friends' 'Soft shadows'*
Image Explicit	*'Day' 'Sun' 'Bright and sunny' 'Teacher' 'Not wanting to be inside' 'Sweating' 'Relax' 'Fresh' 'Lamp, for when it's dark' 'Not enough light'*	*'Classroom' 'Unhealthy office' 'Teamwork' 'Soft' 'Quite bright' 'Feels like prison – no windows' 'Money' 'Unhealthy life' 'Symmetry'*
Words	*'Sunshine' 'Vitamin D' 'No sleep' 'Need it' 'Yellow' 'Happy' 'Vampire' 'Travelling' 'Morning' 'Blue sky' 'Football' 'Freedom' 'Sunglasses'*	*'Blue' 'LED' Street lighting' 'Philips' 'Not sharp' 'Cold light' 'Studio for photography' 'Studying' 'Evening' 'Switch' 'Night table'*

Perceived restorativeness. Items from two subscales (fascination and being away) of the Perceived Restorativeness Scale (Hartig et al., 1997) were administered. For fascination, the following items were administered: *'This setting is fascinating', 'My attention is drawn to many interesting things',* and *'I want to get to know this place better'.* For being away, the following items were used: *'Spending time here gives me a break from my day-to-day routine', 'It is a place to get away from it all', Being here helps me relax my focus on getting things done',* and *'Coming here helps me to get relief from unwanted demands on my attention'*. Respondents were instructed to answer these questions for each light setting on a scale of 1 (not at all) to 7 (to a very higher degree). Cronbach's alpha for the fascination scale was α = .86 and for being away α = .92.

4.2.1.7 Data analysis

For each light source category, the mean scores were calculated for association ratings, preference, and perceived restorativeness. A series of mixed repeated measures ANOVAs were run with light source as a within-subjects variable and Association Generation Method as between subjects-variable.

4.2.2 Results

Our main interest concerned the effects of light source on the valence and nature of associations generated. Therefore, in the text we will mainly report on effects of light source. Association Generation Method was entered as a between-subjects variable in the analyses and outcomes will be included in the tables. However, results of Association Generation Method will be reported if differences in the effect of the Light source manipulation on any of the outcome variables are found.

Association generation and valence, health, energy, and relaxation values

On average, respondents generated a total of 15.69 (*SD* = 3.01) associations for the four stimuli. The number of associations generated ranged between 12 and 20 (the minimum amount required and maximum amount allowed). The same number of associations was generated for daylight as for electric light and the number of associations was also not affected by Association Generation Method (*F* < 2.3, *p* > .106).

Respondents rated the associations on four dimensions; valence, health, energy, and relaxation. Results for these ratings can be found in Table 4.2. For all dimensions, daylight scored significantly more positive than electric light, confirming our hypotheses. In general, more positive scores were obtained in the Text condition than in the Image conditions.

Preference and perceived restoration
Preference was measured on one dimension; attitude. In line with our expectations, Light source significantly affected attitude ($F(1,64) = 191.5$, $p < .001$, $\eta_p^2 = .75$) with higher (more positive) attitude levels for daylight ($M = 5.31$, $SE = .13$) than for electric light ($M = 2.77$, $SE = .12$).

In all conditions, respondents rated the texts or images on fascination and being away. Daylight scored significantly higher on being away and fascination than electric light, see Table 4.3. Thereby also confirming our hypothesis concerning the higher perceived restorativeness of daylight versus electric light. For being away, a significant interaction of Light source * Condition was found. For electric light, no difference between the three conditions was found, whereas for daylight higher scores for being away were reported for the text than the two image conditions.

Table 4.2 F-values, means, and standard errors for the association ratings on valence, health, energy, and relaxation.

		Image Implicit	Image Explicit	Text	Light source		Condition		Light source * Condition	
		M (SE)	M (SE)	M (SE)	F (1,65)	η_p^2	F (2,65)	η_p^2	F (2,65)	η_p^2
Valence	Daylight	4.88^{a,d} (.18)	4.80^{b,e} (.22)	6.07^{c,d,e} (.18)	79.6**	.55	20.1**	.38	.3	-
	Electric	3.29^{a,f} (.21)	3.51^{b,g} (.26)	4.46^{c,f,g} (.21)						
Health	Daylight	4.91^{a,d} (.18)	4.80^{b,e} (.22)	5.53^{c,d,e} (.19)	66.9**	.51	5.4*	.14	.9	-
	Electric	3.54^{a} (.71)	2.46^{b} (.26)	3.98^{c} (.21)						
Energy	Daylight	5.03^{a,d} (.18)	4.78^{b,e} (.23)	5.69^{c,d,e} (.18)	92.2**	.58	9.6**	.23	.4	-
	Electric	3.28^{a,f} (.21)	3.37^{b,g} (.26)	4.15^{c,f,g} (.21)						
Relax	Daylight	4.55^{a} (.19)	4.50^{b} (.23)	4.93^{c} (.19)	41.6**	.39	9.4**	.22	.2	-
	Electric	3.37^{a,d} (.15)	3.38^{b,e} (.19)	4.31^{c,d,e} (.16)						

Means with similar superscript letters are significantly different

Table 4.3 F-values, means, and standard errors for fascination and being away scores

		Image Implicit	Image Explicit	Text	Light source		Condition		Light source * Condition	
		M (SE)	M (SE)	M (SE)	F (1,65)	η_p^2	F (2,65)	η_p^2	F (2,65)	η_p^2
Being away	D	4.22[a,d] (.10)	4.12[b,e] (.25)	5.21[c,d,e] (.20)	89.0**	.58	3.7*	.10	4.3*	.12
	E	2.89[a] (.20)	2.89[b] (.26)	2.91[c] (.21)						
Fascination	D	3.99[a,d] (.23)	3.67[b,d] (.30)	5.13[c,d,e] (.24)	106.8**	.63	13.5**	.30	1.4	-
	E	2.16[a,f] (.17)	2.31[b,g] (.30)	3.03[c,f,g] (.17)						

Means with the same superscript letter are significantly different. D = Daylight, E = Electric light
** p < .05, ** p < .001*

Is the effect of light source on attitude mediated by valence, health, energy, or relaxation ratings of the associations?
Mediation analyses were performed for the mediation of the effects of light source on attitude by the valence of associations as well as by health, energy, and tension ratings. Similar to Study One of Chapter Three, a within-subjects design was employed. Therefore, mediation analyses were performed using hierarchical linear modelling, similar to Section 3.2.2.3. Figure 4.2 displays a graphical overview of these mediation analyses.

Counter to our expectations, valence, health, energy, and tension ratings did not significantly mediate the effect of light source on attitude, see Table 4.4.

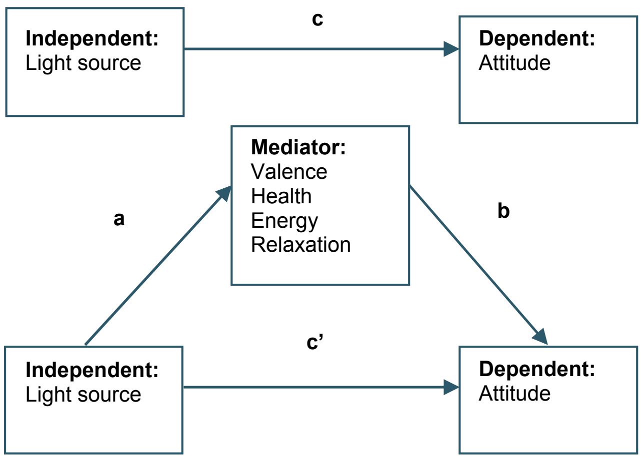


Figure 4.2 Graphical overview of the mediation analyses

Table 4.4 Mediation of the effect of light source on attitude by valence, health, energy, and tension ratings.

Dependent Mediator	a (SE)	b (SE)	c (SE)	c' (SE)	ab Indirect effect (SE)	95% Confidence Interval Indirect effect
Valence	-1.54** (.16)	-.31** (.04)	2.56** (.18)	2.54** (.21)	.02 (.06)	.0002 - .04
Health	-1.43** (.16)	-.32** (.05)	2.56** (.18)	2.55** (.20)	.03 (.009)	.01 - .05
Energy	-1.57** (.16)	-.34** (.05)	2.56** (.18)	2.57** (.20)	-.07 (.01)	-.09 - -.04
Relaxation	-1.00** (.14)	-.25** (.04)	2.56** (.18)	2.55** (.20)	.04 (.002)	.03 - .06

** p < .05, ** p < .001*

4.2.3 Discussion

In this study, we investigated whether daylight generates more positive associations than electric light. In addition to valence, associations were also rated on health, energy, and relaxation. Associations with daylight were rated as more positive, healthy, energizing, and relaxing than associations with electric light. Higher preference ratings were found for daylight than for artificial light. Daylight was also scored higher on two dimensions of perceived restorativeness: being away and fascination.

The outcomes for the valence of associations are similar to the findings for natural versus urban environments, with more positive associations with both nature and daylight than with respectively urban environments and electric light. However, whereas the valence of associations mediated the effect of environment type on preference this effect was not established for light source. In other words, the valence of associations did not significantly mediate the effect of light source on preference, and neither did health, energy, or relaxation ratings.

Three different types of association-generation methods were used to investigate the best way to elicit associations with daylight and electric light. In all three conditions, similar results were found for association ratings, preference, and perceived restorativeness. However, in the text condition more light related associations were generated, whereas in both Image manipulations the associations were sometimes more directed toward the displayed content than about light. Therefore, we decided to proceed with the word manipulation in Study Two. Similar to Studies Two and Three of the previous chapter, in this study we not only investigated effects of light source on association ratings, but also on restorative potential.

4.3 Study Two

In Study Two the aim was to replicate findings regarding associations with daylight versus electric light and their role in preference formation in a between-subject design. Second, we also wanted to investigate the role of associations in potential restorative effects of daylight. In the previous chapter, guided association conditions were run in which respondents were instructed to generate only positive or negative associations. These conditions were added to the free association conditions to study the causal direction of the relation between valence of associations and preference and restorative outcomes. However, in Study One, no evidence was found for mediation of the effect of light source on preference through the valence of associations (or any of the other association ratings). For this reason, no guided association conditions were run in Study Two, only free association conditions.

Words for daylight and electric light generated the most light-relevant associations in Study One. Therefore, we decided to let participants generate associations with words related to either daylight or electric light. Restorative outcomes were investigated in an experimental set-up very similar to Study Three of the previous chapter.

We expected to replicate findings of Study One regarding the effect of light source on association ratings, preference, and perceived restorative characteristics with more positive outcomes for daylight as compared to electric light. In addition, if daylight elicits more positive associations we expected participants associating with daylight to recover better from the initial stressor task than participants associating with electric light. Recovery was measured in terms of mood and performance on the SART task.

4.3.1 Method

4.3.1.1 Design
A between-subjects design was run with Light source (Daylight vs. Electric light) as between subjects variable.

4.3.1.2 Participants
In total, 64 participants (32 females) participated in the study, their age ranged between 18 and 35, with a mean of 22.41 (*SD* = 3.44). They were recruited through the JFS database. The majority of participants were students from the Eindhoven University of Technology or the Fontys Higher Education Institution. The duration of the experiment was approximately 45 minutes and participants received €7.50 compensation for their participation.

4.3.1.3 Procedure
After signing the informed consent form, participants took place behind a desk with a laptop. They first filled in a baseline mood questionnaire (baseline; t_0), followed by the baseline measure of the Sustained Attention to Response Task (SART1). After finishing the baseline

measures, the stress induction task (Retail task) was started. After this task, participants reported their mood for the second time (post induction; t_1). Then, after reading the instructions, the words were displayed on the screen and participants started generating their associations. Afterwards, participants filled in their mood for the third time (post manipulation; t_2), followed by the SART task (SART2). After the SART task, participants reported their mood for the fourth and last time (post SART; t_4). Then, participants reported how difficult it had been to generate the associations and rated the associations on valence, relaxation, energy, and health. Subsequently, participants reported the perceived restorativeness and beliefs for each light setting after which the experiment was finished and participants were thanked and paid for their effort.

4.3.1.4 Manipulation – Daylight vs Electric light

In each condition, participants were presented with three words. For daylight these words were: Daylight, Sun, and Sunlight. For electric light these words were: Electric light, Lamp, and Artificial light. The words were presented in random order on the screen.

4.3.1.5 Manipulation – Association generation

A similar instruction was used as in Study One of Chapter 3, see Section 3.2.1.5. The associations could be written in text fields on the screen, beneath the word. Participants were instructed to generate at least three associations and a maximum of five associations were allowed. Table 4.5 displays some examples of the associations that participants generated in each condition.

4.3.1.6 Induction – Retail task

The retail task was used to induce stress. The same retail task was used as in Chapter 3, see Section 3.4.1.6 for a description.

4.3.1.7 Measures

Association generation & ratings. Participants received the same instruction for generating the associations as described in Section 3.2.1.5. Associations were again rated on valence, energizing, relaxation, and health. See Study One for a detailed description (Section 4.2.1.5).

Table 4.5 Examples of associations in the Daylight and Electric light conditions.

Daylight	*'Sun' 'Night' 'Health' 'Warm' 'Vitamin' 'Moonlight' 'Firefly' 'Nature' 'Happy' 'Beach' 'Sports' 'Outside' 'Sunburn' 'Getting up early' 'Good to study with' 'Smell' 'Relax' 'Grass' 'Greenhouse' 'Window' 'Getting a tan' 'Yellow' 'No electric light' 'Office' 'Holiday' 'Being awake' 'Photo camera'*
Electric Light	*'Hospital' 'IKEA' 'Night' 'Philips' 'Yellow' 'Car' 'Bright' 'Good learn environment' 'Evening on the street' 'Outside' 'Room' 'Technology TU/e' 'Lightning' 'Spanish course' 'Living room' Not cozy' 'Cozy' 'Light bulb' "Photography' 'Plants thinks it is always daytime' 'Screen' 'Working at night'*

Preference. Preference was measured on one dimension; attitude. See Section 2.2.1.4 for a description. Reliability of attitude was good with $\alpha = .95$.

Perceived restorativeness. Perceived restorativeness was measured on two dimensions; fascination and being away. See Section 3.4.1.7 for a description. Both scales had good internal reliability (fascination: $\alpha = .89$; being away: $\alpha = .90$).

Mood. Mood was measured with Visual Analogue Scales, administered at four different times; at baseline (t_0), after the stress induction (t_1), after the association generation phase (t_2), and after the second SART task (t_4). These scales measured three dimensions; tension, energy, and hedonic tone. Participants were asked to indicate on a 100mm scale how they felt, ranging from tense to calm (tension), sleepy to energetic (energy), and depressed to happy (hedonic tone). VAS-scales are an easy and fast way to assess mood in participants under time constraints (Monk, 1989).

Dependent task – Sustained Attention to Response Task (SART). The same SART was used as in Chapter 3, see Section 3.4.1.7 for a description. However, in this experiment, the SART was administered twice instead of three times; at baseline (t_0) and after the association generation (t_1).

4.3.1.8 Data analysis

For mood and performance, residualized change scores were calculated between each time point, see Section 3.3.1.10 for the rationale. Preference, valence of associations, and perceived restorativeness scores were calculated by taking the mean of the three words. A series of ANOVAs were run with Light source as independent variable and change scores (mood, performance), preference, perceived restorativeness, and association ratings as dependent variables. For SART reaction times, raw scores deviating more than 2 standard deviations from the group mean (3 standard deviations for bias and sensitivity) were considered outliers and removed from the analysis. SART bias and sensitivity scores were not normally distributed, therefore effects were tested using Mann-Whitney tests (non-parametric tests).

4.3.2 Results

We will first discuss effects of light source on the association ratings, preference and perceived restorativeness. In the second part of this section, we will discuss the recovery outcomes on mood and SART performance. Mediation analyses were further performed to investigate whether association ratings mediated preference and ratings as well as the restoration outcomes.

4.3.2.1 Associations, preference, and perceived restorativeness

Association generation & Ratings

On average, participants generated a total of 12.01 (SD = 1.79) associations. No difference in the number of associations was found between the Daylight and Electric light conditions ($F(1,62) <.1$, $p > .834$). Furthermore, no differences in difficulty or effort were reported ($F <1.1$, $p > .306$).

In line with the outcomes of Study One, significant differences were found between Daylight and Electric light on valence of the associations ($F\ (1,62) = 39.4$, $p < .001$, $\eta_p^2 = .39$), as well as on ratings concerning health ($F\ (1,62) = 32.7$, $p < .001$, $\eta_p^2 = .35$), energy ($F\ (1,62) = 4.0$, $p =.049$, $\eta_p^2 = .60$), and relaxation ($F\ (1,62) = 16.3$, $p < .001$, $\eta_p^2 = .22$). More positive associations were generated with daylight than with electric light. Moreover, associations with daylight were rated higher on health, energy, and relaxation than associations with electric light, see Table 4.6 for means and standard errors.

Three analyses were run to investigate the effect of Light source on attitude, fascination, and being away. These analyses revealed a significant main effect of Light source on attitude ($F(1,62) = 34.8$, $p < .001$, $\eta_p^2 = .36$), fascination ($F(1,62) = 6.1$, $p = .016$, $\eta_p^2 = .09$), and being away ($F(1,62) = 12.6$, $p = .001$, $\eta_p^2 = .17$). Corroborating our hypotheses, daylight scored better on attitude, fascination, and being away than electric light, see Table 4.7 for means and standard errors.

Table 4.6 Means and standard errors for the association generation variables and association ratings.

	Number Mean (SE)	Effort Mean (SE)	Difficulty Mean (SE)	Valence Mean (SE)	Health Mean (SE)	Energy Mean (SE)	Relax Mean (SE)
Daylight	11.97 (.31)	4.06 (.26)	5.18 (.28)	5.57 (.13)[a]	5.39 (.12)[b]	5.11 (.16)[c]	5.31 (.11)[d]
Electric light	12.06 (.32)	4.26 (.19)	4.77 (.28)	4.52 (.11)[a]	4.15 (.16)[b]	4.68 (.14)[c]	4.49 (.17)[d]

Means in columns with the same superscript letter are significantly different

Preference and perceived restorativeness

Table 4.7 Means and standard errors for preference (attitude) and perceived restorativeness (fascination and being away).

	Attitude Mean (SE)	Fascination Mean (SE)	Being away Mean (SE)
Daylight	5.40 (.19)[a]	4.26 (.18)[b]	4.52 (.18)[c]
Electric light	4.00 (.14)[a]	3.69 (.14)[b]	3.70 (.15)[c]

Means in columns with the same superscript letter are significantly different

Is the effect of light source on attitude and perceived restorativeness mediated by the valence, health, energy, or relaxation ratings of the associations?
In order to calculate mediation, a significant *b* path is necessary. In other words, the proposed mediator must significantly affect the outcome variable. As can be seen in Table 4.8, the majority of the proposed mediators did not significantly affect the outcome variables (i.e., the *b* path remained non-significant). Only energy ratings significantly affected being away. However, mediation analyses revealed no significant mediation of Light source on being away by energy ratings (Z = 1.48, p = .138). Valence of associations, thus, did not mediate the effect of light source on preference and perceived restorative potential. These outcomes are counter to our initial hypotheses, but in line with outcomes of Study One.

4.3.2.2 Restorative outcomes

Mood
One baseline difference was found for energy (F (1,62) = 6.2, p = .015, η_p^2 = .09), with higher reported baseline energy for participants in the Electric light than in the Daylight condition, see Table 4.9. No baseline differences were found for hedonic tone or tension (F < .9, p > .338).

No significant effects of Light source were found on any of the mood dimensions after the association generation phase, nor after the second SART task (F < 1.0, p > .320), see Table 4.9 for means and standard errors. Thus, out hypothesis regarding the beneficial effects of associating with daylight on mood was not confirmed.

Table 4.8 The a, b, and c paths for mediation analyses of Light source on preference and perceived restorativeness.

Outcome Variable	Mediator	a path (SE)	b path (SE)	c path (SE)
Attitude	Valence	-1.05** (.17)	-.07 (.18)	-1.40** (.24)
	Health	-1.14** (.20)	-.06 (.16)	1.42** (.24)
	Energy	-.43* (.21)	-.15 (.14)	-1.45** (.23)
	Relaxation	-.82** (.20)	.14 (.15)	-1.27** (.24)
Fascination	Valence	-1.05** (.17)	-.11 (.18)	-.58* (.23)
	Health	-1.14** (.20)	-.02 (.15)	-.57* (.24)
	Energy	-.43* (.21)	-.21 (.14)	-.64* (.23)
	Relaxation	-.82** (.20)	-.11 (.15)	-.65* (.24)
Being away	Valence	-1.05** (.17)	-.13 (.18)	-.82** (.23)
	Health	-1.14** (.20)	-.02 (.15)	-.82** (.24)
	Energy	-.43* (.21)	-.29* (.14)	-.86** (.23)
	Relaxation	-.82** (.20)	-.04 (.15)	-.86* (.27)

* p < .05, ** p < .001

Table 4.9 Means and standard errors for tension, hedonic tone, and energy.

	Tension Mean (SE)				Hedonic tone Mean (SE)				Energy Mean (SE)			
	t_0	t_1	t_3	t_4	t_0	t_1	t_3	t_4	t_0	t_1	t_3	t_4
Daylight	2.58 (.25)	6,26 (.32)	4.31 (.22)	4.51 (.30)	5.47 (.41)	4.53 (.30)	5.02 (.32)	4.32 (.34)	7.07[a] (.32)	5.01 (.21)	5.63 (.21)	5,43 (.26)
Electric light	2.65 (.23)	6.20 (.28)	4.52 (.23)	5.00 (.23)	6.72 (.27)	4.33 (.36)	5.18 (.27)	4.72 (.39)	7.48[a] (.29)	5.00 (.35)	5.87 (.28)	5.92 (.32)

Means in one row with the same superscript letter are significantly different

Table 4.10 Medians for SART bias and sensitivity scores, and means and standard errors for reaction times.

	Bias Median		Sensitivity Median		Reaction Times Mean (SE)	
	t_0	t_1	t_0	t_1	t_0	t_1[1]
Daylight	.59	.64	2.63	2.94	312.77 (7.31)	299.62 (8.21)
Electric light	.53	.52	2.12	2.49	307.15 (6.48)	310.72 (11.83)

[1]*The mean reported for electric light includes the outlier*

SART performance

SART bias and sensitivity outcomes deviated from the normal distribution. Therefore, non-parametric tests were used to investigate effects of Light source on these two outcome variables. No baseline differences were found for bias or sensitivity, neither did we find any differences after the association generation phase (U < 441.5, p > .461). No significant baseline difference in reaction time was found either (F (1,61) = .3, p = .570). A significant effect was found of Light source on reaction time (F (1,61) = 4.2, p = .045, η_p^2 = .06), with a decrease in reaction time after generating associations with daylight compared to generating associations with electric light. However, there was one outlier in the electric light condition deviating substantially from the mean (> 4 SD). With this outlier removed, the effect of Light source on reaction time became non-significant (F (1,60) = 2.6, p = .111). Taken together, these results disconfirm our hypothesis concerning the restorative potential of associating with daylight on performance. See Table 4.10 for medians, means, and standard errors.

4.3.3 Discussion

In this study, the aim was twofold. First, we wanted to replicate findings of Study One regarding the ratings of associations with daylight versus electric light and their role in preference formation. Second, we wanted to test whether generating associations with daylight versus electric light could be restorative.

Associations with daylight scored higher on valence, energy, relaxation, and health than associations with electric light. Daylight also scored higher on preference as well as on perceived restorativeness than electric light but the associations did not mediate the effect of light source on preference or perceived restorativeness. Thus, all findings of Study One were replicated in this study, using a between-subjects design.

Our hypotheses concerning potential restorative effects of associating with daylight were not confirmed. No evidence was found for increased restoration in the daylight conditions. For performance, SART performance after the second SART task was lower compared to baseline SART performance in the daylight condition than in the electric light condition. However, this outcome was highly affected by one outlier and with this outlier deleted, the effect of Light source on reaction times turned non-significant. Therefore, no conclusive evidence was found for restorative effects of associating with daylight as opposed to electric light on performance.

4.4 General Discussion

The main research question in this chapter was whether people generate more positive associations with daylight and how this is related to preference formation and restorative outcomes. We used similar experimental paradigms as in the previous chapter, in which the same question was answered for natural versus urban environments. In this chapter, we found that some results were in line with what we found for natural environments, but we also found differential effects.

4.4.1 Association ratings and preference

In both studies, we consistently found that more positive associations were generated for daylight than for electric light. We found these differences in valence in both a within-subjects design (contrasting daylight with electric light) and in a between-subjects design. In earlier research investigating associations with bright versus dark these valence differences were only found in within-subjects designs when bright and dark were explicitly contrasted (Lakens et al., 2012; Meier et al., 2007; Okubo, & Ishikawa, 2011). In addition to valence, associations evoked by daylight scored higher on health, energy, and relaxation than those evoked for electric light. These results are in line with previous research reporting more positive beliefs for the effects of daylight on mood and health than for electric light (Veitch, & Gifford, 1996; Veitch et al., 1993).

Daylight also scored higher on preference and two dimensions of perceived restorativeness -fascination and being away - in both studies. People, thus, clearly preferred daylight settings to electric light settings. Indeed, previous research has already indicated that people generally prefer rooms with a window (e.g., Collins, 1975; Markus, 1967). Besides preference, participants also rated settings with daylight significantly higher on fascination and feelings of being away compared to settings with electric light. As introduced in Chapter One, these two dimensions are important building bricks for restoration theory. More specifically, according to ART, fascination and being away are two out of four dimensions that are important requisites for an environment to be restorative. Thus, settings with daylight comply more with at least two dimensions necessary to create restorative environments.

4.4.2 Associations and restorative outcomes

Restorative outcomes of generating associations with daylight versus electric light were investigated in Study Two. No evidence for restorative effects of daylight on mood and performance were found. However, in this study we used words related to daylight and not actual daylight exposure which may have rendered less pronounced restorative effects than exposure to actual daylight. In Chapter 6 we will investigate effects of exposure to real daylight versus electric light. On the other hand, Richter and colleagues (1992) found that thinking of bright light exposure improved mood and reduced depressive symptoms. However, their manipulation was more powerful than ours, with multiple sessions of four hours and participants being put under hypnosis while thinking of bright light exposure. Moreover, as Richter and colleagues did not employ a control condition with exposure to a different kind of light, effects could also be due to the hypnosis sec, or to the activation of the concept of light irrespective of its source.

4.4.3 Limitations

There are some limitations to this study, in Study One we used an Internet-based survey, and respondents from different countries with different latitudes completed the survey. Incorporating different countries of course increases the potential for generalization of the outcomes, but more participants per country or latitude would be required to achieve this. Furthermore, as was already mentioned, we explicitly used words related with daylight or electric light to evoke associations. Because multiple words were used as stimuli to generate associations, the number and diversity of associations generated were higher than when participants were asked to generate associations with a single light setting (which would have been the case with exposure to real daylight or electric light). In addition, when asked to associate with actual daylight exposure the associations will probably be dominated by the view content rather than the light itself. At the same time words might have induced a less powerful light experience than with real daylight or electric light.

4.4.4 Conclusion

To conclude, part of our results for associations with daylight versus electric light and their role in preference formation and restorative potential was in line with findings of the previous chapter, whereas other parts were not. The overlap found pertained to more positive associations for daylight than for electric light and higher preference ratings for daylight than for electric light. Differential effects were found for the role of associations in preference formation. Whereas valence of associations consistently mediated the effect of both environment and weather type on preference it did not mediate the effect of light source on preference. These results provide preliminary evidence for differential underlying (psychological) pathways for beneficial effects of nature and weather versus daylight. However, this claim is slightly premature since we only found limited evidence for restorative effects of natural environments in Chapter Three. In Chapter Five and Six we will further investigate restorative effects of nature and daylight. Therefore, we will come back to this possible difference in underlying psychological pathways in the General Discussion (Chapter Seven).

Part II

Restorative effects of nature and daylight

What you choose to believe in
dictates your rise or your fall
(Junip - Line of fire)

Chapter 5

Natural resistance.
Exposure to nature and self-regulation, mood, and physiology.[1]

It takes a tree
to make a leaf
strong the roots
underneath
(Lamb - Strong the Root)

[1] This chapter is based on: Beute, F., & de Kort, Y.A.W. (2014). Natural resistance. Effects of exposure to nature on self-regulation, mood, and physiology in an ego-depletion paradigm. *Journal of Environmental Psychology, 40,* 167-178.

Abstract. Positive effects of exposure to nature have been reported for stress, mood, and executive functioning. In this chapter we investigated whether viewing natural scenes can also improve self-regulation. In line with recent theoretical propositions these replenishing effects were investigated in a typical ego-depletion paradigm. In two studies we found indications for beneficial effects of a short exposure to nature on lower order self-regulation (e.g., controlling impulses), but not on a higher order executive functioning task. Furthermore, we found beneficial effects on mood and heart rate variability, a physiological measure related to exertion of self-control and stress. Importantly, beneficial effects of nature emerged even when participants had not been previously depleted, which challenges the current postulation that nature mostly has restorative benefits. We propose that nature might also have buffering or 'instorative' effects.

5.1 Introduction

Daily life can place demands on us in many ways. One important way pertains to the exertion of self-control to override feelings, thoughts or inclinations. A recent study demonstrated that, on average, we spend three hours per day exerting self-control (Hofmann, Vohs & Baumeister, 2012). This finding is especially striking in light of research suggesting that exerting self-control depletes a limited resource, a process also labeled ego-depletion (Baumeister, 1998).

High self-control has been related to many positive life outcomes such as health, academic success and interpersonal effectiveness, and inversely with negative outcomes including aggression and alcohol abuse (Hagger, 2010; Tangney, Baumeister, & Luzio Boone, 2004). Accordingly, finding ways to replenish depleted self-control resources could be beneficial for many aspects of life. Such replenishing effects have been demonstrated, for instance after consuming glucose (Gaillot & Baumeister, 2007) or through increasing positive affect (Tice et al., 2007).

Recently, Kaplan and Berman (2010) postulated that nature exposure could also improve self-regulation. Viewing nature has already been found to reduce physiological reactivity after a stressful experience (Fredrickson & Levenson, 1998; Ulrich et al., 1991), and improve mood (Hartig et al., 2003; Berman et al., 2008) and executive functioning (Laumann et al., 2003; Berman, et al., 2008). As seen in Chapter One, no effect studies have explicitly targeted self-regulation yet. In the present research we therefore empirically tested effects of nature on self-control in two studies, both employing a typical ego-depletion paradigm.

On a secondary note, the general consensus in restoration research is to investigate beneficial effects of nature after resource depletion or stress induction. In our second study we tested whether this pre-condition of resource depletion is actually necessary for nature to exhibit beneficial effects.

5.1.1 Nature and executive functioning

To recap what we discussed in Chapter one, Attention Restoration Theory (Kaplan, 1995) proposes that each of us possesses a limited resource to direct attention. Tasks that require executive functioning drain this resource, resulting in a condition labeled directed attention fatigue. Executive functioning, a higher order cognitive process (Suchy, 2009), is involved in a large variety of behaviors, including decision making, planning, and self-control (Cummings & Miller, 2007). Conversely, nature has been suggested to replenish depleted resources, because of its inherent ability to capture attention without effort (Kaplan, 1995). Viewing natural environments, in other words, does not require executive functioning and by not placing a demand on this resource, it can be replenished (Kaplan & Berman, 2010).

Kaplan and Berman (2010) have suggested that executive functioning shares a common resource - prone to depletion - with self-regulation, which has been described in Ego-depletion theory (Baumeister, 1998).

5.1.2 Self-regulation and performance

Self-regulation and executive functioning have already been discussed briefly in Chapter One, but we will discuss both concepts in depth here. Ego-depletion theory holds that exerting self-control in one task can temporarily decrease the capacity for self-regulation on a subsequent task. A variety of self-regulatory behaviors has been found prone to depletion, including for instance controlling impulses, resisting temptation, and focusing attention. Tasks requiring self-control can be as diverse as physical stamina, not thinking of a white bear, refraining from eating tempting food, or solving difficult math problems while being distracted by noise (for an overview, see: Hagger et al., 2010). Baumeister (1998) postulated that these seemingly unrelated behaviors deplete one commonly shared resource.

The depletion of this resource has been at the core of ego-depletion theory. Different theories have been developed to explain the phenomenon of ego-depletion, including the strength model (Baumeister, Vohs, & Tice, 2007) and the process model (Inzlicht & Schmeichel, 2012). The strength model builds on the assumption of self-regulation depending on a limited resource, using a muscle as a metaphor for self-control. Specifically, prolonged exertion leads to fatigue while practice can improve self-control strength in the longer run.

The process model also corroborates the typical ego-depletion findings of lower performance on the second task in a sequential task paradigm, yet challenges the existence of a limited resource. Instead, Inzlicht and Schmeichel propose that exerting self-control leads to temporary shifts in motivation and attention. These shifts are directed away from controlling impulses and toward finding rewards and gratification. As an example, after focusing attention in a vigilance task persons may feel that their hard work has not really paid off, or they may feel justified to exert less effort because they already worked hard.

Thus, they may be motivated to find a reward and redirect their attention accordingly. While directing attention toward finding this reward, people will be more prone to impulsive behaviour. Thus, declines in performance are said to be due to shifts in attention and motivation rather than a resource deficit.

Contrary to ego-depletion theory, others have suggested that the exertion of self-regulation does not necessarily deplete a resource, but can also lead to improvements in performance (Koole, Jostmann, & Baumann, 2012). For instance, the harder the task, the more a person will be involved in it and in subsequent tasks. This would result in more effort mobilization to face a subsequent task (Wright & Kirby, 2001), which may result in better task performance. Similarly, it has also been proposed that people adapt to the difficulty level of a certain task, resulting in improved subsequent performance, a process labelled learned industriousness (Converse & DeShon, 2009). Furthermore, it was found that expectations regarding imminent ego-depleting effects influence performance on a second task more than the actual ego-depletion induction (Clarkson, Hirt, Jia, & Alexander, 2010; Martijn, Tenbült, Merckelbach, Dreezens & de Vries, 2002).

5.1.3 Rationale

The aim of this chapter is to investigate whether exposure to natural scenes can increase self-regulatory capacity. As was reflected in the sections above, prior self-regulation has been found to affect performance on a subsequent task, but no consensus has yet been reached regarding the directionality of this effect, with some predicting self-regulation to harm subsequent performance whereas others state the opposite relation.

In the studies presented here, we used a typical ego-depletion paradigm with successive tasks requiring self-control. In Study One, we first established an ego-depletion effect and subsequently investigated how exposure to natural versus urban environments after initial depletion affected self-regulatory capacity in the subsequent task. If self-regulation harms performance -as is postulated within ego-depletion theory- we expect participants who exerted self-control in the induction task to perform worse on the second task than non-depleted participants. Furthermore, if exposure to natural environments -but not to urban environments- replenishes this depleted resource we expect that after viewing a slideshow of nature no decline in performance will be detected anymore.

In Study Two we investigated effects of natural versus urban environments on self-regulation after either a depleting or a non-depleting induction tasks. The aim was to identify whether beneficial effects of nature on performance only surface after a resource has been depleted, or whether there is a more general positive effect on self-regulatory performance. Beneficial effects of nature on mood, physiology, or performance without an antecedent depletion or stress induction have been investigated very rarely. Hartig and colleagues (1996) conducted one experiment in which they tested effects of natural versus urban scenes without an antecedent fatigue induction and still found beneficial effects of nature on a task following exposure, which they labeled ‘instorative effects’. Another study found buffering effects of a nature video on a subsequent stressor as well (Parssons et al., 1998).

In both studies we manipulated scene type by showing participants a slideshow with photos depicting either natural or urban environments. Moreover, in both studies we also included a no-content condition to distinguish between positive effects of natural and negative effects of urban environments. Generally, in restoration research the duration of exposure to natural environments ranges from 20 to 50 minutes (see Appendix A). Because ego-depleting effects have been found to vanish between three and ten minutes (Tyler & Burns, 2008), we opted for a shorter exposure than usual in the current study.

Besides self-regulation, effects on mood and physiology were also explored. Within ego-depletion research, many studies have found that self-regulatory demands negatively affect mood (Hagger et al., 2010). Exposure to natural environments, on the other hand, have been found to increase positive affect as well as lower negative affect (Berman et al., 2008; Ulrich et al., 1991).

Both exposure to nature and the exertion of self-control can affect physiology. Heart rate variability - indicating the amount of vagal influence - signals self-regulatory capacity (Thayer, Hansen, Saus-Rose, & Johnsen, 2009) as well as self-regulatory activity (Segerstrom & Solberg Nes, 2007). Conversely, exposure to nature can reduce physiological reactivity (i.e., heart rate and pulse transit time) both after the induction of stress (Ulrich et al., 1991; Fredrickson & Levenson, 1998) and mental fatigue (Laumann, et al., 2003).

5.2 Study One

In Study One we employed an incomplete design. Two conditions tested differences in self-regulatory performance, mood, and physiological responses after either a non-depleting or a depleting induction task. In these two conditions, no visual content was presented between the induction and the dependent task. We expected that the depleting version of the induction task negatively affected self-regulatory performance, mood, and physiological responses as compared to the non-depleting task.

Two additional conditions tested whether viewing natural environments as opposed to urban environments after ego-depletion could help overcome ego-depleting effects. We expected that - compared to no content or urban scenes - viewing natural environments would help overcome the detrimental effects of ego-depletion. This would result in better self-regulatory performance, more positive mood, and a reduced physiological response.

5.2.1 Method

5.2.1.1 Design
A between-subjects design was employed with four conditions (No Content (Non depletion), No Content (Depletion), Urban (Depletion), Nature (Depletion)).

5.2.1.2 Participants
Ninety participants (48 females) participated in the study. Their ages ranged from 18 to 35 with a mean of 22.2 (SD = 3.1). They were recruited via email through our participant database. The majority of participants were students from the Eindhoven University of Technology or from the Fontys Higher Education Institute. The experiment lasted approximately 45 minutes and participants received €7,50 compensation for their effort. One participant in the Ego-Depletion Nature condition was colour-blind and his data were therefore excluded from the analysis on Stroop performance. One further participant was excluded from analysis for not adhering to the instructions. Due to technical problems, physiological data was not recorded (reliably) for 18 participants.

5.2.1.3 Procedure
After signing the informed consent form, the physiological equipment was attached. The experiment started with some instructions on the computer, followed by a five-minute baseline measurement for the physiological measures (t_0), during which participants first filled in the baseline mood questionnaire. After the baseline measurements they started with the typing task. Depending on their condition they either completed the non-depleting or depleting variant of this task. During the three-minute experimental block (exp. block), participants in both No-content conditions filled out the mood questionnaire for the second time (t_1, post induction) followed by a short pause; Participants in the Content conditions viewed a slideshow with pictures of urban (Urban (Depletion)) or natural (Nature (Depletion)) environments. After this three-minute period all participants completed the Stroop task. They then rated the difficulty of the typing task and Stroop task before starting the OSPAN (the operation span test, see Section 5.2.1.6) task. Directly following the OSPAN, participants rated the difficulty of the OSPAN task and mood was measured (t_2, experiment end). Participants in the Urban Depletion and Nature Depletion conditions rated the presented slideshow. All participants filled in a number of additional questionnaires (e.g., measuring trait self-control and perceived stress), which will not be reported in this dissertation. After filling in the questionnaires, participants were thanked and paid for their participation. See Figure 5.1 for an overview of the experimental set-up.

5.2.1.4 Ego-Depletion manipulation
The typing task was adapted from Muraven, Shmueli, and Burkley (2006). In all conditions the participants had to blindly retype a paragraph displayed on the screen. The text was adapted from a statistics methods book. In the Depletion conditions, participants were instructed not to type the spacebar, ‘e’, or ‘p’. In the top right corner participants could see how many errors (typing one of the forbidden keys) they had made. In the Non-depletion

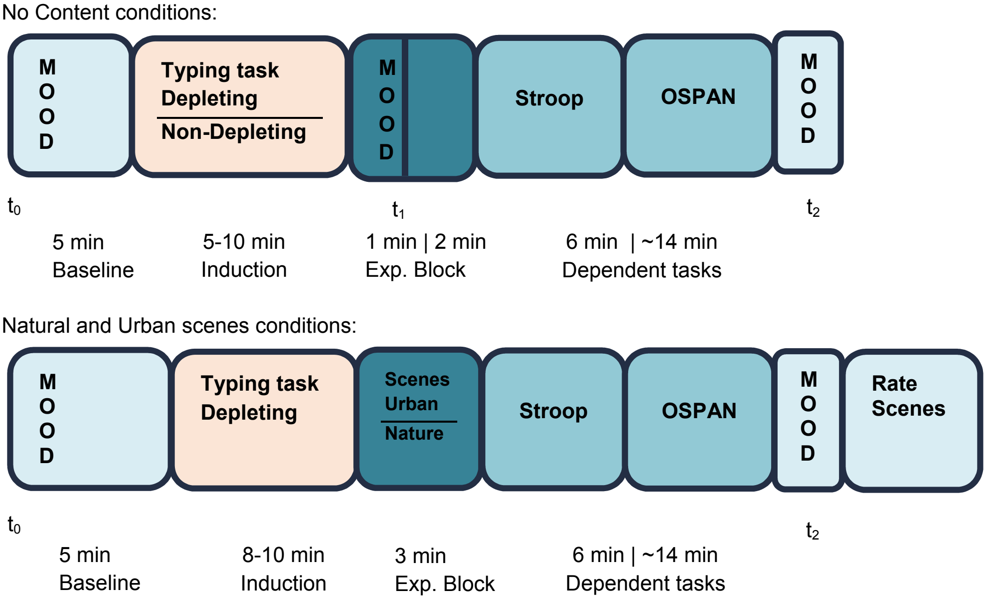


Figure 5.1 Overview of the experimental set-up

condition these restrictions were not given and consequently they received no feedback about errors made.

5.2.1.5 Environmental manipulation

Photos were taken during spring and summer time with clear skies. Natural photos were taken at the “Strabrechtse heide” and the “Genneper parken”. Both are natural areas in or close to Eindhoven, the first containing primarily heath and woodland and the latter containing woodland, a creek and stretches of grass.

The urban photos were all taken in the city centre of Eindhoven. All photos were taken between 10 am and 3 pm on clear days. No humans were present in the nature pictures and no humans were present in the foreground of the urban pictures. Participants either viewed eight natural photos or eight urban photos, see Figure 5.2 for some example photos. The photos were displayed on a television screen **(**32 inch**)** that was placed on the wall behind the laptop on which participants performed the experiment. The instruction was displayed for 20 seconds after which each photo was displayed for 20 seconds. The slideshow lasted three minutes in total.

Figure 5.2 Example photos

5.2.1.6 Measures

Performance task 1 – Stroop task
During the Stroop task, names of colours were presented on the television screen with different font colours. Participants were asked to name the ink colour of the words, but in that process needed to inhibit the names of colours they were reading. In the present research five different colours were used (yellow, red, purple, blue, green). Two subsequent blocks of 50 trials were completed by each participant; each block consisted of 40 congruent and 10 incongruent trials. Dependent variables were the reaction time on incongruent trials and the number of errors made, including omissions. A trial started with a fixation point displayed for 1000 milliseconds, after which the word was displayed for 2000 ms. After 2000 ms. the trial would continue automatically when no response was detected and these instances were later coded as omissions. A trial was concluded with a blank screen displayed for 250 ms. Responses of the participants were recorded on tape to check for errors made, whereas reaction times were recorded instantaneously by the experimenter. The reason for not scoring the errors immediately during the task was that the experimenter could also be sensitive to the Stroop effect. Reaction times and errors were all scored by a single experimenter.

Performance task 2 – The operation span test (OSPAN)
The operation span test (OSPAN; Turner & Engle, 1989; Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005) is a task often used to test central executive functioning. In this task, participants are presented with combinations of a mathematical problem and a word. A mathematical problem was displayed first and participants were asked to indicate whether the answer provided was correct. A mathematical problem would for example be '(9 * 7)-5 = 57, yes / no'. After the mathematical problem a word was displayed on the screen for 2 seconds. They were instructed to memorize the words and solve the mathematical problems at the same time. Example words used are: *street, cell, dog,* or *book.* A block consisted of three to five math-word combinations, presented in random order. At the end of each block, participants were asked to write down the words they memorized. In total, participants had to solve 9 blocks; three of each length. If a participant solved all mathematical problems and recalled all words correctly, the block was considered correct. The OSPAN score was calculated by summing the number of words in correct trials.

Mood Mood was measured along three dimensions; tension, energy, and hedonic tone. Measures were taken at t_0, t_1 (only the No-content groups), and t_2. As in Chapter 3, items for tension and energy were selected from the Activation-Deactivation adjective Checklist (Thayer, 1989). This Activation-Deactivation adjective Checklist measures mood along two axes; tiredness – energy and calm – tension. Seven items were used to measure tension (tense, placid, at rest, nervous, jittery, calm, quiet) and for this dimension the Cronbach's alpha ranged from .73 to .78 at the three different measurement points. Eight items measured energy (energetic, sleepy, wakeful, lack of energy, tired, vital, wide awake, exhausted) with Cronbach's alpha ranging from .83 to .93. Hedonic tone was constructed from a selection of items of the UWIST Mood Adjective Checklist (Matthews, Jones, & Chamberlain, 1990). Five items were selected, namely sad, depressed, happy, content, and enthusiastic with a reliability ranging between $\alpha = 70$ and $\alpha = 79$. Mood was measured on scales ranging from 1 (not at all) to 5 (very much). Alertness was further measured after the OSPAN task using the Karolinska Sleepiness Scale (KSS; Akerstedt & Gillberg, 1990). Participants were asked to indicate how they felt at that moment on a nine-point scale ranging from very alert to very sleepy.

Physiological measures During the experiment Heart Rate Variability (HRV), heart rate (HR), and Pulse Transit Time to the earlobe (PTE) were measured continuously. For the heart rate measures, electrodes were placed according to the lead-II placement using Kendall Arbo H124SG electrodes.

Pulse Transit time to the Ear (PTE) is the time a pulse wave takes to travel toward a distant arterial site, in this case the earlobe. PTE depends on the distensibility of the blood vessels and correlates with blood pressure, with shorter PTE times related to higher blood pressure (Foo & Lim, 2006). PTE was measured by placing a photoplethysmograph on the right ear lobe. PTE was calculated as the time that elapsed between the Q/R-peak and onset of the wave at the earlobe. Values below 70 ms and above 500 ms were considered invalid and treated as missing values. Heart rate variability was defined as the ratio of Low Frequency divided by the High Frequency (LF/HF ratio). Frequencies between .04 Hz and .15 Hz were considered Low Frequency (LF) and frequencies between .15 Hz and .4 Hz were considered High Frequency (HF) (Task force of the European Society of cardiology and The North American Society of pacing and Electrophysiology, 1996). Low Frequency and High Frequency were calculated using Frequency Domain analyses and are expressed in milliseconds squared (ms^2). A higher LF/HF ratio indicates more sympathetic activation while a lower ratio indicates more parasympathetic control. More sympathetic activation (i.e., a higher LF/HF ratio) has been suggested to reflect a higher stress level **(**Sloan, et al., 1994) as well as higher exertion of self-control **(**Segerstrom & Solberg Nes, 2007). A five-minute baseline measurement was included at the beginning of the experiment to measure baseline physiological reactivity.

Assessment of slideshow – Preference and affective responses These questions were only asked in the Urban Depletion and Nature Depletion conditions. Participants were asked to indicate how they had felt while watching the photos on three dimensions using Self-Assessment Mannequins (SAM; Bradley & Lang, 1994). First of all, they were asked to indicate how happy they felt while watching the environments, ranging from very unhappy (-4) to very happy (4). A second scale assessed arousal on a scale ranging from very calm (-4) to very aroused (4). The last scale assessed to what extent participants felt present in the displayed environment, ranging from very present (-4) to not present at all (4).

Because previous studies have consistently found a significant preference for natural over urban environments (see for instance: Beute & de Kort, 2013; Hartig & Evans, 1993) as well as a mediating role of preference on restoration outcomes (van den Berg, Koole, & van der Wulp, 2003), we included questions concerning preference. Participants were asked to indicate how [attractive, pleasant, positive] it would be to spend an hour in the displayed environment (adapted from Staats, Kieviet & Hartig, 2003), measured on a scale from 1 (not at all) to 7 (to a very high degree). Internal consistency of the scale was high ($\alpha = .92$).

5.2.1.7 Data analysis

Mood effects and physiological reactivity were measured using change scores. Residualised change scores were used, see Section 3.3.1.8 for the rationale. Changes in mood for the No-content conditions were calculated between baseline (t_0) and after the typing task (t_1, post induction) and between post induction (t_1) and after the OSPAN task (t_2, experiment end). For the Nature Depletion and Urban Depletion conditions change in mood was measured between baseline (t_0) and after the OSPAN task (t_2). Changes in physiological outcomes were investigated by calculating residualised changes between each subsequent segment (baseline vs, typing task; typing task vs. break period; break period vs. Stroop task; Stroop task vs. OSPAN task). Unless otherwise stated, an ANOVA is run with residualised change scores or performance as outcome variables and condition as between-subjects factor. For reaction times and physiological measures, outliers deviating more than two standard deviations from the mean were removed.

For each parameter – performance, mood, and physiology – we ran two analyses. First, the effectiveness of the depletion induction was investigated by comparing the two No Content conditions. Subsequently, the effects of scene content after depletion were tested (No Content Depletion vs. Nature Depletion vs. Urban Depletion). The results section will end with the assessment of the slideshow and possible mediating effects of this assessment on the restorative outcomes.

5.2.2 Results

In this section we will start by discussing effects on our main outcome variables; starting with self-regulatory performance, followed by effects on mood and physiology. Then, we will report outcomes for possible underlying mechanisms for the Nature Depletion and Urban Depletion conditions. More specifically, we will report effects of the slideshow on preference and how participants rated the urban and natural scenes. As mentioned at the data analysis section, for the main outcome variables we will start each section by reporting effects of the ego-depletion manipulation, followed by the effects of our experimental manipulation (Scene content). In line with ego-depletion theory we expected that an initial task requiring self-regulation would cause a decline in performance on subsequent self-regulatory performance.

5.2.2.1 Self-regulatory performance

First, we compared the two No Content conditions to see how the depletion induction had affected performance. For the No Content conditions, a significant difference was found in reaction times on the Stroop task between the Depletion and Non-depletion condition ($F(1,37) = 5.9$, $p = .02$). As expected, participants in the Depletion condition ($M = 1432.42$, $SE = 27.57$) were significantly slower on incongruent trials of the Stroop task than participants in the Non-depletion ($M = 1336.43$, $SE = 28.29$) condition, see Figure 5.3. Due to a non-normal distribution of the data, the Mann-Whitney test was used to calculate effects of Content type on errors. Participants in the Depletion condition ($Mdn = 2$) did not make significantly more errors than participants in the Non-depletion condition ($Mdn = 1$; $U = 208.5$, $p = .418$). No significant main effect of Depletion induction was found on mean OSPAN performance ($F(1,37) = .10$, $p = .760$). Participants in the Depletion condition ($M = 26.85$, $SE = 1.41$) remembered equal numbers of words during the OSPAN task as participants in the Non-depletion condition ($M = 27.47$, $SE = 1.45$). These results indicated that the ego-depletion induction indeed affected subsequent self-regulatory performance, but only regarding reaction times on the Stroop task.

We then tested whether there was an effect of Content type on performance. A significant effect of Content type on reaction time to the incongruent trials in the Stroop task was found ($F(1,67) = 4.3$, $p = .017$). Planned contrasts revealed a significant difference in reaction times between the No Content and Nature condition ($t(39) = 2.3$, $p = .026$) and between the Urban and Nature condition ($t(50) = 2.7$, $p = .009$), with shorter reaction times after viewing photos of natural scenes ($M = 1355.56$, $SE = 103.91$) than after No Content ($M = 1432.41$, $SE = 115.75$) or urban scenes ($M = 1436.87$, $SE = 105.61$), see Figure 5.3.

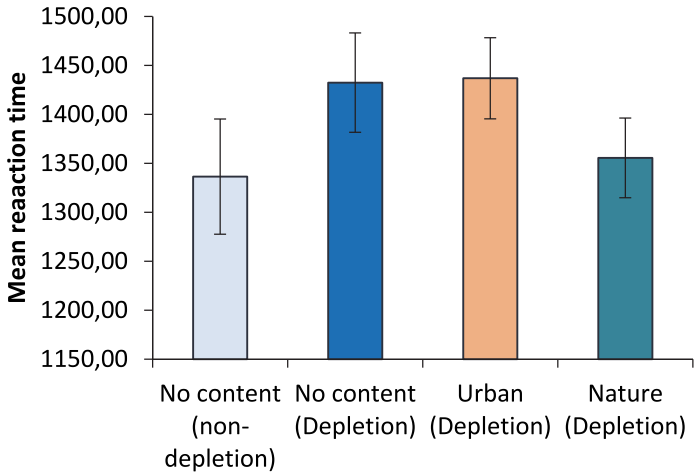


Figure 5.3 Mean reaction times for the incongruent trials of the depletion conditions, bars represent 95 % confidence intervals.

No significant effect of Content type on number of errors was found ($H(2) = .6$, $p = .727$), with participants in the Nature condition making as many errors (*Mdn* = 1) as participants in the Urban (*Mdn* = 2) and No Content (*Mdn* = 2) conditions. No significant main effect of Content type was further found on mean OSPAN performance ($F(2,68) = .9$, $p = .409$). Participants in the Nature condition ($M = 29.12$, $SE = .36$) remembered similar numbers of words as participants in the Urban ($M = 28.84$, $SE = .39$) and No Content ($M = 28.4$, $SE = .45$) conditions. Thus, in line with our expectations, the detrimental effects of the initial depleting task on reaction times to incongruent trials during the Stroop task were overcome by viewing natural environments.

5.2.2.2 Mood

As before, we compared the two No Content conditions to see how the depletion induction had affected mood. The F-values, effect sizes, means, and standard errors for mood at the three different time points can be found in Table 5.1**.** A significant effect of Depletion on hedonic tone was found, with hedonic tone decreasing more in the depletion condition than in the non-depletion condition. No effects of Depletion on tension or energy were found, nor were any effects of Depletion found on the change in mood after the OSPAN task. These outcomes partly confirm our hypothesis that a depleting task would induce a more negative mood than a non-depleting task. Hedonic tone deteriorated after depletion, but energy and tension scores remained unaffected.

Table 5.1 ANOVA outcomes, means and standard deviations of all mood variables (raw scores).

		Mean (SE)				Depletion effect (No Content)[3]		Content type effect (Depletion)[4]	
		No Content (Non-Depletion)	No Content (Depletion)	Urban (Depletion)	Nature (Depletion)	F 1,35	η_p^2	F 2,68	η_p^2
Tension	t_0[1]	1.88 (.46)	1.90 (.12)[a]	2.25 (.11)[a,b]	1.92 (.10)[b]	<.1	-	3.3*	.09
	t_1[2]	2.00 (.39)	2.00 (.39)	-	-	2.0	-	-	-
	t_2[2]	2.01 (.54)	3.72 (.11)	2.20 (.12)	2.09 (.12)	.4	-	.5	-
Hedonic tone	t_0[1]	4.02 (.44)	3.91 (.09)	3.83 (.09)	4.09 (.08)	.7	-	2.7	-
	t_1[2]	4.00 (.39)[a]	4.00 (.39)[a]	-	-	6.7*	.16	-	-
	t_2[2]	3.77 (.53)	2.16 (.12)	3.75 (.11)	3.79 (.10)	1.5	-	1.0	-
Energy	t_0[1]	3.66 (.48)	3.76 (.11)	3.83 (.09)	3.77 (.09)	.4	-	.1	-
	t_1[2]	3.80 (.62)	3.80 (.62)	-	-	2.7	-	-	-
	t_2[2]	3.53 (.63)	3.63 (.14)	3.75 (.11)	3.75 (.11)	1.8	-	.3	-

[1] the F-values represent baseline differences, [2] the F-values represent differences in residualised changes compared to the previous segment. Means with the same superscript letter are significantly different, [3] in these analyses the No Content (Non-depletion) and No Content (Depletion) conditions are compared, [4] in these analyses the No Content (Depletion), Urban (Depletion), and Nature (Depletion) conditions are compared.
** $p < .05$*

Having established that depletion affected hedonic tone, we investigated how the content manipulation affected mood recovery. This was done relatively crudely by comparing mood during baseline with mood after the OSPAN task. At baseline, a significant difference was found between the three groups for tension. Post-hoc analyses revealed that participants in the Urban condition reported feeling significantly more tense than participants in the No Content condition as well as compared to the Nature condition, see Table 5.1. No effects of the content manipulation were found on mood reported at the end of the experiment.

Besides mood effects, we also tested for effects of Depletion and View content on the outcomes for the Karolinska Sleepiness scale measured after the OSPAN task. No significant effects of Depletion or of View content were found on alertness ($F < .95$, $p > .337$).

5.2.2.3 Physiological data

Again, we first compared the two No Content conditions to see how the depletion induction had affected physiology. Contrary to our hypothesis, no differences in physiological response were found. The Depleting version of the typing task did not appear to affect HR, PTE, or the LF/HF ratio differently from the Non-depleting version during the typing task, see Table 5.2. Similarly, no difference in recovery was found during the experimental block, where they were having a short pause between the two tasks. Only one significant effect was found of Depletion on the change in PTE during the Stroop task. Participants in the Depletion condition had a longer ΔPTE (indicating a lower blood pressure) than participants in the Non-depletion condition.

Table 5.2 Means and standard errors for the physiological measures (raw scores).

		Mean (SE)				Depletion effect (No Content)[3]		Content type effect (Depletion)[4]	
		No Content Non-Depletion	No Content Depletion	Urban Depletion	Nature Depletion	*F*	η_p^2	*F*	η_p^2
HR	Baseline	76.92 (12.31)	75.91 (2.98)	74.26 (2.75)	73.65 (2.51)	<.1	-	.2	-
	Type task	79.71 (10.93)	77.75 (3.03)	75.65 (2.62)	73.70 (2.63)	.9	-	<.1	-
	Exp. Block	75.02 (9.60)	74.49 (2.67)	72.74 (2.79)	70.80 (2.52)	2.7	-	.7	-
	Stroop	81.16 (10.67)	81.88 (2.56)	75.95 (2.74)	77.01 (2.41)	<.1	-	.7	-
	OSPAN	78.34 (9.89)	76.65 (2.56)	74.62 (2.68)	71.05 (2.24)	.1	-	1.8	-
LF/HF ratio	Baseline	1.92 (1.37)	2.10 (.52)	1.99 (.30)	2.38 (.41)	<.1	-	.2	-
	Type task	1.54 (.82)	1.79 (.35)	1.42 (.20)	1.50 (.20)	<.1	-	<.1	-
	Exp. Block	2.18 (1.52)	1.84 (.33)	1.76 (.34)	1.96 (.24)	.6	-	.5	-
	Stroop	3.38 (1.99)	3.42[a] (.60)	3.11 (.38)	2.69[a] (.44)	.1	-	2.7	-
	OSPAN	2.61 (.99)	2.59 (.35)	2.70 (.43)	2.55 (.32)	<.1	-	<.1	-
PTE	Baseline	213.15 (5.73)	210.53 (3.35)	218.34 (5.43)	210.66 (3.15)	.2	-	1.2	-
	Type task	211.41 (5.49)	209.83 (3.69)	208.57 (4.58)	208.10 (3.38)	<.1	-	2.2	-
	Exp. Block	215.07 (5.73)	211.63 (4.40)	207.54 (5.64)	212.29 (3.93)	.8	-	.8	-
	Stroop	211.01 (5.30)	213.92 (4.52)	212.28 (5.83)	209.11 (3.56)	5.3 *	.16	1.0	-
	OSPAN	214.77 (5.06)	216.50 (4.05)	217.80 (5.24)	210.86 (3.54)	.3	-	.4	-

[1] the F-values represent baseline differences, [2] the F-values represent differences in residualised changes compared to the previous segment. Means with the same superscript letter are significantly different, [3] in these analyses the No Content (Non-depletion) and No Content (Depletion) conditions are compared, [4] in these analyses the No Content (Depletion), Urban (Depletion), and Nature (Depletion) conditions are compared.
** $p < .05$*

Looking at the effects of Content type after depletion, no differences in heart rate or PTE were found between the three content types during the experiment, see Table 5.2. One non-significant trend of Content type emerged for ∆LF/HF ratio during the Stroop task ($F(2,50) = 2.7$, $p = .074$). Planned contrasts revealed a significant difference in change between the No Content and the Nature condition and a marginally significant difference between the Nature and Urban condition, with higher LF/HF ratios for the Urban and No Content conditions than for the Nature condition, see Table 5.2. No further significant effects of content type were found.

Table 5.3 Means and standard errors for assessment of the urban versus natural scenes

	Natural Scenes Mean (SE)	Urban Scenes Mean (SE)
SAM-pleasure	1.85 (.23)[a]	1.12 (.20)[a]
SAM-arousal	-1.62 (.32)	-.76 (.34)
SAM-presence	-1.36 (.24)	-.92 (.36)
Preference (Attitude)	5.83 (.19)[a]	3.92 (.20)[a]

Means with similar superscript numbers are significantly different

5.2.2.4 Assessment of urban versus natural scenes

Participants were asked to assess the slideshows in the Urban and Natural scene condition. Three one-way ANOVAs were run with Environment (Natural vs. Urban) as between-subjects variable and SAM-energy, SAM-pleasure, and SAM-presence as dependent variables. Environment type significantly affected SAM-pleasure ($F(1,49) = 5.5$, $p = .023$, $\eta_p^2 = .10$), whereas a non-significant trend was found for SAM-arousal ($F(1,49) = 3.34$, $p = .074$). Environment did not affect SAM-presence ($F(1,49) = .98$, $p = .327$). Furthermore, significant difference in preference was found between the two scene types ($F(1,49) = 49.34$, $p < .001$), see Table 5.3 for means and standard errors.

5.2.2.5 Mediation assessment of urban versus natural scenes on restorative outcomes

To see whether preference ratings for natural and urban scenes mediated the beneficial effects of nature on self-regulation, LF/HF ratio during the Stroop task, and SAM-pleasantness, we planned to run a number of mediation analyses. Preference ratings did not significantly affect reaction times or LF/HF ratio ($b < .18$, $p > .425$), therefore no mediation analyses were conducted for these outcomes. Preference ratings did, however, fully mediate the effect of Environment on SAM-pleasantness (Z = 2.06, $p = .010$), see Figure 5.4.

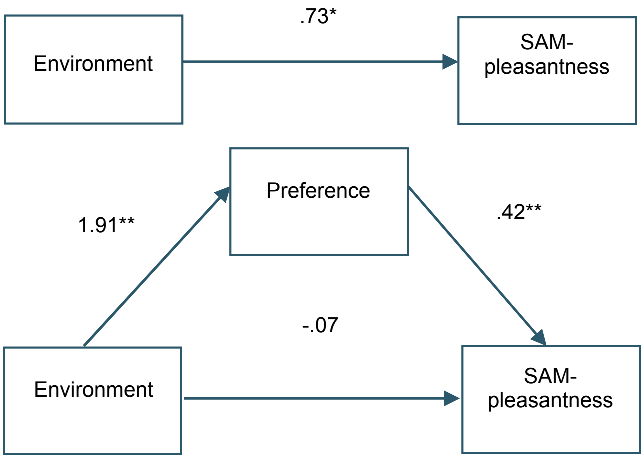


Figure 5.4 Mediation of pleasure experienced while viewing natural or urban scenes through preference ratings

5.2.3 Discussion

In Study One, we tested whether viewing natural scenes could help replenish depleted resources. To be able to establish possible ego-replenishing effects of natural environments, we first had to ensure that our manipulation was successful in inducing ego-depletion. Therefore, we also added two No Content conditions in which participants completed either the non-depleting or depleting variant of the typing task. Outcomes of these two conditions partly confirmed our hypothesis regarding ego-depleting effects of the typing task on self-regulation, mood, and physiology. Depletion appeared to lower hedonic tone and decreased reaction times to incongruent trials on the stroop task, but did not affect physiological responses or mood in the expected direction.

Our main research objective was to test whether natural environments can overcome ego-depleting effects. Again, we found partial evidence for our hypothesis. We found that participants who had viewed a slideshow of natural scenes had faster reaction times to incongruent trials on a subsequent Stroop task and also had a lower increase in LF/HF ratio during the Stroop task (indicating a lower increase in the exertion of self-regulation or lower stress levels). Performance on the OSPAN task remained unaffected, as well as heart rate and pulse transit time. Mood was measured relatively crudely by comparing baseline mood scores to those after the OSPAN task and did not show any effects of our environmental manipulation on mood.

Unfortunately, there were baseline differences in reported hedonic tone and tension between the depletion conditions. However, effects of scene content on Stroop performance and LF/HF ratio appeared largely unaffected by these baseline differences. By adding a No-content condition, we were able to establish that our findings were due to beneficial effects of natural environments rather than negative effects of urban scenes.

We did not find evidence for physiological responses to our ego-depletion induction. There were, however, some indications for a buffered response to the Stroop task after viewing natural scenes as LF/HF ratio increased less after viewing natural scenes. In other words, these results hint at instorative effects of natural environments, with a lower physiological stress-response to the Stroop task after viewing natural environments. Ego-depletion paradigms involve control tasks that are very similar to the depleting tasks, but do not require self-control enabling us to compare effects of nature with and without a depletion induction. Therefore, in Study Two, we also investigated the effects of natural versus urban scenes after these non-depleting tasks.

5.3 Study Two

In Study Two our aim was to replicate findings of Study One with a slightly different design as well as to investigate the possibility of buffering or ‘instorative’ rather than restorative effects of nature. Mood effects of our environmental manipulation were measured only crudely in Study One and therefore yielded inconclusive results. We added mood measurements after the induction tasks and after the slideshows to measure mood changes more sensitively. Furthermore, we used both the typing task and Stroop task as induction to increase initial depletion effects. Last, to extend our results regarding effects of natural environments on self-regulation a different dependent task was used. Whereas the Stroop task used in Study One required participants to control impulses, we opted for a higher order executive functioning task (the 2-back task) as the dependent task in the current study.

5.3.1 Method

5.3.1.1 Design

A 2 (Depletion vs. Non-depletion) by 2 (Natural vs. Urban environment) between subjects design was employed.

5.3.1.2 Participants

A total of 121 participants (51 female) participated in this study with ages ranging between 18 and 32 years (*M* =21.1, *SD* = 2.2). Students were recruited via the personal network of the researchers and via our database. The majority of participants were students from the Eindhoven University of Technology or from the Fontys Higher Education Institute in Eindhoven. Due to technical problems, for 7 participants no results on the 2-back task and for 22 participants no (reliable) physiological data were recorded. The experiment lasted approximately 45 minutes and participants received €7,50 compensation.

5.3.1.3 Procedure

After arriving at the laboratory, participants first read and signed a consent form after which the electrodes for the physiological measurements were attached. The experiment started with a baseline measurement period of 3 minutes for the physiological measurements, during which the participants also filled in a first mood questionnaire (t_0, baseline). Once the baseline period finished, they started with the typing task followed by the Stroop task. Participants either performed the non-depleting or depleting variants of these tasks. After these tasks, participants rated their mood (t_1, post induction). Subsequently, they watched a slideshow with either natural or urban pictures. Directly after the slideshow, participants again rated their mood on the VAS scales (t_2, post slideshow) after which the 2-back task started. After finishing the 2-back task, they again reported their mood (t_3, experiment end) and rated the tasks on difficulty and the slideshows on preference. Figure 5.5 displays a schematic overview of the experimental set-up.

5.3.1.4 Ego-depletion manipulation

Two subsequent tasks were employed to induce depletion vs. non-depletion: a typing task (as in Study One) and a Stroop task (not used in induction phase of Study One). The same two variants (Depleting and Non-depleting) of the typing task were used as in Study One, except that a different passage from a statistics book was used.

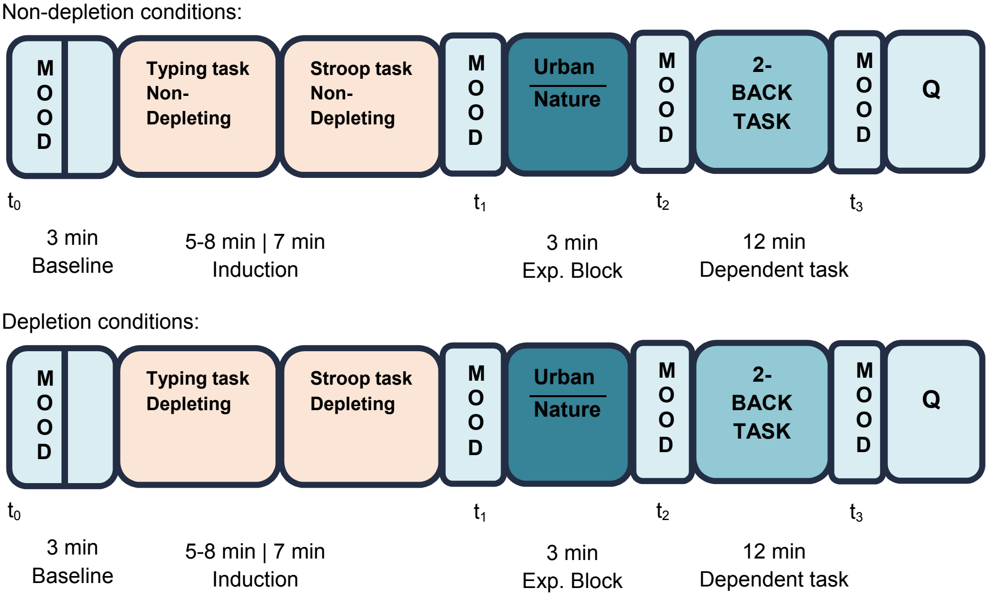


Figure 5.5 Schematic overview of the experimental set-up

During the Stroop task, four different colours were presented; red, blue, yellow, and green. Each trial started with a fixation point displayed on the screen for 500 ms. after which the word was displayed for 1500 ms. During the 1500 ms. display of the word, participants were allowed to respond. After this time, the next trial would start automatically. All participants first practiced during a practice round consisting of 16 trials and further completed 5 rounds of 32 trials.

In the Non-depletion version of the task, participants performed the Stroop task on a computer and all trials were congruent. Participants were asked to respond by pressing the key corresponding to the first letter of the ink colour (respectively: r, b, y, or g). In the Depletion version of the task, participants performed the Stroop task by calling out loud the names of the ink colours and the majority of the trials (75 %) were incongruent.

5.3.1.5 Environment manipulation

The exact same slideshows were used as in Study One, with the same instructions. See Section 5.2.1.5 for a description.

5.3.1.6 Measures

Performance Task: The 2-back task The 2-back task is a working memory span task (Conway et al., 2005). During the 2-back task a sequence of digits (0-9) is displayed on the screen. Participants were asked to indicate whether the digit is the same as ('s' key) or different from (‘a’ key) the digit displayed two sequences before. Participants first performed a practice round with feedback (18 trials, 6 targets). The dependent task consisted of 192 trials (64 targets). During each trial, the digit was displayed for 500 ms. after which participants were given 3000 ms. to respond. Both reaction times and errors made (including omitted responses) were dependent variables for this task.

Mood Mood was measured on three dimensions (tension, hedonic tone, and energy) at four different times using Visual Analogue Scales (VAS); at baseline (t_0), after the (Non) Depletion induction (t_1), after the slideshow (t_2), and after the 2-back task (t_3). See Section 4.3.1.8 for a detailed description.

Physiology Heart rate and Heart Rate Variability were measured, see Study One for a detailed description. Means were calculated for HR and LF/HF ratio for five different segments; baseline, typing task, Stroop task, slideshow, and 2-back task.

Preference Similar to Study One, preference was measured. See Section 5.2.1.6 for a description. Again, this scale showed a good reliability (α = .92).

5.3.1.7 Data analysis

We used residualised change scores for mood and physiological measures, see Section 3.3.1.8. Residual change scores for mood were calculated to test for effects of the induction tasks (t_0 / t_1), of the slideshow (t_1 / t_2), and of the dependent task (t_2 / t_3). For the physiological measures residualised change scores were calculated for the induction tasks (baseline / typing task; baseline / Stroop), the slideshow (Stroop / slideshow), and the 2-back task (slideshow / 2-back). For the physiological measures and 2-back performance, values exceeding two standard deviations from the mean (participant mean for performance and group mean for physiology) were considered outliers. Unless otherwise stated, the data was analysed using an ANOVA with residualised change score or performance as dependent variable and Environment and Depletion as between-subjects variables.

5.3.2 Results

In the results section, we will sequentially report effects of the Depletion and Environment manipulations on self-regulatory performance, mood, and physiology. After establishing these restorative or instorative effects, we will further investigate the role of preference in restorative outcomes by running meditation analyses.

5.3.2.1 Self-regulatory performance

To investigate restorative or instorative effects of natural environments on performance on the 2-back task, two ANOVAs were run with Depletion and Environment as between-subjects variables and reaction time and amount of errors made on the 2-back task as dependent variables. For reaction times, no significant main or interaction effects were found ($F < .3$, $p > .575$). Due to non-normal distribution of the data, the influence of condition on omissions was analysed using a non-parametric test (Kruskall-Wallis), which revealed no significant effect of condition ($H(3) = 4.0$, $p = .263$).

5.3.2.2 Mood

For mood, analyses were run for three different time intervals. The outcomes for these analyses are summarized in Table 5.4. First of all, mood scores after the induction task (t_1) were compared to those at baseline (t_0) to investigate the effect of the induction tasks on mood outcomes. We expected that a larger deterioration of mood would be found for participants who completed the depleting versions of the induction tasks as compared to those finishing the non-depleting variants. Our expectations were partly met as a main effect of Depletion was found on tension, with a larger increase in tension in the Depleting conditions than in the Non-depleting conditions.

Second, we investigated possible mood enhancing effects of the environmental manipulation. We expected that natural environments would improve mood more than urban environments. Moreover, if effects of the natural environments are restorative an interaction of Environment * Depletion would be expected with improvements in mood only after performing the depleting induction tasks. Results indicate a main effect of Environment on hedonic tone, whereas none of the other main effects or interaction effects reached statistical significance. Hedonic tone improved more after viewing natural scenes than after viewing urban scenes, irrespective of whether participants were initially depleted or not. Figure 5.6 displays the residualised change scores for hedonic tone.

Last, the subsequent change in mood after the 2-back task was analysed. These analyses revealed a significant effect of Depletion on energy and a significant effect of Environment on hedonic tone. For tension, a non-significant trend was found for the interaction of

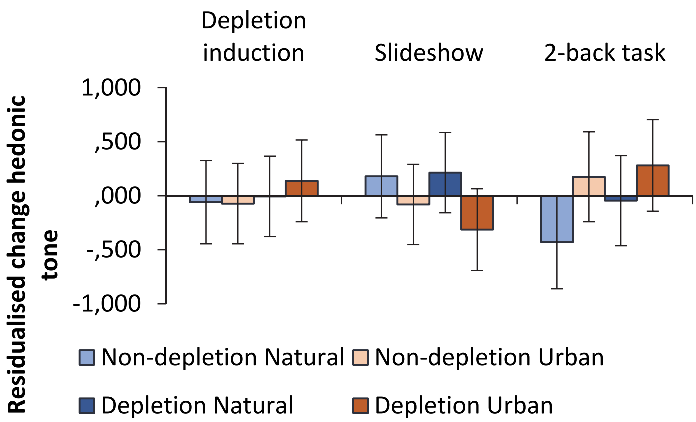


Figure 5.6 Residualised changes after the induction, slideshow and 2-back task for Hedonic Tone. Error bars represent 95% Confidence intervals.

Table 5.4 ANOVA outcomes, means and standard deviations for the Tension, Energy, and Hedonic Tone (raw scores).

		Mean (SE)				Depletion		Environment		Depletion * Environment	
		Non-Depletion		Depletion							
		Nature	Urban	Nature	Urban	F	η_p^2	F	η_p^2	F	η_p^2
Tension	t_0[1]	3.50 (2.08)	3.03 (1.76)	2.81 (1.79)	3.22 (2.13)	1.0	-	.1	-	.9	-
	t_1[2]	3.40[a] (1.72)	3.45[b] (1.97)	4.20[a] (2.05)	5.02[b] (2.08)	15.0**	.11	1.7	-	.3	-
	t_2[2]	2.57 (1.28)	2.95 (1.40)	2.58 (1.41)	3.18 (1.28)	2.1	-	2.6	-	<.1	-
	t_3[2]	3.10 (2.14)	4.24 (2.54)	4.08 (2.21)	4.11 (2,08)	.8	-	.3	-	3.2	-
Energy	t_0[1]	5.43[a] (1.82)	6.28[a] (1.77)	6.27 (1.79)	5.87 (2.11)	.1	-	.5	-	4.6*	.04
	t_1[2]	5.09 (1.45)	6.04 (1.58)	5.48 (1.76)	5.49 (1.64)	.6	-	2.4	-	.4	-
	t_2[2]	4.90 (1.44)	5.76 (2.02)	5.12 (1.89)	5.29 (1.99)	<.1	-	.3	-	< .1	-
	t_3[2]	3.76[a] (1.95)	4.58 (1.84)	4.75[a] (1.95)	4.67 (2.36)	5.5*	.05	<.1	-	.5	-
Hedonic tone	t_0[1]	6.82 (1.40)	7.24 (1.34)	7.33 (1.50)	6.86 (1.64)	.2	-	.5	-	.7	-
	t_1[2]	6.21 (1.08)	6.51 (1.80)	6.65 (1,59)	6.43 (1.62)	.5	-	.1	-	.2	-
	t_2[2]	6.65 (1.35)	6.65 (1.86)	7.06 (1.57)	6.35 (1.85)	.3	-	4.2*	.04	.5	-
	t_3[2]	5.69 (1.79)	6.29 (2.00)	6.46 (2.05)	6.11 (2.13)	1.3	-	4.7*	.04	.4	-

[1] the F-values represent baseline differences, [2] the f-values represent differences in residualised changes compared to the previous segment. Means with the same superscript letter are significantly different. Please note: no comparisons were made across categories (e.g., nature depletion vs. urban non-depletion).
* $p < .05$, ** $p < .001$

Environment * Depletion. After the 2-back task, energy had decreased more for the non-depletion group and hedonic tone decreased more for participants who had viewed natural environments.

5.3.2.3 Physiology

Similar to the analyses for mood outcomes, we analysed effects on physiological outcomes in three different intervals. The outcomes for these analyses are displayed in Table 5.5, together with the means and standard errors for all physiological outcomes. First, we compared physiological responses during the typing task and Stroop task to the baseline as a manipulation check. We expected that the depleting variants of the induction task would increase psycho-physiological responses. Depletion did not significantly affect HR or LF/HF ratio during the typing task, but did significantly affect both physiological outcomes during the Stroop task, with a higher increase in HR and LF/HF ratio in the Depletion conditions than in the Non-depletion conditions.

After completing the Stroop task, participants viewed either natural or urban scenes. During the slideshow, a main effect of Depletion on heart rate was found. Participants in the Depleting conditions had a larger decrease in HR than participants in the Non-depletion conditions. These results indicate that -after an increase in HR during the depleting version of the Stroop task- their HR recovered during the slideshow, irrespective of the scene content viewed. A main effect of Environment was found on LF/HF ratio, with a larger decrease for participants who viewed natural scenes than for participants viewing urban scenes, see Figure 5.7. These results indicate that natural environments positively affected physiological responses, but only for Heart Rate Variability.

Last, we also measured physiological response to the 2-back task, which participants performed directly after viewing the slideshow. No effects of Environment or Depletion were found on HR or LF/HF ratio change during the 2-back task.

5.3.2.4 Preference

A significant main effect of Environment was found on preference ($F(1,117) = 46.0$, $p < .001$, $\eta_p^2 = .28$), with higher preference ratings for Natural ($M = 5.05$, $SE = .16$) than for Urban ($M = 3.54$, $SE = .16$) scenes. No other main or interaction effects were found ($F < .4$, $p > .506$).

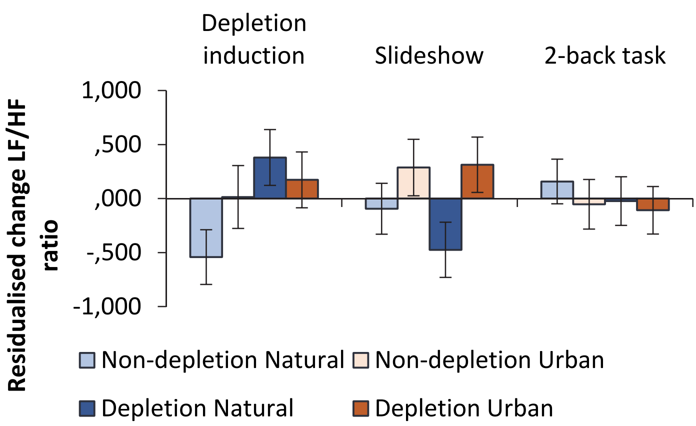


Figure 5.7 Residualised change scores for the LF/HF ratio. Error bars represent 95 % confidence intervals.

Table 5.5 ANOVA outcomes, means, and standard errors for heart rate and LF/HF ratio

		Mean (SE)				Depletion		Env.		Depletion * Env.	
		Non-Depletion		Depletion							
		Nature	Urban	Nature	Urban	*F*	η_p^2	*F*	η_p^2	*F*	η_p^2
HR	Baseline[1]	74.41 (10.28)	71.69[a] (8.12)	72.66[b] (10.47)	79.00[a,b] (10.44)	1.9	-	.8	-	5.0*	-
	Typing task[2]	78.63 (9.30)	77.98 (8.89)	77.64 (10.33)	83.22 (10.09)	<.1	-	1.8	-	<.1	-
	Stroop[2]	74.68[a,b] (9.33)	75.54[a] (8.77)	77.90[b] (9.73)	81.74 (9.59)	9.1*	.09	1.4	-	3.6	-
	Slideshow[2]	72.92[a] (8.60)	71.48 (7.84)	72.07[a] (9.52)	77.51 (9.45)	5.2*	.05	.3	-	2.5	-
	2-back[2]	74.24 (8.54)	74.52 (8.03)	73.53 (8.77)	79.60 (9.52)	<.1	-	2.0	-	<.1	-
LF/ HF	Baseline[1]	1.83 (1.26)	1.47 (.93)	1.70 (1.34)	2,23 (1.31)	1.5	-	.1	-	3.0	-
	Typing task[2]	2.19 (1.63)	2.15 (1.38)	2.12 (1.75)	2.18 (1.30)	.5	-	<.1	-	.2	-
	Stroop[2]	1.96 (1.44)	2.63 (1.67)	2.82 (1.49)	2.92 (2.17)	4.1*	.05	.4	-	2.1	-
	Slideshow[2]	1.74 (1.41)	2.45 (1.87)	1.72[a] (.93)	2.63[a] (1.30)	.5	-	5.4*	.06	.6	-
	2-back[2]	2.16 (1.38)	2.29 (1.14)	2.24 (1.30)	2.47 (1.30)	.3	-	.4	-	<.1	-

[1] the F-values represent baseline differences, [2] the f-values represent differences in residualised changes compared to the previous segment. Means with the same superscript letter are significantly different. Please note: no comparisons were made across categories (e.g., nature depletion vs. urban non-depletion).
** p < .05, ** p < .001*

5.3.2.5 Mediation of recovery effects by preference

To investigate whether beneficial effects of natural environments on LF/HF ratio and hedonic tone were mediated by preference ratings, we planned to mediation analyses. The results of these analyses are summarized in Table 5.6. For the mediation paths, see Figure 5.4. For hedonic tone, no significant effect of environment on recovery of hedonic tone was found after adding preference as mediator. However, the *b* path (effect of preference on hedonic

Table 5.6 Overview of the mediation analyses for preference on the effect of environment on hedonic tone and LF/HF ratio

Dependent	a (SE)	b (SE)	c (SE)	c' (SE)	ab Indirect effect (SE)	95% Confidence Interval Indirect effect	Sobel (Z)
Hedonic tone	-1.51** (.22)	.15 (.08)	-.39* (.19)	-.17 (.22)	-.23 (.13)	(-.52) - (-.01)	-1.83
LF/HF ratio	-1.34** (.27)	.05 (.10)	.57* (.25)	.63* (.28)	-.06 (.14)	(-.42) – (.17)	-.49

Note: the ab path is calculated using bootstrapping and no significance is indicated
** p < .05, **p < .001*

tone) showed a non-significant trend (*p* = .063) and Sobel's test also revealed a marginally significant mediation effect (*p* = .068). For LF/HF ratio, no significant mediation of preference was found.

5.3.3 Discussion

In Study Two, the aim was to replicate findings of Study One. Furthermore, we added a more sensible measure of mood and tested for instorative as well as restorative effects. An alternative dependent self-regulation task was employed. This time, no significant effects of Depletion or Environment were found on performance. Thus, although beneficial effects of natural environments on self-regulation (controlling impulses) were established in Study One, these were not confirmed in the higher-order executive functioning task in the present study.

Natural environments did significantly affect improvement in hedonic tone and LF/HF ratio while viewing the slideshow. The effect of Environment occurred irrespective of whether participants had performed the Depleting or Non-depleting induction tasks. Thus, beneficial effects on mood and physiology appeared to occur irrespective of depletion.

5.4 General discussion

Our first aim in this chapter was to empirically test a recently proposed theoretical link between ego-depletion and Attention Restoration Theory (Kaplan & Berman, 2010), by investigating whether exposure to natural environments could have ego-replenishing effects. We tested this in two studies, which were similar in terms of procedure with a number of exceptions. In the second study we used a stronger depletion induction, a more cognitively taxing performance task, and the design was slightly revised in order to allow testing of instorative effects.

5.4.1 Ego-replenishing effects of nature on self-regulatory performance

In Study One we indeed found that viewing pictures of natural environments after depletion resulted in better self-control capacity than viewing urban images or no content at all. Furthermore, we found beneficial effects on mood, physiology, and preference. In Study two, we did not replicate the restorative effects of brief nature exposure on the performance task, but again found beneficial effects on mood – (hedonic tone) and on physiology (HRV). Interestingly, in Study Two we found that these beneficial effects of nature occurred irrespective of whether participants had been depleted or not.

The main goal of this chapter was to test whether brief exposure to nature -in comparison to urban scenery- could serve to replenish ego-depletion within a typical ego-depletion test paradigm. We tested this twice, yet unfortunately the effects on performance found in Study One were not replicated in Study Two. In Study One, we used the Stroop task as the dependent self-control task, requiring participants to suppress impulses. After the Stroop task, we included the OSPAN task, a working memory task. Whereas we found beneficial effects of nature on performance on the Stroop task, we found no effects of scene content on the OSPAN task. Initially we hypothesized that the detrimental effects of the depletion induction or the beneficial effects of natural scenes might have vanished by the time participants started the OSPAN task. However, in Study Two, we used a memory task (the 2-back task) to measure self-regulation instead of the Stroop (immediately following the slideshow) and did not any find evidence for beneficial effects of nature here either. In past research, beneficial effects of nature have mostly been found on tasks similar to the Stroop task, but some field studies have shown better performance on tasks similar to the 2-back task (e.g., Berman et al., 2008; Kuo & Sullivan, 2001). Our findings therefore appear to contradict these earlier studies. The crucial difference between those studies and ours is perhaps that because ego-depletion effects vanish rather quickly, we used an extremely short exposure to nature (3 minutes instead of 20-50 minutes generally used in restoration research). We suspect that only the lower order self-regulatory tasks (e.g., controlling impulses) will benefit from this shorter exposure duration and that more complex tasks may require longer exposure in order for nature to take effect.

The Strength model poses that exerting self-control depletes a limited resource, resulting in temporarily lowered self-regulation strength. Process theory, on the other hand, poses that a decline in self-regulatory performance is not due to resource depletion (Inzlicht & Schmeichel, 2012). Rather, it is caused by shifts in motivation and attention. According to Inzlicht and Schmeichel (2012), people will actively seek gratification after exerting self-control. We only found evidence for beneficial effects of nature on self-regulatory performance in Study One. In this study, we only investigated effects of nature after performing a depleting task. In Study Two, we did investigate performance effects after performing both a depleting and non-depleting task but did not find evidence for any improvements in performance. As discussed above, this may be due to the nature of the task used in Study Two. For these reasons, we are unable to conclude whether the improvements in self-regulatory performance found are due to restorative or instorative processes. However, as will be discussed in the next sections, there are some indications for instorative rather than restorative effects for mood and physiological response.

5.4.2 Effects on mood and physiology: restorative or instorative?

Participants of Study One reported feeling more pleasure during the slideshow depicting natural environments. In Study Two we added mood measures before and after the slideshow and found that the increase in reported hedonic tone for participants viewing natural scenes was larger compared to participants viewing urban scenes, again irrespective of whether they first performed the depleting or non-depleting task. These results are in line with earlier research reporting positive effects of nature on mood (Berman et al., 2008; van den Berg, et al., 2003).

In both studies, participants who had viewed natural scenes also reported a higher preference for the displayed environments than participants who had viewed urban scenes.

Earlier research has already indicated that emotional recovery during nature exposure mediated preference ratings (van den Berg et al., 2003). We were able to show mediation in the opposite direction; higher preference mediated the increase in hedonic tone.

Although heart rate appeared insensitive to our manipulations, we did find beneficial effects of exposure to nature scenes on heart rate variability in both studies. In Study One, viewing natural scenes buffered the HRV response to the subsequent Stroop task. In Study Two, participants who viewed nature scenes had a better HRV recovery, irrespective of whether they were depleted beforehand. Heart rate variability has been found related to both the exertion of self-control (Thayer et al., 2009) and to stress (Berntson & Cacioppo, 2004). The present study did not enable us to distinguish between these two processes. Therefore, a lower LF/HF ratio in the nature groups could have signalled both a decrease in stress level as well as a decrease in the amount of self-regulatory capacities needed.

These results indirectly suggest that improvements in self-regulatory performance may be as much instorative as they are restorative. Research has already indicated that nature can increase intrinsic motivation (Weinstein, Przybylski, & Ryan, 2009). Moreover, exposure to natural environments has consistently been found to improve mood (Berman et al., 2008, van den Berg et al., 2003; Hartig et al., 2003), a result also found in both our studies. Positive affect, in turn, has been linked with better self-regulation (Aspinwall, 1998; Tice et al., 2007). Nature, thus, might be the reward people are looking for and beneficial effects of nature on self-regulation might run through affective pathways.

5.4.3 Limitations

There are some limitations to the studies reported in this chapter. First, in Study One the experimenter recorded reaction times on the Stroop task. As the experimenter was not blind to conditions, this might have (unconsciously) affected outcomes. However, the verbal Stroop task has generally been administered in this manner. Second, in Study Two the induction tasks sometimes affected groups differently. For instance, the change in heart rate during the Stroop task in the Non-depletion condition differed between the Urban and Natural group. This difference can be considered a baseline difference, as this difference occurred before the groups watched the two different environmental scenes. On the other hand, these baseline differences were not found for our main outcomes; LF/HF ratio and hedonic tone, suggesting that outcomes on these variables were not affected by baseline differences.

5.4.4 Conclusion

Only few studies have compared beneficial effects of nature with vs. without an initial stress or attentional fatigue induction. Our results seem to suggest that beneficial effects of nature occur regardless of mental fatigue induction. In other words, it appears that nature has, what Hartig and colleagues (1996) call instorative effects on self-regulation rather than restorative effects.

Regardless of the pathways through which nature influences self-regulation, the results indicate that a three-minute exposure to natural environments could potentially already help us improve self-regulatory capacity needed to control impulses. As a strong self-regulatory capacity is important for numerous health outcomes, our findings once more stress the importance of exposure to nature in our daily lives.

Chapter 6

In broad daylight.

Effects of daylight versus electric light on self-regulation, mood, and physiology.[1]

Black turns beamy bright
Turning on the light
Today is gonna be the day
you hear somebody say
we need you wide awake
(Agnes Obel - Just so)

[1] This Chapter is based on: Beute, F. & de Kort, Y.A.W. (in preparation). Exposure to daylight versus electric light and self-regulation, mood, and physiology after ego-depletion.

Abstract. Restorative effects of daylight versus electric light on self-regulation, mood, and physiology were investigated. A short exposure duration to daylight was employed, similar to the research paradigm used to test for restorative effects of nature in the previous chapter. The main focus was on psychological as opposed to biological effects of daylight, through the beliefs and connotations people have with daylight. Whereas a short exposure to natural environments was found to consistently improve hedonic tone and heart rate variability, no evidence was found for restorative (or instorative) effects of a short exposure to daylight. Surprisingly, beliefs regarding effects of daylight on wellbeing were not always different from beliefs about electric light. Preference ratings for daylight were consistently higher than for electric light. A lack of restorative effects could be due to the absence of more positive beliefs about daylight compared to electric light. An alternative explanation for the absence of restorative effects is that we used a foil to avoid view content, thereby excluding some characteristics that normally accompany daylight such as a view or directional sun beams. These additional characteristics of daylight might be crucial for daylight to exhibit restorative effects through psychological pathways.

6.1. Introduction

Generally, if people have the choice they will prefer sitting close to the window. Windows not only bring us a view to the outside, but also offer daylight entrance during daytime. In the previous chapter we saw beneficial effects of natural views on self-regulation, hedonic tone, and heart rate variability. In this chapter, we will investigate whether daylight exposure - stripped from view content- also exhibits beneficial effects. Importantly, one of the main findings in the previous chapter was that, contrary to the prevailing experimental tradition in restoration research, the beneficial effects of nature occurred irrespective of any antecedent manipulation. Lighting research has a slightly different research tradition. At first sight, little research has investigated effects of light after experimentally inducing resource depletion or stress. However, in many studies stressful situations or low affective states had already been introduced or were naturally present, albeit implicitly in some instances. For example, effects of light have often been studied using constant routine protocols. These protocols are employed to reliably measure biological effects of light on the circadian rhythm, but pose unnatural and possibly stressful situations on the participants. For instance, during this constant routine, participants are isolated from the outside world, they do not receive any time cues, are sleep deprived, and are oftentimes kept in a supine position. Other studies have focused on the therapeutic effects of light, investigating beneficial effects of exposure to bright light on pre-existing (mental) disorders. In this chapter we will investigate whether exposure to natural light as opposed to electric light can have beneficial effects on self-regulation, mood, and physiology after experimentally inducing resource depletion in healthy participants. Two studies were conducted to investigate whether a short exposure to daylight as opposed to electric light can be restorative, with the main focus on psychological underlying pathways. To this end, a similar research paradigm as used in Chapter Five was employed.

6.1.1 Effects of daylight on self-regulation, mood, and physiology

In Chapter One, we reviewed a variety of effects of bright light on mood, executive functioning, and physiology. In this section, these effects will be briefly revisited, but only for studies investigating exposure to daylight.

A number of studies has found that exposure to daylight can increase positive affect. First of all, a 30-minute exposure to daylight at noon was found to improve feelings of pleasure (Kaida et al., 2007). In an experience sampling study among participants with subsyndromal Seasonal Affective Disorder, it was further found that light with intensity higher than 1000 lx (which is very likely to represent exposure to daylight) increased positive affect (aan het Rot et al., 2008). Similarly, a reduction in depressive symptoms after walking outdoors in daylight in winter was found for patients suffering from Seasonal Affective Disorder (Wirz-Justice et al., 1996). Amount of sunshine has also been found to be related to an increase in positive affect, both in an experience sampling study using momentary correlations between mood and weather data (Kööts et al., 2011) and in a study comparing online diary data with daily weather indices (Denissen et al., 2008). Studies investigating the opposite relation between light and wellbeing revealed that too little daylight exposure can also be harmful, with underexposure to daylight at work related to an increase in stress (Alimoglu, & Donmez, 2005) and a decrease in sleep quality (Leger, Bayon, Elbaz, Philip, & Choudat, 2011). Beneficial effects of daylight on mental wellbeing have been reported as well. For instance, having windows in an Intensive Care Unit was proven beneficial for mental wellbeing (Keep, James, & Inman, 1980; Wilson, 1972). In both studies, patients staying in an IC unit with windows had a better recollection of the stay in the unit and experienced less hallucinations.

Besides effects of the presence or absence of windows, the amount of daylight entering hospital rooms has been found to affect patient's wellbeing. A shorter duration of hospitalisation was reported in bright as compared to dim rooms for depressed patients (Beauchemin & Hays, 1996; Benedetti et al., 2001) and cardiac patients (Beauchemin & Hays, 1998). Besides length of stay, the use of pain medication after spinal surgery was found to be lower in brighter rooms than in dim rooms (Walch, et al., 2005).
Some studies also investigated the effect of daylight exposure on physiological responses.

The amount of sunshine was found related to the production of the mood-related neurotransmitter serotonin (Lambert et al., 2002). Furthermore, one study compared long-term physiological responses to daylight versus electric light in classrooms in Sweden (Küller & Lindsten, 1992). They found a seasonal pattern for cortisol production, with higher morning cortisol levels in summer than in winter. However, children allocated to classrooms

with no windows showed a disturbed seasonal pattern of cortisol production. Based on these findings, the authors concluded that windowless classrooms should be avoided.
Last, some studies have investigated the relation between daylight and performance. Exposure to daylight positively influenced subjective alertness, but not actual performance on the psychomotor vigilance task (Kaida et al., 2006). Münch and colleagues (2012) found further evidence for possible beneficial effects of daylight on executive functioning. They exposed participants to 8 hours of either (dim) electric light or (bright) daylight and found that executive functioning improved. Indirect evidence for beneficial effects of daylight on executive was found in an experience sampling study, namely that spending time outdoors increased vitality (Ryan et al., 2009). As was already mentioned in Chapter One, vitality is highly related to self-regulation with higher vitality related to better self-regulatory capacity.

6.1.2 Rationale

The relatively low number of studies on beneficial effects of daylight reported in the previous section is indicative of how little attention has been given to effects of daylight within the light domain. Furthermore, even fewer studies directly compared daylight with electric light. And those studies that made this direct comparison did not match the intensity of the light conditions, thereby introducing a possible confound. Therefore, as of yet the predictions regarding beneficial effects of exposure to daylight need to be mainly extracted from studies investigating effects of exposure to bright electric light. As was introduced in Chapter One, (repeated) exposure to bright electric light has been found to improve mood (Avery et al., 2001; Leppämäki et al., 2002; Partonen, & Lönnqvist, 2000), executive functioning (Phipps-Nelson et al., 2003; Smolders et al., 2012), and cardiovascular activity (Krause et al., 1998; Rechlin et al., 1995). However, our predictions concern a superior effect of daylight over electric light, through psychological mechanisms.

These predictions are based on the preferences, beliefs, and connotations that people have with daylight. In Chapter Two, a consistent explicit preference was found for pictures that were sunny and bright (i.e., containing more daylight). Moreover, in Chapter 4, a preference for daylight over electric light was reported. Preference serves adaptive purposes, guiding humans to approach healthy or avoid detrimental environments. We also saw that preference has been empirically linked with the restorative potential of an environment. Therefore, higher preference ratings for daylight as opposed to electric light gave us a first indication of the possible restorative potential of daylight. Humans not only as a fairly general rule prefer daylight over electric light, studies have also indicated that we generally believe that daylight has better effects on our mood, health, and performance than electric light (Haans, 2014; Veitch et al., 1993; Veitch & Gifford, 1996; Wells, 1965). Similarly, in Chapter Four, we found that associations with daylight consistently score higher on health, energy, and relaxation than electric light. Furthermore, people generally prefer having windows in their office over having no windows (e.g., Markus, 1967). Besides more positive preference ratings and beliefs, in Chapter Four we also found that people generally have more positive connotations with daylight than with electric light. These results regarding preference and associations were largely in line with findings regarding natural versus urban environments.

In the previous chapter, we saw that a three-minute exposure to natural environments improved positive affect, heart rate variability, and self-regulatory performance. In this chapter, a similar short exposure duration was used for exposure to daylight versus electric light, albeit that after introducing daylight to the room it remained present throughout the experiment. The studies discussed in the previous section all used longer exposure durations, with the shortest exposure to daylight being 30 minutes in the study by Kaida and colleagues (2007). In the studies presented here, effects of exposure to daylight were measured after a mere 1 or 2-minute initial exposure. We explicitly opted for a relatively short initial exposure duration as well as matching the light intensity of daylight and electric light as much as possible because we were mainly interested in psychological effects of daylight versus electric light. In line with effects of natural environments, these effects could run through higher preference ratings resulting in differential approach and avoidance motivations. Other possible pathways run through the superior beliefs people have concerning daylight versus electric light and through associative pathways.

6.2 Study One

6.2.1 Method

6.2.1.1 Design

The experiment contained four conditions, in an incomplete design. Two conditions were added to test for the effectiveness of the ego-depletion induction. They either contained a non-depleting (No light (Non-depletion)) or depleting (No light (Depletion)) induction task, with no additional light exposure. Two conditions tested the effects of exposure to Electric (Electric (Depletion)) versus natural (Daylight (Depletion)) light after depletion. First, we expected that when comparing the two No light conditions, a decrease in performance on the second task would arise for the Depletion condition compared to the Non-depletion condition. We further expected the Depleting version of the typing task to negatively affect mood and physiological responses. Second, we expected exposure to daylight -but not exposure to electric light- to overcome these depleting effects on performance, mood, and physiology.

6.2.1.2 Participants

In total, 76 participants participated in the study (40 males). The No Light (Non-depletion) and No light (Depletion) conditions were both completed by 18 participants, whereas 20 participants completed either the Electric light (Depletion) or the Daylight (Depletion) condition. The age of the participants ranged between 18 and 50, with a mean age of 23.32

(*SD* = 5.34). The duration of the experiment was approximately 45 minutes and participants received €7.50 as compensation.

6.2.1.3 Procedure

After signing the consent form, the ECG electrodes were attached and participants were seated behind a computer and desk facing either the (closed) window or wall armature (switched off). The experiment started with a baseline mood measurement (baseline; t_0), followed by a baseline period of three minutes for the physiological measurements. During this period, participants were instructed to sit still and relax and were told that the experiment would proceed within a couple of minutes. A subsequent Stroop task completed the baseline phase. Then, the induction task started (the typing task). Participants either completed the non-depleting (No light (Non-depletion)) or depleting (No light (Depletion); Daylight (Depletion); Electric light (Depletion)) version. The typing task was followed by the one-minute experimental light block in which participants in the No light conditions received no additional light and completed a second mood questionnaire (Post induction, t_1), whereas participants in the Daylight and Electric light condition received additional light (either natural or electric). After the experimental light block, all participants again completed the Stroop task. Participants in the No light conditions completed the mood questionnaire for the third time (Post Stroop; t_2), whereas participants in the Daylight and Electric light conditions had a one-minute experimental light block to take in the light setting and subsequently performed a second performance task (the Backward Digit Span task). After this task, participants in the Daylight and Electric light conditions completed the mood questionnaire for the second time (Post BDS ;t_3). The experiment ended for all participants with a questionnaire consisting of various scales (e.g., measuring perceived stress; trait self-control), which will not be discussed in this dissertation. Participants were thanked and paid for their effort. See also Figure 6.1 for the experimental set-up.

6.2.1.4 Ego-depletion induction – Typing task

For the induction, the same typing task was used as in the previous Chapter, see Section 5.2.1.4.

6.2.1.5 Manipulation – Lighting settings

The experiment was run in late winter and springtime (March, April, and May), in the HTI Lighting Lab, see Figure 6.2 for the experimental set-up. The baseline light setting for the experiment was a horizontal light intensity of 200 Lx on the desk (vertical illuminance approximately 75 Lx. at eyelevel) with a Correlated Colour Temperature (CCT) of 4000 K. For the baseline light setting ceiling armatures (DALI controllable Savio light fixtures) were used. In the Daylight and Electric light conditions, additional daylight or electric light was allowed in the room once participants were finished with the mood questionnaire after the induction task. Contrary to the manipulations used in Chapter Five, the light manipulation remained present until the end of the experiment.

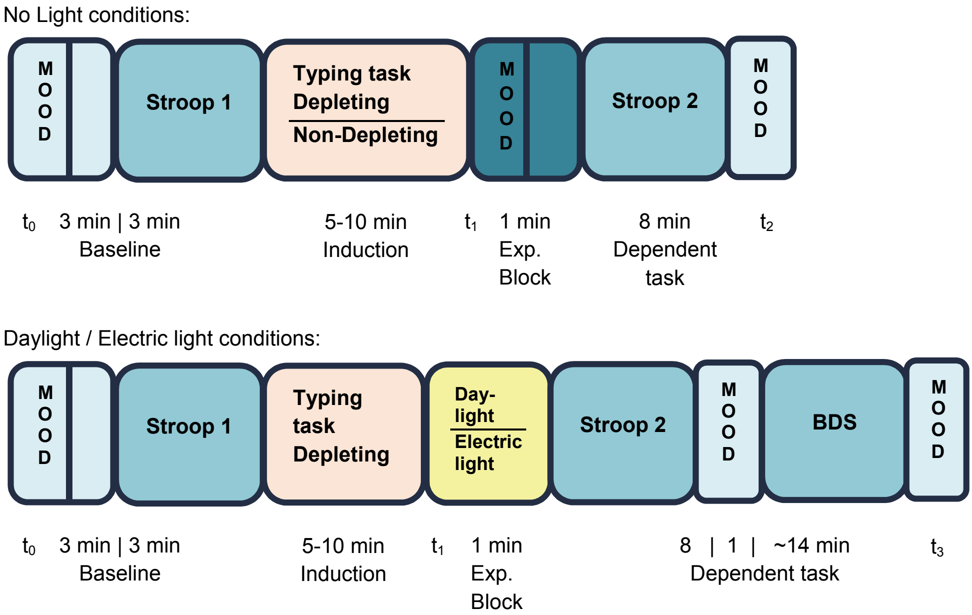


Figure 6.1 Overview of the experimental set-up

For the daylight condition, a sunscreen was opened in front of a window (1.49 x .69 m) with an orientation to the East. To avoid confounds by view content, the window was covered with a translucent foil. For the electric light condition, a wall-mounted armature of approximately the same dimensions (1.24 x .62**,** DALI controllable Philips Savio fixtures) was used.

Light intensity was matched for the electric light and daylight condition. To this end, the daylight condition was always run before the electric light condition. Light intensity was logged throughout the experiment with two lux cells. One lux cell was placed on the desk measuring the horizontal light intensity and one lux cell measured vertical light intensity at eyelevel (1.20 m.). Light intensity of the electric light was matched to that of the daylight condition at eyelevel, in the gaze direction. CCT was measured once at eyelevel in the direction of gaze at the end of the experiment and this value was used to set the CCT in the electric light condition.

Figure 6.2 Laboratory set-up for the daylight condition.

Because of our biological rhythm, light can affect humans differently at different times of the day. Therefore, it is important to have an even distribution of lighting conditions across the day. During the experiment, therefore, it was ensured that a similar amount of conditions were conducted in the morning versus the afternoon. A chi-square analysis was conducted to confirm an even distribution of daylight and electric light conditions over the morning and evening ($\chi^2(1) = 1.0$, $p = .337$). Table 6.1 displays the distribution of the light conditions over the different timeslots, including the mean light intensities (measured at eyelevel). To further establish that both conditions were successfully matched in light intensity and CCT, two ANOVA's were run with condition (daylight vs. electric light) and time of day (morning vs. afternoon) as independent variables and CCT and intensity as dependent variables. These analyses revealed a significant difference in light intensity between morning and afternoon ($F(1,36) = 5.8$, $p = .022$, $\eta_p^2 = .14$), with a higher light intensity for both conditions in the afternoon ($M = 284.7$, $SE = 14.8$) than in the morning ($M = 230.1$, $SE = 17.3$), see Figure 6.3. No further significant main effects or interaction effects for either the intensity of the light or CCT ($F < 2.2$, $p > .150$) were found indicating that no difference in light exposure was found between conditions.

Table 6.1 Light conditions, light intensity, and CCT distribution over the different timeslots

		9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Daylight	Number of participants	0	6	1	4	4	2	1	3
	Mean light intensity	-	227.5	167.0	348.5	281.3	292.0	182.0	217.7
	Mean CCT	-	5322.2	5144.0	5542.8	5168.0	5178.5	5093.0	4919.3
Electric light	Number of participants	2	5	3	2	1	2	3	3
	Mean light intensity	219.3	255.1	233.2	299.6	392.5	360.6	223.1	286.2
	Mean CCT	50250	5218.0	5136.3	5434.0	5812.0	5612.0	5243.0	5130.0

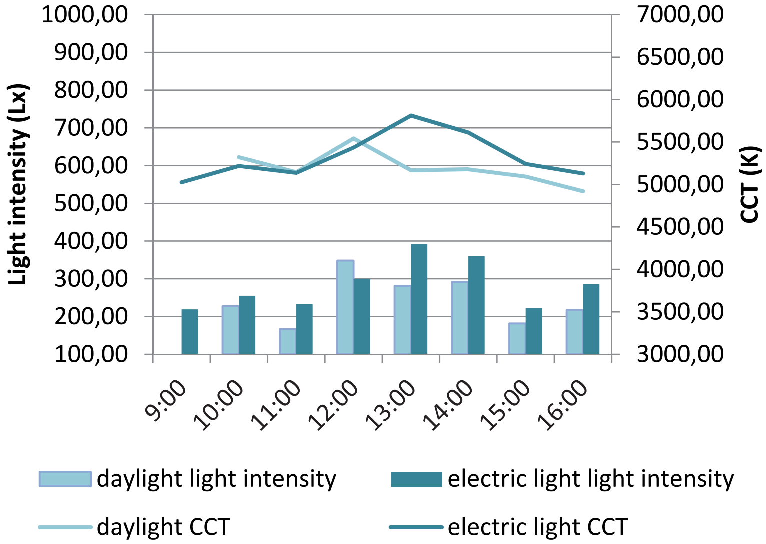


Figure 6.3 Light intensity and CCT in the different timeslots

6.2.1.6 Measures

Mood Mood was measured with a 20-item mood scale, measuring three dimensions (hedonic tone, energy, and tension), see Section 3.3.1.8 for a description.

Performance task 1 – Stroop Participants performed a computerized version of the Stroop task twice, once to establish a baseline and once as the dependent variable. Two colours were used for the ink colours and word names; red and blue. Participants were instructed to respond with the keys ‘g’ (for blue) and ‘h’ (for red). In both sessions, the trials were predominantly congruent (80%).

Each trial was proceeded by a fixation point displayed for 500 ms. The word was displayed for 200 ms. and participants were given 1500 ms. to respond. Before the baseline measure, participants first completed 20 practice trials. In the baseline Stroop task, participants completed 80 trials and the dependent Stroop task consisted of 200 trials. Dependent variables were the amount of errors made and reaction times to incongruent trials.

Performance task 2 – Backwards Digit-Span task This second performance task was only administered to the participants in the Electric light and Daylight conditions. Sequences of digits were displayed on the screen, with sequence size varying between 3 and 9 digits each. Participants were instructed to report each sequence in backward order. In total, 14 trials (2 for each sequence length) were completed. Scores were calculated as the total number of digits in correctly reported trials as well as the largest correct span.

Physiological measures. Similar to Study One of the previous Chapter, we measured heart rate (HR) and heart rate variability (LF/HF ratio). See section 5.2.1.6 for a detailed description. A three-minute baseline was added at the beginning of the experiment to establish a baseline for the physiological measures.

Lighting assessment – Manipulation check (naturalness & lightness), Preference, and Beliefs. In the Electrical light and Daylight conditions, participants were asked to rate the lighting conditions on a number of variables. Two questions were added as a manipulation check; they were asked to report how natural and how light the lighting setting was, on a scale of 1 (not at all) to 7 (to a very high degree).

Preference was measured on two dimensions; aesthetics and attitude (after Staats, Kieviet, & Hartig, 2006). Aesthetics was measured by asking participants how [beautiful, pleasant] they rated the current lighting situation. Attitude was measured by asking participants how [pleasant, attractive, positive] it would be to stay in their current light setting for one additional hour. Both aesthetics and attitude were measured on a scale ranging from 1 (not at all) to 7 (to a very high degree). Both scales had good reliabilities (aesthetics: $\alpha = .81$; attitude: $\alpha = .95$).

Lighting beliefs were assessed with 8 items (after Haans, 2014**)**. Factor analysis revealed one predominant factor (Wellbeing Beliefs) incorporating 6 of the 8 items (*"How beneficial do you think this light is for your health?", "Do you think this light cheers you up?", "To what extent does this light improve your concentration?", "Do you think this light improves your health?", "Do you expect this light to give you renewed energy?",* and *"Do you think this light increases your fitness?"*), with a reliability of $\alpha = .9$. Two items did not fit this factor (*"How well do you think your attention to your task is influenced by this light?"* (Attention) and *"To what extent can you relax with this light?"* (Relaxation)). These items were analysed as single items.

6.2.1.7 Data analysis

Again, residualised change scores were used to calculate the effect of ego-depletion and our light manipulation on mood and physiological responses to overcome problems with conventional change scores, see Section 3.3.1.8 for the rationale. Furthermore, residualised change scores were also calculated for performance on the Stroop task.

For the physiological analyses, the continuous physiological data were subdivided into segments (baseline; Stroop1; typing task; experimental light block (only HR); Stroop2; BDS (only daylight & electric light condition)). Changes in heart rate and LF/HF ratio were analysed by calculating residualised change scores for each subsequent segment. For the LF/HF ratio, however, the experimental light block was disregarded because this segment was too short to reliably measure heart rate variability. Therefore, the change score was calculated between the typing task and Stroop task. Because the same Stroop task was administered twice, cardiovascular response to the second Stroop task could also be compared to the first to establish effects of the Depletion or Light manipulation on HR and LF/HF ratio. For reaction times and physiological measures, scores deviating more than two standard deviations from the mean were considered outliers and deleted from the data.

6.2.2 Results

We will first discuss the effects on self-regulatory performance. Then, the results on mood, physiology, and assessment of the light setting will be discussed (in this order). In each section two different analyses will be presented. First, the effects of the Depletion manipulation were tested by comparing the two No light conditions. Second, the analysis of the restorative effects of the light manipulations was conducted by comparing the three Depletion conditions (No light vs. Daylight vs. Electric light).

6.2.2.1 Effects of the depletion induction and light manipulation on self-regulatory performance

First, the two No Light conditions were compared to confirm ego-depleting effects of the induction task on performance. We used a similar experimental paradigm as in Section 5.2, but contrary to our expectations and the findings in that study, we did not find evidence for ego-depleting effects of the typing task on a subsequent Stroop task here. The change in reaction times to incongruent trials during the second Stroop task compared to the baseline Stroop task appeared unaffected by Depletion ($F(1,33) = <.1$, $p = .963$). Moreover, no significant difference in the change in amount of errors made during the second Stroop task was found ($F(1,33) = .3$, $p = .591$). See Table 6.2 for means and standard errors.

Similarly, no effects of the light manipulation on performance were found on reaction times or amount of errors made ($F < .9$, $p > .427$), see Table 6.2. No significant difference between

Table 6.2 Performance on Stroop task and BDS task (raw scores).

			No light (Non-depletion) Mean (SE)	No light (Depletion) Mean (SE)	Electric light (Depletion) Mean (SE)	Daylight (Depletion) Mean (SE)
Stroop 1	Reaction times	congruent	217.5 (19.66)	191.39 (15.54)	194.23 (12.29)	180.18 (13.74)
		incongruent	261.03 (27.21)	202.43 (20.33)	210.03 (14.25)	199.94 (17.81)
	Errors	congruent	4.44 (1.30)	4.28 (.84)	3.80 (.79)	4.70 (1.32)
		incongruent	2.61 (.62)	3.67 (.84)	2.45 (.58)	2.70 (.33)
Stroop 2	Reaction times	congruent	205.85 (14.08)	180.89 (12.08)	181.34 (11.89)	175.93 (13.64)
		incongruent	229.86 (18.35)	199.10 (15.95)	195.56 (12.70)	196.89 (16.89)
	Errors	congruent	7.39 (2.19)	6.78 (1.11)	8.15 (2.11)	8.80 (2.13)
		incongruent	5.17 (1.12)	5.72 (1.11)	7.05 (1.87)	5.70 (.76)
BDS	number of correct digits		-	-	25.60 (3.21)	25.60 (2.70)
	largest correct span		-	-	5.85 (.36)	6.15 (.28)

Table 6.3 Means and standard errors of all mood variables (raw scores).

	Time	Tension M (SE)	Energy M (SE)	Hedonic tone M (SE)
No light	Baseline (t_0)	2.04 (.10)	3.90 (.13)	3.86 (.12)
(Non-Depletion)	Post Induction (t_1)	2.38 (.12)	4.06 (.16)	3.73 (.13)
	Post Stroop (t_2)	2.25 (.11)	3.81 (.16)	3.63 (.14)
No light	Baseline (t_0)	2.19 (.11)	3.69 (.10)	3.76 (.12)
(Depletion)	Post Induction (t_1)	2.48 (.15)	3.69 (.11)	3.51 (.14)
	Post Stroop (t_2)	2.40 (.13)	3.58 (.13)	3.50 (.13)
Electric light	Baseline (t_0)	2.21 (.09)	3.72 (.14)	3.91 (.09)
(Depletion)	Post BDS (t_3)	2.38 (.13)	3.54 (.16)	3.62 (.12)
Daylight	Baseline (t_0)	2.16 (.10)	3.79 (.13)	3.90 (.07)
(Depletion)	Post BDS (t_3)	2.52 (.13)	3.73 (.14)	3.58 (.08)

the daylight and electric light condition in BDS performance was found on either the total amount of correct digits or the largest correct span ($F < .3$, $p > .589$), see Table 6.2.

6.2.2.2 Effects of the depletion induction and light manipulation on mood

No baseline differences were found between any of the four conditions on hedonic tone, energy, or tension (all $F < 1.5$, all $p > .227$). After establishing that no baseline differences had occurred, we first investigated whether mood was affected by the induction task by comparing changes in mood after the induction (t_1) between the Depletion and Non-depletion condition. No significant effect of the Depletion task was found on energy, hedonic tone, or tension ($F < 1.7$, $p > .207$). These findings disconfirmed our hypotheses concerning the effect of Depletion on mood. Subsequently, no difference in mood between the two depletion conditions was found on any of the mood dimensions after the Stroop task (t_2; $F < .6$, $p > .449$).

Mood was measured at different times in the No light conditions than in the Daylight and Electric light conditions, therefore only mood outcomes for Daylight and Electric light were compared. The effect of the light manipulation was measured by comparing residualised change scores between baseline (t_0) and after the Backward Digit Span Task (t_3), which revealed no significant effect of the light manipulation on any of the mood dimensions (all $F < .8$, all $p > .427$). Table 6.3 displays the means and standard errors for the mood dimensions.

6.2.2.3 Effects of the depletion induction and light manipulation on physiological responses

First, the effect of Depletion on heart rate and LF/HF ratio was investigated by comparing the No light (Depletion) condition with the No light (Non-depletion) condition. No baseline differences in HR and LF/HF ratio ($F < .5$, $p > .659$) were found. These analyses again did not confirm our hypothesis, as no significant effect of Depletion on HR and LF/HF ratio during any of the segments ($F < .8$, $p > .387$) was found. When comparing cardiovascular response during the second Stroop task (Stroop2) to the baseline Stroop (Stroop1), only a

Table 6.4 Means and standard errors for the physiological measures (raw scores).

	Segment	Heart Rate M (SE)	LF/HF ratio M (SE)
No light	Baseline	72.90 (2.39)	1.67 (.31)
(Non-depletion)	Stroop1	71.19 (2.98)	1.17 (.24)
	Type task	74.26 (2.65)	1.31 (.22)
	Experimental light block	75.04 (2.61)	-
	Stroop2	73.66 (3.25)	1.33 (.26)
No light	Baseline	73.61 (3.33)	1.28 (.27)
(Depletion)	Stroop1	75.27 (3.27)	1.47 (.36)
	Type task	75.37 (3.60)	2.31 (.31)
	Experimental light block	74.96 (3.48)	-
	Stroop2	74.20 (3.45)	1.60 (.44)

non-significant trend was found for Depletion (F(1,23)= 3.2, p = .087, $\eta_p{}^2$ = .12), with a slightly higher heart rate in the Depletion condition during the second Stroop task. See Table 6.4 for means and standard errors.

Second, the three Depletion conditions (No light vs. Daylight vs. Electric light) were compared. As can be seen in Table 6.5, no baseline differences were found. One significant effect of the light manipulation on HR change during the one-minute experimental light block was found (F(2,33) = 3.7, p = .034, $\eta_p{}^2$ = .19). Planned contrasts revealed a significant difference between the Daylight and Electric light condition (t(33) = 2.8, p = .010), with a decrease in HR in the Daylight condition as opposed to an increase in HR during the Electric light condition, see Table 6.5. No further significant effects of the lighting manipulation were found on HR or LF/HF ratio.

6.2.2.4 The assessment of the light setting: Manipulation check, preference, and beliefs

In the two lighting conditions, we asked participants to rate their lighting situation. Participants in the Daylight condition rated the light as significantly more natural (M = 4.33, SE = .30) than participants in the Electric light condition (M = 2.05, SE = .30; F(1,40) = 28.3, p < .001, $\eta_p{}^2$ = .41). Furthermore, the light in the daylight condition was rated as equally light (M = 4.05, SE = .33) as in the electrical light condition (M = 4.00, SE = .33; F(1,40) = .1, p = .920). These outcomes indicate that our manipulation was successful in introducing natural vs. electric light with the same perceived intensity, see Figure 6.4.

When investigating differences in beliefs concerning the lighting situation, a non-significant trend was found between the Daylight and Electric light condition (F(1,40) = 3.0, p = .092, $\eta_p{}^2$= .07) on beliefs concerning the effects of light on Wellbeing, with slightly more positive beliefs for daylight than for electric light. A significant effect was found on beliefs concerning relaxation (F(1,40) = 10.4, p = .003, $\eta_p{}^2$= .21), with daylight scoring higher on relaxation than electric light, see Table 6.6.

Table 6.5 F-values, means, and standard errors for the physiological measures in the Light manipulation conditions (raw scores)

	No Light	Electric Light	Daylight	Effect Light manipulation		
Heart Rate	M (SE)	M (SE)	M (SE)	df	F	*ηp2*
Baseline[1]	73.61 (3.33)	75.25 (3.06)	69.78 (3.27)	33	.4	-
Stroop1[2]	75.27 (3.27)	77.34 (2.68)	73.21 (3.53)	32	.9	-
Type task[2]	75.37 (3.60)	77.73 (3.11)	73.20 (3.51)	32	<.1	-
Light block[2]	74.96 (3.48)	80.13 (3.17)[a]	70.87 (2.65)[a]	33	3.8*	.19
Stroop2[2]	74.20 (3.45)	77.61 (3.25)	71.66 (3.03)	34	1.1	-
BDS[2]	-	77.56 (2.92)	70.89 (3.14)	23	.5	-
Stroop1 vs 2[3]	-	-	-	32	1.4	-
LF / HF ratio						
Baseline[1]	1.28 (.27)	1.51 (.40)	1.17 (.22)	33	.3	-
Stroop1[2]	1.47 (.36)	1.05 (.24)	1.52 (.39)	32	1.0	-
Type task[2]	2.31 (.31)	1.01 (.16)	1.00 (.19)	31	.3	-
Light block[2]	-	-	-	-	-	-
Stroop2[2]	1.60 (.44)	1.15 (.24)	1.30 (.25)	31	.7	-
BDS[2]	-	1.47 (.21)	1.51 (.26)	22	<.1	-
Stroop1 vs 2[3]	-	-	-	32	.4	-

[1] the F-values represent baseline differences, [2] the f-values represent differences in residualised changes compared to the previous segment, [3] the f-values represent the difference between the baseline Stroop (Stroop1) and second Stroop task (Stroop2). Values in rows with the same superscript letter are significantly different.
** $p < .05$*

Preference toward the lighting situation was measured on two dimensions; aesthetics and attitude. We found that participants in the Daylight condition rated the light as more aesthetically pleasing than participants in the Electrical light condition ($F(1,40) = 10.4$, $p = .003$, $\eta_p^2 = .21$). Participants in the Daylight condition also indicated a more positive attitude toward spending one hour in that light setting than participants in the Electric light condition ($F(1,40) = 7.4$, $p = .010$, $\eta_p^2 = .16$), see Table 6.6 and Figure 6.5.

Table 6.6 Preference (attitude and aesthetics) and Lighting beliefs

		Electric light (Depletion) Mean (SE)	Daylight (Depletion) Mean (SE)
Preference	Aesthetics	2.88 (.31)[a]	4.12 (.24)[a]
	Attitude	3.03 (.34)[b]	4.30 (.30)[b]
Lighting beliefs	Wellbeing	3.20 (.31)	3.98 (.33)
	Relaxation	4.30 (.37)[c]	5.00 (.31)[c]
	Attention	3.40 (.32)	4.90 (.29)

Values in rows with the same superscript letter are significantly different

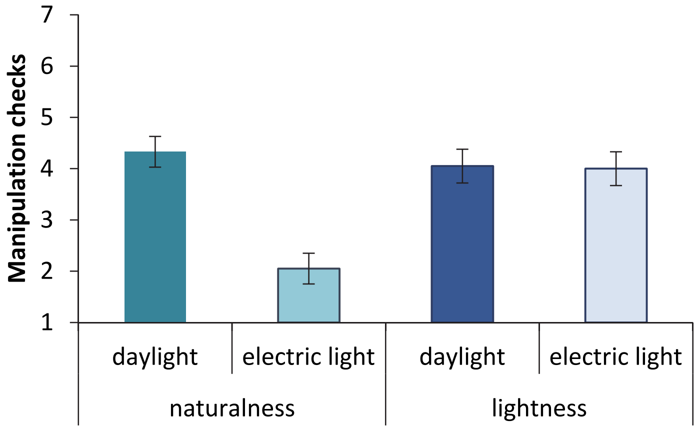


Figure 6.4 Perceived naturalness and lightness of the light setting, error bars represent standard errors

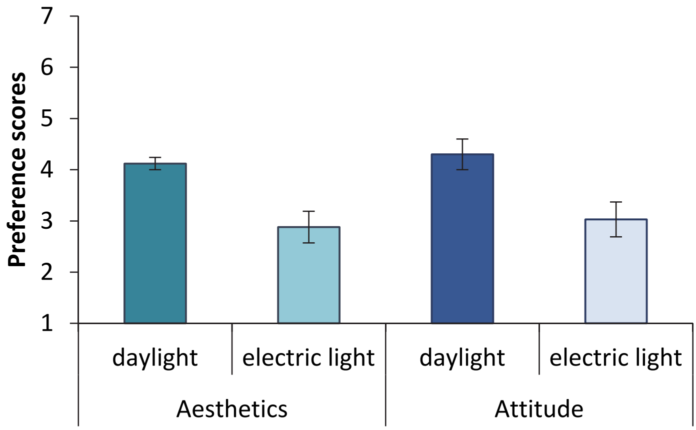


Figure 6.5 Aesthetics and Attitude toward Daylight and Electric light, error bars represent standard errors

6.2.3 Discussion

In the current study, the aim was to investigate restorative effects of daylight versus electric light after induction of resource depletion. A similar induction of ego-depletion was used as in Study One of Chapter Five, but whereas the induction yielded significant ego-depletion effects in the previous chapter the same induction proved to be ineffective in this study. The manipulation inducing a natural versus electric light setting with a similar perceived light intensity did prove successful as indicated by the manipulation checks.

Because the antecedent task did not appear to induce ego-depletion in the current study, formally restorative effects of daylight versus electric light on self-regulation, mood, and physiology could not be tested. Therefore, our hypotheses concerning ego-replenishing effects of daylight versus electric light could not be tested. However, in the previous chapter, we did find instorative effects of natural environments, occurring irrespective of any antecedent resource depletion. No evidence for instorative effects of daylight was found in the current experiment. However, directly after the light manipulations started, a significant increase in heart rate was found in the Electric light condition compared to the Daylight condition. This may indicate that the two light manipulations did affect participants in a distinct manner.

Preference ratings were significantly higher for daylight than for electric light. Moreover, a trend was found for more positive beliefs for daylight regarding the effects of light on Wellbeing than for electric light. Also, participants in the Daylight condition reported the light setting to be more relaxing than participants in the Electric light condition.

In sum, because the ego-depletion induction proved ineffective in reducing self-regulatory performance, mood, and in increasing physiological responses we were not able to formally test our hypotheses concerning the ego-replenishing effects daylight as opposed to electric light. For this reason, a second experiment was conducted with a more powerful ego-depletion induction. Furthermore, the range of light intensities yielded in this study for the daylight manipulation was rather limited, therefore we changed the set-up in Study Two to allow for a larger range in light intensities.

6.3 Study Two

A second study was run to investigate possible restorative effects of daylight versus electric light after ego-depletion. A number of changes was implemented to increase the strength of the ego-depletion induction on the one hand and to increase the effect of the daylight versus electric light manipulation on the other. First of all, to allow for stronger resource depletion, we used two tasks to induce resource depletion: the same typing task as used in Study One and the Stroop task (similar to Study Two for natural vs. urban environments in Chapter Five).

Second, to increase the strength of the light manipulation, a few changes were also made to the light protocol. First of all, the duration of exposure to the light setting after opening the sunscreen or turning on the electric light before the performance task started was increased from one to two minutes. Moreover, the desk was placed closer to the window and a more translucent foil was selected to allow for a larger range in light intensities. Another change pertained to the mood measurements. In the current study, mood was measured both before and after the initial two-minute light exposure to better measure affective responses to the light.

We hypothesized that with a stronger ego-depletion induction an effect of Depletion would be found, with a reduction in self-regulatory performance and mood, and an increase in cardiovascular response to the depleting versions of the induction tasks. We further hypothesized that self-regulatory performance, mood, and physiology would recover more in the daylight condition than in the electric light condition.

6.3.1 Method

6.3.1.1 Design

A similar design was used as in Study One; an incomplete design with four conditions. The conditions were the following: No light (Non-depletion); No light (Depletion); Electric light (Depletion); and Daylight (Depletion).

6.3.1.2 Participants

Ninety-five participants (54 males) participated in this study. Their ages ranged between 18 and 33 years (M = 21.8, SD = 2.8). The distribution of participants along conditions was as follows; 17 participants conducted the No light (Non-depletion) condition; 18 the No light (Depletion) condition; 32 the Daylight (Depletion) condition; and 28 the Electric light (Depletion) condition.
Participants were recruited through the personal contacts of the researchers, face-to-face recruitment on campus, and by inviting participants of the JFS database. The majority of participants were students from the Eindhoven University of Technology or the Fontys Higher Education Institute. All participants had normal, or corrected-to-normal, vision. The duration of the experiment was approximately 45 minutes and participants received €7.50 compensation.

One participant was excluded from the analyses, because he or she had consumed alcohol directly before participating in the study.

6.3.1.3 Procedure

After signing the informed consent form, the ECG electrodes were attached and the participant was seated behind a desk with a notebook. Participants started with filling in the first mood questionnaire (Baseline; t_0) followed by a three-minute baseline period for the physiological measures in which participants were instructed to relax and sit still. After the baseline period, participants completed the typing task and Stroop task in either the non-depleting (No light (Non-depletion) or depleting (No light (Depletion); Daylight (Depletion; Electric light (Depletion)) versions. Directly after the tasks, participants filled in the VAS mood scales for the second time (Post induction, t_1).

Then the experimental phase started: during a two-minute experimental light block, either (1) no changes were made to the light setting (No light (Non-depletion); No light (Depletion)), (2) the sunscreen in front of the window was opened (Daylight (Depletion)), or (3) the wall armature was switched on (Electric light (Depletion). After these two minutes, participants filled in the VAS mood scales again (Post light block; t_2) followed by the 2-back task. After the 2-back task, participants filled in the VAS mood scales for the last time (Post 2-back; t_3). After rating the light setting, the experiment was finished and participants were thanked and paid for their effort, see Figure 6.6 for an overview of the experimental design.

6.3.1.4 Ego-depletion manipulation: Typing task and Stroop task

A similar ego-depletion induction was used as in Study Two of the previous Chapter, with the typing task followed by the Stroop task. See section 5.2.1.4 for a more detailed description.

6.3.1.5 Light manipulation

The experiment was conducted in springtime, from March 26th to June 21st. A similar light protocol was used as in Study One, see section 6.2.1.5. However, this time light intensity was logged throughout the experiment with three lux cells. One lux cell was again placed on the desk measuring the horizontal illuminance and two lux cells measured vertical illuminance at eye level (1.20 m. height), on both sides of the participant. The reason for measuring light intensity at both sides was to take into account possible shifts in directionality of daylight entrance at different times of the day. The light intensity of the

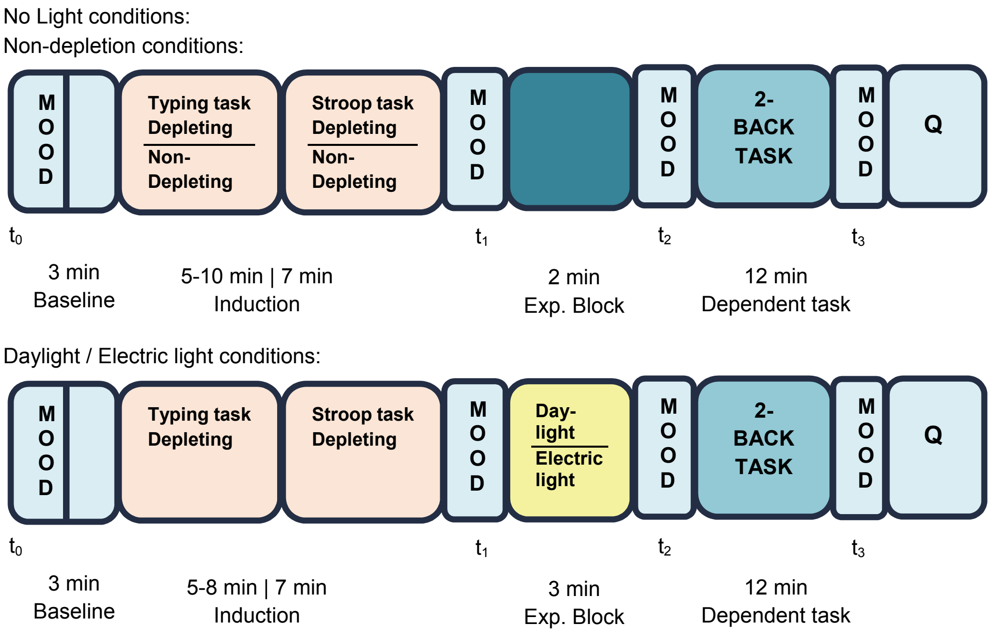


Figure 6.6 Overview of the experimental set-up

electric light was matched at the eyelevel, taking the average of both horizontal measurements. At some instances, the Correlated Colour Temperature (CCT) measured in the daylight condition exceeded the maximum reachable CCT value for the electric light condition. In these instances, the maximum CTT possible was used in the electric light condition. The maximum CCT depended on the intensity of the light with higher intensities allowing for lower maximum CCT values. As research of effects of light during daytime has found more pronounced effects for light intensity than for CCT, it was decided to give priority to the correct light intensity. This sometimes resulted in a lower CCT in the matched electric light condition than in the daylight condition.

Again, during the experiment it was ensured that a similar amount of daylight and electric light conditions were run in the morning and afternoon sessions, see Table 6.7. A chi-square analysis was conducted to confirm an even distribution of daylight and artificial light conditions over the morning and evening ($\chi^2(1) = .2$, $p = .664$). However, looking at the distribution over the individual timeslots (starting each whole hour), there are some differences (e.g., at 9:00 hours), see Table 6.7.

Again, we ran two ANOVA's to confirm the two conditions were matched in light intensity and CCT and to check whether there were any differences between the morning and afternoon timeslots. Even though the CCT in the electric light conditions was sometimes slightly compromised, these analyses revealed no main or interaction effects ($F < 2.1$, $p > .155$) for CCT or intensity.

Figure 6.7 displays the distribution of light intensities and CCTs for the different timeslots for each condition. No significant differences were found in light intensity between the daylight and electric light condition ($F(1,54) = .3$, $p = .591$), neither was there a difference in light intensity between morning and afternoon ($F(1,54) = .4$, $p = .441$) nor an interaction of condition (daylight vs. electric light) and time of day (morning vs. afternoon) ($F(1,54) = .4$, $p = .554$), see Table 6.7.

Table 6.7 Light conditions, light intensity, and CCT distribution over the different timeslots

Starting time		9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Day-light	Number of participants	7	2	3	3	4	6	4	2	1
	Mean light intensity	435.7	578.0	685.3	618.7	293.0	475.2	467.5	401.5	673.0
	Mean CCT	5787.4	6367.0	6257.0	6163.7	6121.3	5863.5	5853.5	5779.0	4992.0
Elec-tric light	Number of participants	1	4	4	3	2	3	5	5	1
	Mean light intensity	274.0	431.0	565.0	730.7	560.0	405.7	538.8	496.8	546.0
	Mean CCT	6001.0	5857.5	5762.5	5712.7	5873.0	5775.0	5774.0	5763.6	5934.0

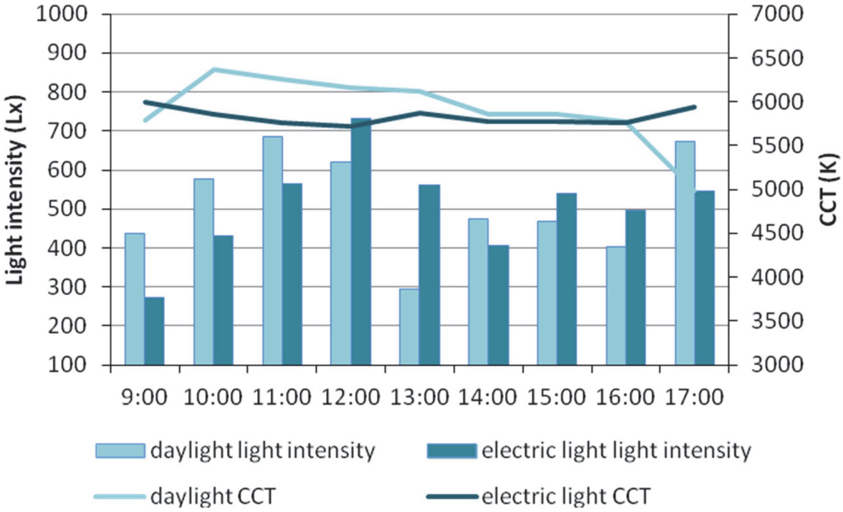


Figure 6.7 Light intensity and CCT in the different timeslots

6.3.1.6 Measures

Mood Mood was measured with three VAS-scales (Tension, Hedonic tone, and Energy). See Section 5.3.1.6 for a description.

Performance task: 2-back Task The same 2-back task was used as in Study Two of the previous Chapter, see Section 5.3.1.6 for a description. Three dependent variables were derived for this task. Besides reaction time, two different types of scores were used; sensitivity (d') and bias (c'), see Section 3.4.1.7 for a description.
In the 2-back task, sensitivity reflects the ability to discriminate between targets and non-targets. Bias indicates which criterion the participants used to differentiate between targets and non-targets. A more lenient criterion would result in a higher amount of responses to non-targets, resulting in a lower bias. Conversely, a stricter criterion would result in a decrease in responses to non-targets, resulting in a higher bias.

Physiology As in Study One, Heart Rate (HR) and Heart Rate Variability (HRV; LF/HF ratio) were measured. In addition, Pulse Transit Time to the Earlobe (PTE) was recorded. See Section 5.2.1.6 for a description.

Light assessment – Manipulation check, preference, and beliefs The same items were used as in Study One, see Section 6.2.1.6. Reliabilities for the preference scales were again high (aesthetics: α = .83; attitude: α = .94). For the beliefs about effects of light on Wellbeing scale, the reliability was also good with α = .89.

6.3.1.7 Data analysis

Again, residualised change scores were calculated for mood and physiology, see Section 3.3.1.8 for the rationale. For physiology, change scores were calculated for each consecutive segment, for mood change scores were calculated for each subsequent measurement instance. Reaction time scores and physiological outcomes deviating more than 2 standard deviations from the mean were considered outliers and deleted from the analysis.

6.3.2 Results

In this section the results on the performance task, mood measures, physiological outcomes, and assessment of the light setting will be discussed (in this order). Each section will start with the analysis of the effects of the Depletion manipulation by comparing the two No light conditions. After establishing possible effects of the depletion manipulation, possible restorative effects of the light manipulations are investigated by comparing the three Depletion conditions (No light vs. Daylight vs. Electric light).

6.3.2.1 Effects of the depletion induction and light manipulation on performance on the 2-back task

Again, we first investigated effects of the Depletion induction on performance by comparing the No Light (Depletion) condition to the No Light (Non-depletion) condition. No effects were found on reaction times, sensitivity, or response bias ($F < 2.9$, $p > .097$). Thus, again our hypothesis concerning ego-depleting effects on performance was not confirmed.

Comparing the three depletion conditions (No Light vs. Daylight vs. Electrical Light) revealed no significant difference in reaction times, sensitivity, or bias ($F < .8$, $p > .451$). Table 6.8 displays means and standard errors for all performance indicators.

Table 6.8 Means and standard errors for the 2-back task

		No light (Non-depletion) Mean (SE)	No light (Depletion) Mean (SE)	Electric light (Depletion) Mean (SE)	Daylight (Depletion) Mean (SE)
2-back task	Reaction time (sec)	.46 (.04)	.47 (.04)	.47 (.04)	.50 (.03)
	Sensitivity	4.79 (.43)	5.47 (.51)	5.59 (.33)	5.00 (.32)
	Bias	.29 (.10)	.11 (.11)	.07 (.07)	.11 (.09)

6.3.2.2 Effects of the depletion induction and light manipulation on mood

Again, we first investigated effects of Depletion on mood, by comparing changes in mood between the No light (Depletion) and No light (Non-depletion) conditions. Second, we analysed effects of our light manipulation by comparing the three Depleting conditions (No light vs. Daylight vs. Electric light). Results of these analyses can be found in Table 6.9, as well as all means and standard errors.

First of all, no baseline differences were found. As can be seen in Table 6.9, in line with our expectations the Depletion manipulation affected tension and hedonic tone, with lower hedonic tone and higher tension after the depleting version of the task. For energy, a difference was found at the end of the experiment (after the 2-back task), with participants in the Non-depleting condition reporting a lower decrease in energy level than participants in the Depleting condition. Counter to our expectations, no effects of the Light manipulation on any of the mood variables was found.

Table 6.9 F-values, means and standard errors of all mood variables (raw scores).

	No Light Non-Depletion	No Light Depletion	Electric Light	Daylight	Effect Induction Tasks[1]		Effect Light manipulation[2]	
Tension[3]	M (SE)	M (SE)	M (SE)	M (SE)	F (1,28)	ηp^2	F (2,72)	ηp^2
Baseline (t_0)	2.86 (.32)	2.95 (.37)	2.99 (.37)	3.78 (.29)	.4	-	2.6	-
Post induction (t_1)	4.18 (.44)[a]	5.05 (.48)[a]	5.14 (.39)	5.74 (.32)	5.4*	.16	.2	-
Post light block (t_2)	3.30 (.34)	3.30 (.42)	3.73 (.39)	4.02 (.24)	1.9	-	.2	-
Post 2-back (t_3)	4.38 (.54)	4.03 (.52)	4.47 (.46)	4.93 (.29)	<.1	-	.4	-
Hedonic tone[3]								
Baseline (t_0)	7.05 (.32)	7.14 (.43)	7.26 (.24)	6.81 (.21)	<.1	-	.9	-
Post induction (t_1)	6.35 (.32)[b]	5.62 (.36)[b]	5.91 (.30)	5.50 (.22)	13.4**	.32	.6	-
Post light block (t_2)	6.30 (.26)	6.12 (.41)	6.70 (.27)	6.02 (.20)	1.4	-	1.3	-
Post 2-back (t_3)	5.86 (.46)	5.43 (.43)	5.41 (.33)	5.28 (.26)	2.0	-	1.2	-
Energy[3]								
Baseline (t_0)	5.39 (.49)	6.04 (.50)	5.89 (.39)	6.18 (.26)	.4	-	.3	-
Post induction (t_1)	4.84 (.42)	4.64 (.44)	5.26 (.38)	5.00 (.26)	.4	-	.9	-
Post light block (t_2)	4.26 (.50)	5.11 (.36)	6.25 (.28)	5.64 (.22)	3.9	-	2.7	-
Post 2-back (t_3)	3.97 (.55)[c]	2.87 (.42)[c]	4.40 (.42)	3.79 (.33)	9.1*	.25	.7	-

[1] The effects of the induction task represent the comparison of the No light (Non-depletion) with No Light (Depletion) conditions, [2] The effects of the light manipulation represent the analyses with No light (Depletion), Daylight (Depletion), and Electric light (Depletion),[3] The F-values represent the analyses with residualised change scores compared to each preceding measurement time, except for the baseline which represents the analysis for possible baseline differences. Values in rows with the same superscript letter are significantly different

** p < .05, ** p < .001*

6.3.2.3 Effects of the Depletion induction and Light manipulation on Physiological responses
First, effects of Depletion on HR, HRV, and PTE were analysed, followed by the effect of the Lighting manipulation, Table 6.10 shows the F-values, means, and standard errors for both analyses.

No baseline differences were found. One significant effect of Depletion was found on LF/HF ratio. In line with our hypothesis, for participants completing the Depleting version of the Stroop task, the LF/HF ratio increased indicating higher exertion of self-regulation or a

Table 6.10 F-values, means, and standard errors for the physiological measures (raw scores)

	No Light Non-Depletion	No Light Depletion	Electric Light	Daylight	Effect Induction Tasks[1]		Effect Light manipulation[2]	
Heart Rate[3]	M (SE)	M (SE)	M (SE)	M (SE)	F (1,28)	ηp2	F (2,72)	ηp2
Baseline	71.08 (3.94)	67.06 (3.42)	75.95 (2.34)	76.96 (3.28)	.6	-	2.0	-
Type task	74.21 (3.46)	73.64 (3.64)	78.77 (1.87)	77.63 (2.73)	.2	-	1.3	-
Stroop	71.61 (2.68)	73.42 (3.64)	79.95 (1.77)	78.42 (2.59)	.9	-	.4	-
Light block	70.93 (2.95)	71.15 (2.61)	75.11 (1.55)	73.94 (2.22)	1.0	-	.3	-
2-back	68.86 (3.13)	70.60 (2.96)	75.08 (2.26)	75.08 (2.26)	.8	-	<.1	-
LF/HF ratio[3]								
Baseline	1.30 (.22)	1.02 (.18)	1.36 (.26)	2.01 (.32)	1.0	-	2.5	-
Type task	1.42 (.32)	1.53 (.30)	1.63 (.19)	2.03 (.27)	.3	-	.2	-
Stroop	1.24 (.23)[a]	2.66 (.61)[a]	2.53 (.33)	3.54 (.35)	5.9*	.27	.8	-
Light block	1.36 (.41)	2.02 (.34)	2.32 (.30)	2.02 (.34)	<.1	-	1.7	-
2-back	1.43 (.24)	2.07 (.23)	1.88 (.21)	2,07 (.23)	3.8	-	.4	-
PTE[3]								
Baseline	213.00 (3.01)	216.64 (3.30)	210.20 (3.34)	209.49 (2.80)	.7	-	.8	-
Type task	216.63 (4.35)	218.83 (3.59)	209.75 (3.08)	209.98 (2.22)	4.2	-	2.6	-
Stroop	216.29 (4.08)	216.09 (3.71)	208.31 (3.45)	210.41 (2.73)	.9	-	.7	-
Light block	217.56 (3.90)	222.60 (4.42)	214.73 (3.38)	214.34 (2.38)	3.6	-	1.2	-
2-back	220.25 (4.16)	225.45 (3.95)	220.08 (3.46)	215.83 (2.25)	2.3	-	1.2	-

[1] The effects of the induction task represent the comparison of the No light (Non-depletion) with No Light (Depletion) conditions, [2] The effects of the light manipulation represent the analyses with No light (Depletion), Daylight (Depletion), and Electric light (Depletion), [3] The F-values represent the analyses with residualised change scores compared to each preceding measurement time, except for the baseline which represents the analysis for possible baseline differences. Values in rows with the same superscript letter are significantly different
** p < .05, ** p < .001*

higher stress level. Conversely, for participants in the Non-depletion condition the LF/HF ratio decreased during the Stroop task. Thus, the Depletion induction affected LF/HF ratio, but no effects of Light manipulation on LF/HF ratio were found. No effect of the Light manipulation was found on any of the other physiological outcomes, thereby disconfirming our hypothesis concerning restorative effects of the light manipulation on physiological responses.

6.3.2.4 The assessment of the light setting - Manipulation checks, preference, and beliefs

For these analyses, the effect of the four different conditions on lighting beliefs and preferences were analysed. Therefore, analyses were run with Condition (No light (Non-depletion) vs No light (Depletion) vs. Daylight (Depletion) vs. Electric light (Depletion)) as independent variable and naturalness, lightness, beliefs, and preference as dependent variables.

First, we assessed the manipulation checks measuring perceived naturalness and lightness. For naturalness, a main effect was found for Condition ($F(3,91) = 23.4$, $p < .001$, $\eta_p^2 = .44$). Planned contrasts revealed significant differences between Daylight and No light (Non-depletion; $t(91)=6.7$, $p < .001$), No light (Depletion; $t(91)=6.6$, $p < .001$), and Electric light ($t(91)=5.8$, $p < .001$). Daylight scored significantly higher on naturalness than all other conditions, see Table 6.11. For lightness, a significant main effect of Condition was found as well ($F(3,91) = 9.9$, $p < .001$, $\eta_p^2 = .25$). Planned contrasts revealed significant differences in perceived lightness between the No light (Non-depletion) condition and both Daylight ($t(91)=5.8$, $p < .001$) and Electric light ($t(91)=5.8$, $p < .001$), with lower lightness score for the No light (Non-depletion) condition than in the Daylight ($t(91)=4.0$, $p < .001$) and Electric light ($t(91)=4.2$, $p < .001$) conditions. Similarly, lightness was perceived significantly lower in the No light (Depletion) condition than in the Daylight ($t(91)=3.5$, $p = .001$) and Electric light ($t(91)=3.7$, $p < .001$) conditions, see Table 6.11. Importantly, no significant difference in perceived lightness was found between the Daylight and Electric light condition ($t(91)=.3$, $p = .733$). These outcomes confirm that the light manipulation functioned as intended.

After establishing the manipulation worked as intended, effects of Condition on preference ratings were investigated. For aesthetics, this analysis revealed a main effect of condition ($F(3,91) = 12.3$, $p < .001$, $\eta_p^2 = .29$). Planned contrasts revealed that the Daylight condition scored significantly higher on aesthetics than the No light (Non-depletion; $t(91)=5.7$, $p < .001$), No light (Depletion; $t(91)=3.2$, $p = .002$), and Electric light ($t(91)=4.1$, $p < .001$) conditions. Furthermore, the Electric light condition scored significantly higher on aesthetics than the No light (Non-depletion ; $t(91)=2.2$, $p = .034$) condition. A very similar pattern emerged for attitude scores ($F(3,91) = 11.4$, $p < .001$, $\eta_p^2 = .27$), with higher scores for the Daylight condition than for the No light (Non-depletion; $t(91)=5.2$, $p < .001$), No light (Depletion; $t(91)=3.7$, $p < .001$), and Electric light ($t(91)=4.3$, $p < .001$) conditions, see Table 6.11. Figure 6.8 displays the scores on aesthetics and attitude for all four conditions.

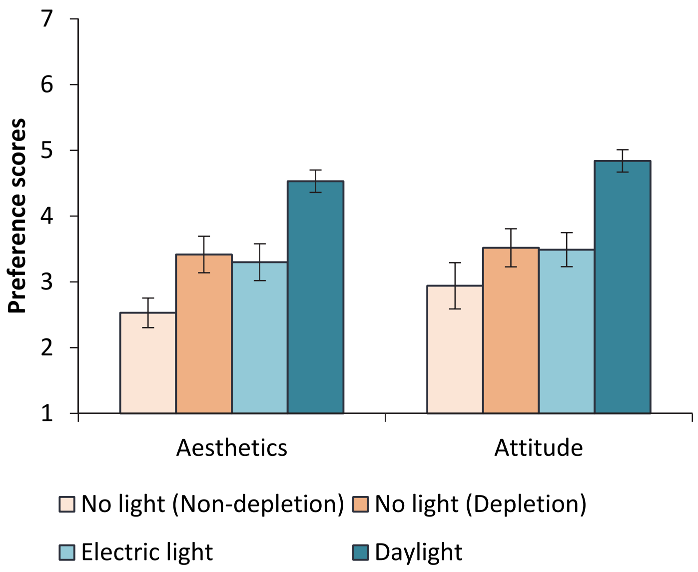


Figure 6.8 Preference ratings for No light, Electric light, and daylight, error bars represent standard errors

Last, effects of Light type on beliefs were tested. These analyses revealed a significant main effect of Light manipulation on beliefs concerning Wellbeing (F(2,92) = 6.9, p < .001, η_p^2 = .19). Planned contrasts revealed significant differences between the No light (Non-depletion) condition and both Daylight (t(91)=3.7, p < .001) and Electric light (t(91)=2.8, p = .005), with a lower Wellbeing belief score for the No light (Non-depletion) condition than for the Daylight (t(91)=3.7, p < .001) and Electric light (t(91)=2.8, p = .005) conditions. Similarly, Wellbeing beliefs were significantly lower in the No light (Depletion) condition than in the Daylight (t(91)=3.4, p = .001) and Electric light (t(91)=2.5, p = .013) conditions, see Table 6.11. For the single-item measuring relaxation, a non-significant trend was found for Condition (F(2,92) = 2.5, p = .066, η_p^2 = .08), but planned contrasts revealed significant differences between the Electric light condition and the No light (Depletion; t(91)=2.3, p = .025) and Daylight condition (t(91)=2.3, p = .027). Electric light scored lower on relaxation than Daylight, but also lower than the No light (Depletion), see Table 6.11.

Table 6.11 Manipulation checks (naturalness and lightness), Preference (aesthetics and attitude), and Light beliefs

		No light (Non-Depletion) Mean (SE)	No light (Depletion) Mean (SE)	Electric light (Depletion) Mean (SE)	Daylight (Depletion) Mean (SE)
Manipulation checks	Naturalness	2.29 (.31)[a]	2.39 (.24)[b]	3.00 (.30)[c]	5.03 (.34)[a,b,c]
	Lightness	3.53 (.24)[a,b]	3.72 (.28)[c,d]	5.14 (.26)[a,c]	5.03 (.17)[b,d]
Preference	Aesthetics	2.53 (.22)[a,d]	3.42 (.28)[b]	3.30 (.28)[c,d]	4.53 (.17)[a,b,c]
	Attitude	2.94 (.35)[a]	3.52 (.29)[b]	3.49 (.26)[c]	4.84 (.17)[a,b,c]
Lighting beliefs	Wellbeing	2.83 (.29)[a,b]	2.95 (.28)[c,d]	3.82 (.32)[a,c]	4.08 (.17)[b,d]
	Relaxation	4.12 (.34)	4.78 (.38)[a]	3.79 (.33)[a,b]	4.63 (.18)[b]
	Attention	4.59 (.19)	4.54 (.26)	4.54 (.26)	4.59 (.19)

In each row, the same letters in superscript indicate significant differences.

6.3.3 Discussion

In Study Two, the depleting task lowered hedonic tone, and increased tension and LF/HF ratio (indicating higher levels of stress or self-regulatory exertion). Self-regulatory performance was, however, unaffected by the ego-depletion manipulation. These results are in line with finding of Study Two in Chapter Five, where the same induction tasks and outcome variables were used.

The Depletion induction again did not influence performance on the 2-back task. These outcomes were similar as Study Two of the previous Chapter. Contrary to the effects found for the nature manipulation, we did not find any evidence for instorative or restorative effects of daylight versus electric light on mood or physiology. The manipulation checks indicated that, again, the light manipulation had been successful in distinguishing in naturalness between the daylight and electric light condition, without introducing any confounds due to differences in perceived lightness.

Compared to Study One, mixed results were found regarding beliefs of the participants concerning the effects of light on Wellbeing. This time, no differences were found between daylight and electric light. Only differences between the no light and the daylight and electric light conditions were found, indicating that effects of light manipulation on Wellbeing beliefs were due to differences in intensity rather than naturalness of the light source.

The preference outcomes of Study One were replicated in this Study, with higher preference for daylight than for electric light, regardless of whether additional light was added by the wall armatures or not.

6.4 General Discussion

In this Chapter, restorative effects of a brief exposure to daylight versus electric light on mood, self-regulation, and physiology were investigated. Studying restorative effects requires an antecedent manipulation to successfully affect the variables under study. In Study One, the manipulation proved to be insufficient in inducing a decline in mood, physiology, and self-regulation performance. Therefore, expectedly, restorative effects were not found. Heart rate, however, was affected by the electric light manipulation but not by the daylight manipulation, but this effect was not replicated in Study Two.

6.4.1 Ego-replenishing effects of daylight

In Study Two, the resource depletion manipulation successfully affected mood and physiology negatively. But despite these affective and physiological responses to the depletion induction, no evidence for restorative effects of brief exposure to daylight versus electric light on these outcomes was found. In the previous Chapter, beneficial effects of natural versus urban environments were found independent of the antecedent condition. In other words, instorative rather than restorative effects of nature were found. If beneficial effects of natural light would follow similar pathways as beneficial effects of natural views, instorative effects could have been expected in both studies, even when no successful resource depletion had taken place. This was, however, not the case.

The absence of beneficial effects (restorative or instorative) of daylight could be due to a number of factors. To begin with, we did not take previous exposure to daylight of our participants into account. They might have been close to a window or outside just before arriving in the laboratory. For this reason, they may have had a low craving for daylight. The results might have been different if participants had been deprived of daylight for a longer time before starting the experiment.

6.4.2 Daylight and a view

Another possible explanation for the lack of restorative effects is related to the foil we used to avoid a view to the outside. Some important characteristics of daylight were lost due to this foil, for instance directional sun beams were replaced by a more diffuse light entrance. Normally daylight is accompanied by a number of other factors that we have (partially deliberately) excluded by using a foil. For windows daylight entrance is for instance accompanied by a view to the outside, relief from claustrophobia, or information about weather and time of day (Collins, 1975). These additional factors might be necessary for daylight to exhibit beneficial effects.

On the other hand, the informational cues provided by a view to the outside have also been suggested exhibit reverse effects. Recent research has indicated that when the weather is good this negatively affected productivity, possibly because workers had to suppress more task-unrelated thoughts about being outside (Lee, Gino, & Staats, 2014). Therefore, as daylight also provides informational cues about the weather type, participants may have also been distracted by daylight in good weather. Both studies presented here were conducted in springtime and it has been suggested that effects of sunshine are most pronounced during this time of year, especially in relation to time spent outdoors (Keller et al., 2005). Therefore, the weather type may have had influence on participant's responses to daylight. Our samples were not large enough to investigate possible influences of weather type.

6.4.3 Matching daylight and electric light

Matching electric light with daylight as much as possible on intensity and CCT might have influenced results as well. Because we matched the daylight and electric light, the light exposure in the electric light condition could be viewed as daylight simulation. Thus, participants were receiving the same light as they would get from daylight entrance. Research has already indicated that people have a preference for light that follows a daylight cycle (Begemann, van den Beld, Tenner, 1997).

The short exposure to daylight together with matching the daylight and electric light conditions on intensity enabled ruling out biological effects of light to a large extent, because effects of light intensity are often found by contrasting bright with dim light setting and usually take longer than a few minutes to affect us. In both studies, participants were exposed to light for a very short period of time (1 to 2 minutes) only before effects on mood, physiology, and self-regulation were measured. We explicitly opted for this short exposure duration as the aim was to test whether psychological pathways, such as the beliefs and connotations that people have with daylight, could induce beneficial effects. For natural environments, these swift beneficial effects had already been identified in Chapter Five. Indeed, light exposure -independent from the source- did not appear to affect mood, physiology, or self-regulation in general, whereas previous studies have shown effects of bright as opposed to dim light exposure on these parameters (see e.g., Rechlin et al., 1995; Smolders et al., 2012). Furthermore, previous research found being in daylight as opposed to electric light for longer periods of time to influence both mood and executive functioning (aan het Rot et al., 2008; Kaida et al., 2006; Münch et al., 2012).

6.4.4 Preference and beliefs

In spite of the absence of exposure effects on mood, performance and physiology, consistently, higher preference was found for daylight over artificial light, both regarding aesthetics and the attitude toward spending one hour in the light setting. These outcomes are consistent with findings in Chapter Two and Four. We were, however, not able to replicate findings regarding the beliefs toward the effects of light on wellbeing (Veitch et al., 1993, Veitch & Gifford, 1996). In Study One, a non-significant trend appeared for more positive beliefs regarding daylight than electric. But in Study Two, both the electric light and daylight conditions scored higher than the conditions in which no additional light was presented, with daylight not scoring significantly higher on these beliefs than electric light. This suggests that the variation in beliefs was due to differences in light intensity rather than the type of light source.

These results are counter to the outcomes of Chapter Four, where we consistently found more positive beliefs regarding relaxing, energizing and health enhancing effects of -as well as more positive associations with- daylight as opposed to electric light. Only results from the single item assessing light beliefs concerning relaxation were in line with the outcomes of Chapter Four, with participants consistently rating daylight to be more relaxing than electric light. In this chapter the participants did not express negative beliefs regarding the effects of bright electric light. It might be that opinions toward electric light are shifting, with the increase in publicity concerning beneficial effects of bright electric light. Another possibility for the lack of differential beliefs regarding daylight versus electric light is that we used a stripped version of daylight (with diffuse light and no view to the outside) which might have elicited less of these positive beliefs. In other words, the concept of daylight may go beyond the mere light phenomenon itself, associative patterns may also automatically include other aspects as spatial freedom, a view, or nice weather (see e.g., Collins, 1975).

6.4.5 Limitations

There are some limitations to this study. Matching daylight and electric light conditions on intensity and CCT required daylight conditions to always precede electric light conditions, possibly introducing an order effect. Furthermore, conditions were matched in CCT but not in spectral composition of the light. One value of CCT can be produced by a number of different spectral combinations. Effects of differences in spectral composition can therefore not be ruled out. Furthermore, in Study Two, the measured CCT for daylight sometimes exceeded the range of the wall armatures in the electric light condition.

6.4.6 Conclusion

To conclude, even though daylight was preferred over electric light, this did not translate into better restorative or instorative outcomes. Whereas natural environments were found to elicit beneficial effects after a very short exposure duration, this did not appear to be the case for daylight. In Chapter Three and Four, we found that the effect of environment on preference was mediated by the valence of associations that people generated with natural environments, whereas the valence of associations for daylight did not mediate the effect of light source on preference. Furthermore, we did not consistently find that participants believe daylight is better for wellbeing than electric light in this chapter. Taken together, these results suggest that possible beneficial psychological effects of daylight run through different pathways than beneficial effects of natural environments. However, we used a very basic form of daylight, stripped from other characteristics that normally accompany this phenomenon as for instance directional sun beams, a view to the outside, informational cues, and relieve from claustrophobia. It could also be that these additional characteristics are necessary for daylight to exhibit beneficial effects. Indeed, in Chapter Four we did consistently find more positive beliefs regarding the effects of daylight compared to electric light on energy, relaxation, and health. A more complete form of daylight, therefore, could still provide relieve and restorative potential after a short duration. A broader interpretation of daylight may be needed to achieve these beneficial effects, with the concept of daylight extending beyond the mere light characteristics. Separating daylight from view content possibly removes the beneficial psychological effects of daylight. Beneficial effects of daylight, thus, may require view content as well. In the next chapter, the General Discussion, we will further discuss the restorative effects of daylight and view content.

Chapter 7

Powered by Nature.
General Discussion

Tie strings to clouds
Make your own lake - Let it flow
Throw seeds to sprout
Make your own break - Let them grow

Let them grow
Let them grow

You wish surprise, will never stop wonders
You wish sunrise, will never fall under

You wish surprise, will never stop wonders
You wish sunrise, will never fall under
We should always know that we can do anything
(Jonsi - Go do)

For decades, nature has been seen as a place of sanctuary and retreat. The link between nature and health goes back to ancient history. Nature not only encompasses trees, plants, rivers, and flowers, but also the rays of the sun, the weather, the day-night cycle, and the different seasons. Beneficial effects of exposure to daylight and nature on health and wellbeing were the main focus of this dissertation. All studies centred around one main research question: We wanted to study restorative effects of daylight and nature within the same research paradigms to see whether they share underlying psychological pathways. We will begin this discussion by revisiting the review of beneficial effects of nature and daylight, which inspired us to compare psychological benefits of nature and daylight. Subsequently, we will discuss the empirical findings of this dissertation concerning the potential underlying psychological pathways and restorative effects of daylight and natural views. We will end this Chapter by looking at the lessons that can be learned from lighting research and the societal and practical implications of our empirical findings.

7.1 Existing evidence base concerning beneficial effects of nature and daylight

Our journey began by reviewing the considerable overlap in beneficial effects between daylight and nature in Chapter One. Besides this striking overlap in beneficial effects, we made a number of additional observations. It proved to be difficult to compare research outcomes as the two natural phenomena were studied in separate research domains, each with their own research traditions, outcome variables, and focus. For instance, within the light domain very little research had focussed on effects of light exposure on stress reduction. The separation of research domains has in some cases resulted in tunnel vision, with studies investigating effects of nature and thereby discarding effects of daylight and vice versa, while both phenomena often co-occur. In some studies, especially in cross-sectional and epidemiological studies, one phenomenon possibly confounded effects of the other. In both domains, placebo effects are difficult to control for. Therefore, it was proposed to include baseline measurements and to measure effects on multiple outcome variables (e.g., including subjective and ‘objective’ measures) such as mood, physiology, and performance (see, e.g., Veitch & Galasiu, 2012).

Specific criticisms per domain were discussed as well. Within the lighting domain, the majority of research has been using artificial bright white light to investigate effects on well-being instead of using - the less stringently controllable - daylight. Some criticism has been expressed concerning the plurality of light exposures used in these studies. The light manipulations differ substantially in exposure duration and timing, and in spectral composition and intensity of the light. Alternatively, in studies exploring restorative effects of natural environments, some ambiguity exists on whether these effects were due to positive effects of nature or rather due to detrimental effects of urban environments.

To conclude, because effects of view content and light have been investigated in different research domains with different research traditions, one of the main conclusions of the introduction was that comparing types of effects between these two natural phenomena is very difficult. Moreover, in some studies exposure to view content was confounded by light entrance and vice versa. For this reason, we decided to test effects of daylight and nature separately, while strictly controlling for possible confounding effects of the other phenomena. And whereas effects of light exposure on health and wellbeing are often attributed to biological pathways, we believed empirical evidence also intimated psychological pathways. These psychological pathways were investigated in Chapters Two, Three, and Four.

7.2 Psychological pathways

Our physical environment can offer general resistance resources (Antonovsky, 1979) that enable us to face daily stressors and setbacks. Psychological benefits of our environment have already been recognized for natural environments, but to a much lesser extent for daylight exposure. In the first part of this dissertation, we discussed possible psychological pathways for effects of natural environments and daylight. First, preferences were investigated expressed as aesthetic experience and an individual’s attitude toward spending time in the pertinent condition, using preference measures developed by Staats, Kieviet, and Hartig (2003). Within restoration theories, preference plays an important role. Preference ratings for natural environments have already been well established, whereas preference for daylight has been less intensively studied.

Preference formation, in turn, relies highly on associative patterns (Strack & Deutsch, 2004). Therefore, after investigating preferences with natural environments and daylight, we investigated the role of associations and connotations with the two natural phenomena as opposed to their artificial counterparts in preference formation.

7.2.1 Preference

The general consensus is that we prefer environments that are good for us (e.g., van den Berg et al., 2003). From an evolutionary point of view, environmental preference serves adaptive purposes by aiding us to approach environments that are good for us and avoid unfavourable places. Preference was measured in two ways; implicitly and explicitly. In restoration research, implicit preferences are thought to reflect evolutionary based automatic affective responses while explicit preferences reflect more cognitively based processes. This distinction between automatic implicit preference and the more cognitively deliberate explicit preference has also been voiced in attitude and preference research in social psychology. But automatic responses reflecting associative patterns between the stimulus and the target, need not necessarily be based solely on evolutionary affective responses but may also be grounded in previous experiences (Strack & Deutsch, 2004).
In restoration research the superiority of natural environments is often measured by contrasting it to urban environments. In the first series of experiments of this dissertation, we

investigated both implicit and explicit preference for different scenes types. These scene types differed not only in naturalness, but also in weather type and brightness as characteristics of amount of daylight present. Results of these studies indicated a consistent explicit preference for sunnier brighter and more natural scenes, but no evidence for implicit preference was found. These latter findings contrast those of a Finnish group of scholars, who did report evidence for implicit preference for natural environments, employing protocols very similar to ours (Korpela et al., 2002; Hietanen, & Korpela, 2004; Hietanen, et al., 2007). These differential outcomes for implicit preferences could be due to differences in the experimental set-ups or stimuli used. For instance, we explicitly chose not to select only 'ugly' city photos. Rather, we aimed at taking photos of the city of Eindhoven that were representative for this city. Similarly, we also did not use photos of spectacular nature scenes, but of nature typical for our region. Therefore, a number of urban photos also contained natural elements. In most of the photos used by Korpela and colleagues, urban environments were represented by parking garages and very unappealing urban environments. As we used less negative urban photos, the environmental manipulation was less extreme and we expect this could explain (at least part) of the null effects. Alternatively, differential outcomes could be due to idiosyncratic design choices or sampling strategies.

The fact that explicit, but not implicit preferences were found indicates that when using less extreme positive natural and negative urban scenes, at least some level of cognitive deliberation is needed for clear preferences to emerge. Importantly, our photographic stimuli, although perhaps less extreme than in earlier studies, did prove effective in inducing restorative effects in subsequent studies.

The same urban and natural scenes were used for the sunny versus overcast and dark versus light manipulation. Not only did we find consistent explicit preference for natural over urban scenes, similar results were found for sunny over overcast and bright over dark photos. These results point to the adaptive function of sunshine and brightness. Brightness was already found highly related to the distinction between positive versus negative emotions (Meier et al., 2007).

The outcomes for explicit and implicit preferences were not only replicated multiple times, they were also found in both a within-subjects and between-subjects design. Because all participants in these experiments were Dutch citizens, these results might only apply for residents living in a moderate climate. Arguably, results for the weather and brightness manipulation might be different for instance for those living in more tropical climates.
The consistently higher explicit preference for sunshine and bright photos in Chapter Two was the first indication for possible psychological benefits of daylight and encouraged us to proceed with this line of investigation. In all subsequent experiments, we always measured explicit preference. This way, we were not only able to replicate preferences for natural environments over urban environments (Chapters Three and Five), but also found that daylight is consistently preferred over electric light (Chapters Four and Six). For the view

content comparison, we found some evidence for the mediating role of preferences in mood enhancing effects of nature in Chapter Five. More specifically, preference mediated improvement of hedonic tone. As with earlier research, these outcomes do not establish the causal direction of this effect. Higher preference for environments could induce better mood, but the improvement of mood in these environments could also increase preference ratings as was found in earlier research (van den Berg et al., 2003). We further investigated the formation of preference and its influence on restorative potential by looking at learned associations with natural versus urban environments and daylight versus electric light.

7.2.2 Associations and connotations

Having established higher preference ratings for natural and sunny environments over urban and overcast environments, as well as for daylight over electric light, we continued our search for psychological underlying pathways by looking at associations. Associative patterns play an important role in the formation of implicit and explicit evaluations (Strack & Deutsch, 2004). Therefore, it could be expected that a relation between preference formation and associations exists. Indeed, scholars have already postulated the possible role of learned associations in preference formation and the restorative potential of environments (Tuan, 1974; Ulrich, 1983).

For daylight versus electric light, preference research has mainly focused on preferences for rooms with and without windows. Obviously, windows not only bring us daylight entrance but also a view to the outside. Whereas little research has directly focussed on preference for natural versus electric light, there have been studies investigating beliefs regarding the effects of different light sources on health and wellbeing. Generally, people believe daylight is better for their health, mood, and performance than electric light (Haans, 2014; Veitch & Gifford, 1996; Veitch et al., 1993; Wells, 1965). Though investigating light effects from a different perspective, these results also indicate that people have different associations and connotations with daylight than with electric light.

In a series of experiments reported in Chapters Three and Four, we consistently found that more positive associations were generated for natural as opposed to urban environments, sunny versus overcast environments, and daylight versus electric light. For environment and weather type the valence of these associations further mediated preference formation. The more positive associations with natural versus urban environments are in line with expectations voiced by other researchers as for instance Roger Ulrich (1983) and Yi-Fu Tuan (1974).

In line with our expectations, we found that valence of associations mediated the effect of environment and weather type on preference scores. Interestingly, no evidence was found for mediation of the effect of light source on preference through the valence of associations, neither did ratings concerning health, energy, and relaxation of the associations significantly mediate outcomes. The lack of mediation of the valence of associations with light source could have been due to the fact that people were generating their associations with words rather than images. However, we feel this explanation is unlikely as associations and preferences for these words did parallel those to natural versus urban images. Moreover, outcomes regarding preference ratings were similar to those with real daylight versus electric light in Chapter Six. More likely is the conclusion that possible beneficial effects of daylight over electric light run through different psychological pathways than the beneficial effects of view content. This conclusion is further corroborated by the outcomes of the effect studies, which we will discuss in more detail now.

7.3 Effect Studies

In the effect studies, the influence of environment type and light source on self-regulatory performance, mood, and physiology was investigated. For each natural phenomenon (natural view content and natural light), the effects were contrasted with their artificial counterpart (urban view content and electric light respectively). We used very similar research paradigms to investigate effects of natural versus urban environments (Chapter Five) and of daylight versus electric light (Chapter Six). This not only enabled us to investigate how both phenomena affect human wellbeing and functioning, but it also made it possible to compare both natural phenomena, not in the magnitude of beneficial effects but on the type of beneficial effects.

Self-regulation performance was tested using a typical Ego-Depletion research paradigm. According to Ego-Depletion theory, exerting self-control temporarily reduces the capacity to exert self-control on a subsequent task. Evidence for ego-depletion theory comes from studies in which participants first complete either a non-depleting or depleting induction task followed by a dependent task requiring self-regulation. Generally, a decline in performance on this dependent task is found for participants who completed the depleting version of the task compared to those who completed the non-depleting version. Ego-replenishing effects of nature or daylight would manifest themselves by overcoming the decline in self-regulatory performance after performing a prior depleting task.

In Chapters Five and Six, two different induction tasks were used; the typing task and the Stroop task. The Stroop task was also used as the dependent task in two studies. Besides the Stroop task, the Backward Digit Span task, 2-back task, and OSPAN task were administered as dependent tasks. In general, ego-depletion effects have been reported for a multitude of different outcome tasks (Hagger et al., 2010). The induction tasks in our studies yielded mixed results and have proven quite unreliable at times. Before discussing restorative effects of nature and daylight, we will first reflect on the induction tasks used.

7.3.1 Induction of stress and ego-depletion

In this dissertation, several tasks were used to induce stress or depletion. In this section, we would like to discuss two issues; the distinction between stress-induction and ego-depletion, and the effectiveness of tasks to induce stress or depletion.

The induction tasks used in this dissertation (i.e., MPA task and Retail task in Chapters Three and Four; typing task and Stroop task in Chapters Five and Six) appeared to reliably affect mood and physiological responses, whereas effects on self-regulatory performance or executive functioning did not appear consistent. In Chapter Five, we found that the depleting version of the typing task negatively affected reaction times to incongruent trials of the Stroop task. This effect was not replicated in Chapter Six, in which a very similar research paradigm was used. Moreover, in both Chapters Five and Six, performance on the 2-back task remained unaffected by both the induction task and the environment or light source manipulation. In these studies, one could argue that during the time that elapsed between the induction and dependent task (approximately three minutes) participants had naturally recovered. However, in Chapter Three we used two tasks to induce stress (MPA task and Retail task), which also required exertion of executive functioning as both tasks involved a number of arithmetic problems. For these two tasks, we measured performance on the Necker Cube task (after the MPA task) and SART task (after the Retail task) directly after finishing the induction tasks. In both studies, performance directly after the stress induction was not affected, thereby implying that the connection between these induction tasks and cognitive performance is doubtful - at least for the MPA task and Retail task. Similarly, before running the ego-depletion studies in Chapters Five and Six, multiple pilot studies had failed to find a relation between depletion and performance on a subsequent task. We have used a wide variety of different ego-depletion manipulations (i.e., controlling attention during a video; Baumeister et al., 1998 / letter circling task; Wright, Stewart, & Barnett, 2008 / writing an essay without typing certain letters; Schmeichel, 2007), in one studies we also used a combination of induction tasks (attention video followed by the essay). Similarly, different dependent tasks (i.e., solvable anagrams; Gordijn, Hindriks, Koomen, Dijksterhuis, & van Knippenberg, 2004 / OSPAN task; Schmeichel, 2007 / persistence on an unsolvable puzzle; Schmeichel & Vohs, 2009 / Stroop / Necker Cube Task) have been employed. In some instances, we even used the original tasks provided to us by the researchers via email (i.e., letter circling; Wright et al., 2008 / OSPAN task; Schmeichel, 2007 / persistence on an unsolvable puzzle; Schmeichel & Vohs, 2009) or by downloading the task (attention control video; The Baumeister & Tice Social Psychology Lab). Oftentimes, performance remained unaffected by the depletion manipulations and in some instances performance even improved after performing a depleting task.

Contrary to the popular notion of ego-depletion, researchers have also posited that exerting self-regulation can *improve* performance on a subsequent task. According to Koole and colleagues (2012), how self-regulation affects your performance depends on personality characteristics. They distinguish between action-oriented people, who generally thrive well when under self-regulatory pressure, while performance for state-oriented people is negatively affected under pressure. Possibly, our sample differed on self-regulation orientation compared to the samples in other studies, or perhaps subtle details in our protocols and instructions to participants differed from those of scholars with successful ego-depletion inductions. On a different note, in Ego-Depletion research solid manipulation checks are not always performed. Perceived difficulty is often used as the main manipulation check. In our studies, perceived difficulty did always score higher for the depleting than for non-depleting tasks but this only rarely translated into diminished self-regulatory performance on a subsequent task.

To conclude, the induction tasks used in this dissertation did not always successfully induce a decline in self-regulatory performance. Arguably, the fairly consistent lack of effects on cognitive performance as opposed to the more consistent presence of mood decline and cardiovascular responses, this would classify most of the tasks used as stress-induction tasks rather than depleting tasks. Other researchers have, in turn, struggled with stress induction. This is reflected for instance by the addition of a selection procedure in which only those participants were selected that showed an increase in physiological stress responses during a stressor task before data analysis (e.g., Parsons et al., 1998). Moreover, in our studies these effects on mood and physiology sometimes appeared to vanish rather quickly, even without any form of restorative manipulation as will be discussed in the next section.

7.3.2 Restorative effects of nature and daylight

To study the restorative effects of daylight and nature, both phenomena were contrasted with their artificial counterpart. The natural versus urban contrast has served numerous investigations of the role of naturalness in restorative effects of the environment. We should note, however, that the manipulation of natural versus urban environments is not the same comparison as daylight versus electric light. Formally, what electric light is to daylight would perhaps be more like what virtual nature is to nature. This difference in analogues stresses the notion that effects should never be compared on strength but only on the type of effects. Because ego-depletion effects have been found to vanish rather quickly (within 3-10 minutes; Tyler & Burns, 2008), relatively short exposure durations to either light or view content were employed in the effect studies reported in Chapters Five and Six.

Nature

Two studies were conducted to measure restorative effects of nature (Chapter Five). Even though a number of studies have already been performed regarding beneficial effects of nature on physiology and mood, the results of these studies extended the existing knowledge base in a number of ways. First of all, we empirically tested a previously asserted theoretical link between Ego-Depletion theory and Attention Restoration Theory (Kaplan & Berman, 2010) by using induction tasks and protocols previously used in Ego-Depletion research. Second, in a subsequent study we tested effects of nature exposure also after a non-depleting control task. This experimental set-up enabled us to test for what Hartig and colleagues (1996) have labelled instorative rather than restorative effects of nature. In other words, we tested whether only participants who performed the depleting version of the induction tasks benefitted from exposure to natural environments or whether exposure to natural environments also buffered subsequent self-regulatory performance for participants who were not initially depleted.

Evidence for ego-replenishing effects of nature was established in Study One of Chapter Five, in which participants who viewed natural scenes after the depleting version of the typing task performed better on the Stroop task than participants who viewed no content or urban scenes after depletion. However, this result was not replicated in Study Two. Even though a more powerful ego-depletion induction was used in Study Two, with two instead of one induction task, performance on the 2-back task remained unaffected. In Chapter Six, a similar experimental set-up was used, which again yielded no performance decline in 2-back performance. We postulated this difference could be due to the differences in the cognitive processing level required for the two different dependent tasks. In Study One, the Stroop task was used requiring participants to control impulses. In contrast, in the second study the 2-back task was selected, which is a higher-order cognitive-functioning task. However, the fact that the depleting effect of the typing task on Stroop performance was not replicated in Chapter Six already indicates the weak relation between depletion and cognitive performance.

Self-regulatory performance -or executive functioning- is one of the main outcome variables tested in ego-depletion theory. But whereas mixed results were yielded for self-regulatory performance, consistent outcomes were found for the ratio of Low Frequency and High Frequency (LF/HF ratio) and hedonic tone. In both studies, natural environments increased pleasant feelings and lowered LF/HF ratio either while viewing natural scenes, or directly afterwards. A lower LF/HF ratio indicates more parasympathetic nervous system involvement in heart rate, which has been linked with lower stress levels (Berntson & Cacioppo, 2004) and lower exertion of self-control (Thayer et al., 2009). In both studies, preference ratings further significantly mediated the effect of environment on hedonic tone. These results are in line with findings by van den Berg and colleagues (2003). They suggest that the beneficial effects of nature found in our studies were related to stress rather than depletion. Beneficial effects of nature on stress have been found to occur after shorter exposure durations than attention outcomes (Hartig et al., 2003, see also Appendix A). As we used very short exposure durations, this may explain the lack of beneficial effects on executive functioning.

At the same time, as ego-depletion effects vanish quickly (Tyler & Burns, 2008) and natural environments have generally been found to require relatively long exposure durations to improve cognitive performance, they may not be suitable to overcome ego-depletion in a typical ego-depletion paradigm. However, self-regulatory performance could still benefit from nature exposure when longer exposure durations are used.

The discussion of the relative timing of environmental scene manipulations to overcome depletion may not be the most relevant one as results of Study Two indicated that beneficial effects of nature occurred irrespective of the antecedent condition. The ostensibly restorative effects of nature occurred after both the depleting and non-depleting conditions. Thus, it appeared that for nature to exhibit beneficial effects on humans, no antecedent stress or depletion condition was necessary. Not only did Study Two provided evidence for this claim, in Study One we already found that LF/HF ratio during the Stroop task was lower *after* viewing natural environments.

These ‘instorative’ (Hartig et al., 1996) rather than restorative effects of nature point to the need to reconsider current theories in restoration research. In future research we should expand our focus, not solely investigating recovery of mental resources but exploring buffering and possibly motivation-enhancing effects of nature as well. A limited number of studies have already successfully shown instorative effects of nature (Hartig et al., 1996; Parsons et al., 1998). The majority of studies, however, have measured effects of nature after a stressor of mental fatigue inducing task, but did not include a condition in which effects of nature exposure in the absence of such a stressor task were measured. Therefore, even though this experimental paradigm has been used repeatedly it remains questionable whether induction tasks are essential to the beneficial effects of nature. We believe these instorative effects of nature offer possibilities for new theoretical explorations to expand and complement existing restoration theories.

Perhaps nature presents us with a reward to increase motivation to perform well rather than that it helps overcome diminished resources, in line with process theory (Inzlicht & Schmeichel, 2012), as discussed in Chapter Five. In Chapter Three we already saw that nature evokes more positive associations than urban environments and that these thoughts mediate the effect of environment on preference. Associations were generated immediately while viewing natural scenes and did not require much time. Indeed, the beneficial effects of nature we found occurred after a relatively short exposure to natural scenes (3 minutes). Moreover, consistently, we found that natural scenes improved hedonic tone of participants.

Based on the literature and our findings we believe positive affect plays an important role in the beneficial effects of nature. Not only can positive emotions increase cognitive performance (Ashby, Isen, & Turken, 1999), vitality and motivational strength (Ryan & Deci, 2000), and overcome cardiovascular responses to negative emotions (Fredrickson & Levenson, 1998), it has also been found an important general resistance resource for health and wellbeing. According to the Broaden and Build Theory (Fredrickson, 2004) positive emotions broaden one’s mental focus, enabling one to see the bigger picture and be creative in finding solutions for future problems. This way, positive emotions can help buffer future stressors. In their review, Pressman and Cohen (2005) further posited that several different health outcomes stand to benefit from positive emotions.

In Chapter Three, we tested whether positive associations with natural environments could explain the beneficial effects of nature on mood and performance. Unfortunately, little evidence was found for restorative effects of natural environments in those studies. We postulated that the task of generating associations in Chapter Three possibly interfered with restorative potential of natural environments, either by distracting participants away from the images or by imposing awkward feelings because associations were reported verbally. Notably, a secondary task while viewing nature images did not necessarily result in diminished restorative outcomes: Berman and colleagues (2008) for instance, had participants rate each - of a total of fifty – photo(s) in their study during the natural versus urban environments exposure and still report beneficial effects of these natural scenes. Perhaps the task we gave our participants was more taxing than theirs though.

On the other hand, we did find evidence that when explicitly instructed to generate positive associations, hedonic tone improved during the task. This suggests that generating positive associations can be restorative. In one of the two studies, this improvement in hedonic tone occurred only for natural environments and not for urban environments, indicating that the positive associations generated for natural environments were more effective in increasing hedonic tone than for urban environments. These findings all imply that positive affect plays a central role in the beneficial effects of nature. Additional (indirect) evidence for this claim comes from empirical findings indicating beneficial effects of calm positive emotions on health while similar beneficial effects on health have been reported for nature (van Dillen et al., 2012; Mitchell & Popham, 2008; White et al., 2013).

Positive affect already forms the basis for one of the two prevailing restoration theories; Automatic positive affective responses to nature form the basis for Psycho-evolutionary theory (Ulrich, 1983). The emphasis in this theory is on evolutionary processes. ART (Kaplan, 1995), on the other hand, generally discards the role of affect and physiological responses in causing beneficial effects of nature. Instead, Kaplan suggests that positive affect may be the result of attention restoration rather than the opposite. The outcomes of our studies clearly show that if any, the affective and physiological responses were the most consistent outcomes after a short exposure to natural environments. Combined with the outcomes of Chapters Two and Three, our hypothesis is that affective responses indeed are central to nature’s benefits. We further believe that the mechanism by which it works goes beyond evolutionary preferences and also entails the personal experiences with these environments, i.e. nurture in addition to nature.

Not only would we like to posit that benefits of nature go beyond evolutionary mechanisms, we further claim - based on our findings - that effects of nature are not only restorative, but can also help build resources to buffer future challenges. Indeed, nature appears to exhibit vitalizing effects, in line with for instance outcomes by Ryan and colleagues (2009). Arguably, the magnitude of restorative effects is larger when emotional states deviate more from the optimum. In other words, it is probably more likely to improve positive affect for someone who is feeling bad than for someone who is already feeling very happy. For this reason, there may be wisdom in first inducing a negative affective state when hoping to demonstrate restorative effects, but this does not mean that we can only benefit from nature when ‘the going gets tough’. On the contrary, we believe an important role for natural environments is also reserved for buffering future stressors or attentional demands.

Importantly, please note that we do not claim that, based on our studies, one should discard the idea of attentional benefits of exposure to nature. Numerous studies have reported improved attentional capacity (e.g., Bermans et al., 2008; Kuo & Sullivan, 2001; Laumann et al., 2003). However, within the timeframe of our experiments, which employed very brief exposures to natural content, very little evidence was found for improvement of self-regulatory capacity. However, we do question whether the effects reported in earlier studies really concern restorative effects rather than instorative effects. In our experiment, after completing two subsequent depleting tasks with an overall duration of approximately 20 minutes, effects diminished relatively quickly (for the 2-back task even within 3 minutes). Usually, studies investigating attentional benefits of nature use exposure durations of up to 50 minutes. It is questionable whether fatiguing effects of a 30-40 minute induction task are still present after a 50-minute walk. Based on our experiences, it is more likely that nature improves attentional capacity for subsequent tasks, for instance by increasing resources or motivation rather than restoring them.

An often-expressed criticism on restoration research entails the sometimes seemingly arbitrary content of the scenes used (White, Smith, Humphryes, Pahl, Snelling, & Depledge, 2010). In our experiments, all scenes were visually matched on extent and composition. Moreover, results of Chapter Two indicate that matching the weather type on the photos is crucial as well. Therefore, in all studies scenes were matched in weather type and brightness. And even though we made an explicit effort to exclude aversive urban environments, the contrast between natural and urban scenes emerged as it did in other studies. This corroborates the argument that the contrast between these scene types is a conceptual and meaningful one, rather than an artefact of the selection of specific images.

One additional issue discussed in Chapter One pertains to whether restorative effects of natural environments stem from beneficial effects of nature or detrimental effects of urban environments. By adding a no content condition to Study One of Chapter 5, we were able to assess whether urban environments hampered recovery or whether instead natural environments enhanced recovery. Compared to the no-content condition, natural environments improved performance and heart rate variability whereas for urban environments outcomes were similar to those in the no-content condition. These results indicate that restorative outcomes we established are due to positive effects of nature rather than negative effects of urban environments. This claim is supported by the valence of associations generated in Chapter Three. Whereas more positive associations were generated for natural environments, the associations with urban environments were not necessarily very negative.

Daylight
Similar to the view content studies, two studies were conducted testing restorative effects of a short exposure to daylight in comparison to artificial light on mood, physiology, and self-regulation. The aim was to investigate potential beneficial effects of daylight over electric light through psychological pathways. Therefore, the daylight and electric light conditions were matched in light intensity and colour temperature to minimize biological effects. Additionally, the relatively short exposure duration further ensured little interference by biological mechanisms. To avoid possible confounds by view content in the daylight condition, a foil was used to block away the view.

The use of this foil may have lowered effectiveness of the daylight manipulation, as some characteristics of daylight got lost, such as a view to the outside, directional sunbeams, and sunpatches. These additional characteristics might be inextricably joint with daylight experiences. Moreover, any transformations added to daylight have been found to reduce perceived naturalness (Haans & Olijve, 2012). However, our manipulation checks did indicate that daylight was perceived as more natural than electric light.

We did not find consistent evidence for superior effects of daylight over electric light on mood, physiology, or self-regulation. In one study, we found that heart rate increased directly after the electric light was switched on, whereas this did not happen for daylight. The induction tasks in these studies not always successfully induced resource depletion, therefore restorative effects were not always likely to be found. This may have affected the outcomes of these studies. On the other hand, for natural environments the effects appeared to be instorative rather than restorative, questioning whether we actually need effective induction tasks to measure beneficial effects.

The question that arises is whether the absence of superior effects of daylight over electric light was due to the light manipulation used or whether the psychological mechanism by which daylight improves wellbeing is different than for natural environments. For nature, results indicated that restorative or instorative effects occur swiftly, possibly due to the more positively valenced associations and preference for these environments. For daylight (at least in the form that we used) these immediate benefits did not seem to occur. In Chapter Four we found that while the valence of associations mediated the effects of scene content on preference, it did not mediate the effect of light source on preference. These outcomes suggest that preference formation for natural environments depends on the experiences that people have had with these environments, but experiences with daylight per se do not seem to influence preference ratings.

The explanation for these outcomes may lie in the following. There is no visual perception without light, as for instance Florence Nightingale (1860) noted:

“The sun is not only a painter but a sculptor. You admit that he does the photograph.”

Or as the architect Tadao Ando (2008) argued:

“Light is the origin of all being. Light gives, with each moment, new form to being and new relationships to things, and architecture condenses light to its most concise being. The creation of space in architecture is simply the condensation and purification of the power of light”

But even though there is no visual perception without light and vice versa, we often do not consciously perceive light. It merely just seems to be there. Daylight is highly intertwined with everyday life. During the biological day it is ever-present as long as you are outside or indoors in a room with a window. Even though plants and trees are all around us, all-natural environments are far less frequently encountered in everyday life than daylight, at least for those living in urban environments, which the majority of people do. Therefore, all-natural environments might be more special – more notable - for participants and represent distinct geographical locations with more salient (positive) experiences, whereas daylight is ever-present and may be less specifically tied to certain events and locations. For this reason, immediate psychological effects of natural environments might be more powerful than those of daylight. Possible future steps would be to do a content analysis on the associations participants generated in Chapters Three and Four and see whether differences in the specificity and type of associations generated exist.

A related issue pertains to the level of deprivation prior to conducting the experiment. Participants entering our lab were much more likely to have been deprived of all-natural environments than of daylight. For this reason, natural environments might have had a more immediate and stronger effect on participants than daylight in the experimental set-up that we used.

A third explanation pertains to the matching of electric light to daylight. Light exhibits certain biological benefits based on intensity, exposure duration, exposure timing, and spectral composition. These beneficial effects of daylight may not distinguish themselves from exposure to electric light as long as the intensity and spectral composition are simulated. In other words, if electric light is presented with the right light composition for a particular biological timing, it could have similar beneficial effects to daylight. Indeed, many studies reporting benefits of light have used bright electric white light as the manipulation (e.g., Partonen & Lönnqvist, 2000; Smolders et al., 2012; VandeWalle et al., 2009 ; 2010). This is also exactly what we have done in the current studies; we matched the electric light as much as possible to daylight in intensity and colour temperature. This is clearly different from outcomes concerning effects of view content, where not only positive effects of nature have been reported (e.g., Annerstedt & Währborg, 2011) but also negative effects of urban environments (e.g., Lederbogen et al., 2011). Negative effects of electric light often pertain to receiving electric light at the wrong biological timing (e.g., jetlag; Cho, 2011, or shift work; Czeisler, Moore-Ede, & Coleman, 1982).

At first sight these results seem to indicate that daylight does not have superior beneficial effects over electric light, but we should be cautious to discard this hypothesis for a number of reasons. First of all, we have seen that nature has been found to increase positive affect. Both exposure to nature and positive affect have, in turn, been found to improve health. Similar findings have been found for daylight, with a connection between sunlight or daylight and positive affect (e.g., Kaida et al., 2007; aan het Rot et al., 2008) on the one hand, and with health (e.g., Walch et al., 2005; Wirz-Justice at al., 1996) on the other. In the majority of these studies, daylight exposure was accompanied by a view.

The intertwinement of daylight entrance with view content presents us with another pathway through which daylight could exhibit psychological benefits. Other benefits also accompany daylight while being outdoors or close to a window, such as a relief from claustrophobia, informational cues about the outside world, and a distraction from daily routines (e.g., see Collins, 1975). Without these additional characteristics that accompany daylight and rely on the presence of a view to the outside, no psychological benefits may occur. In a similar fashion, people generally prefer having a window to not having a window (Collins, 1975, Markus, 1967). These preferences may not only reflect the need for daylight entrance, but also for having a view, as is reflected in the following quotes by Florence Nightingale (1860):

"It is the unqualified result of all my experience with the sick, that second only to their need of fresh air is their need of light; that, after a close room, what hurts them most is a dark room. And that it is not only light but direct sun-light they want."

"Therefore, that they should be able, without raising themselves or turning in bed, to see out of window from their beds, to see sky and sun-light at least, if you can show them nothing else, I assert to be, if not of the very first importance for recovery, at least something very near it."

In our studies, we consistently found higher preference ratings for the natural light setting over the electric light setting. However, these preferences did not always translate into restorative or instorative effects in Chapter Six. Interesting also is the fact that beliefs about the effects of daylight and electric light on health and wellbeing were equally positive. Differences in beliefs were related to the intensity of the light, but not to the naturalness of the light source. On the other hand, in Chapter Four we did find that the associations with natural light scored higher on valence, health, relaxation, and energy than associations with electric light in Chapter Four. Possibly, these superior effects of daylight over electric light pertain to the fact that daylight is oftentimes accompanied by a view which participants in the association studies might have automatically included in their judgement. We explicitly removed the view for the effect studies in Chapter Six and therefore may the beliefs participants voiced in Chapter Four may not pertain to these conditions. In other words, these beliefs might rely on a view accompanying daylight entrance. Previous research has found superior effects of daylight versus electric light concerning beliefs toward health, mood, and performance (Haans, 2014; Veitch & Gifford, 1996; Veitch et al., 1993; Wells, 1965).

The interconnectedness of view content and daylight has also been demonstrated in a different line of research, investigating discomfort glare (Tuaycharoen & Tregenza, 2005; 2007). Algorithms developed to calculate discomfort glare for electric light, do not hold for daylight (Chauvel, Collins, Dogniaux, & Longmore, 1982). In two separate studies, Tuaycharoen and Tregenza (2005; 2007) found that the point at which a person perceived the incoming light to produce discomfort glare differed with the type of view presented, with higher light levels tolerated for nice (and natural) views.

Not only did we investigate preference for daylight over electric light, we also looked at effects of weather type. Whereas the valence of associations with daylight versus electric light did not seem to play a role in preference formation, this did appear to be the case for sunny versus overcast weather. These results preliminarily indicate that if sunny environments are more restorative than overcast ones, these effects might run through associative pathways. Here we see a possibility to continue this line of inquiry in future research. The sun, sky, and clouds may be an intrinsic part of daylight experiences. Possibly, daylight could still exhibit beneficial effects on human wellbeing after a brief exposure through psychological pathways by manipulating weather type.

In the previous section we saw that criticism had been expressed concerning the plurality of different types of natural and urban environments used in restoration research. Daylight is even more complex, entailing not only a multitude of different characteristics but also different temporal and geographical influences. More so than for natural versus urban environments, we do not yet know which of these characteristics are important. Even though we generally prefer daylight over electric light, which characteristics of daylight relate to this preference is still a sort of a mystery as is nicely illustrated by the following quote from the Swiss architect Peter Zumthor (2006a, pp. 61):

“Thinking about daylight and artificial light I have to admit that daylight, the light on things, is so moving me that I feel it almost has a spiritual quality. When the sun comes up in the morning - which I always find so marvelous, absolutely fantastic the way it comes back every morning - and casts it’s light on things, it doesn’t feel as if it quite belongs to this world.

I don't understand light. It gives me the feeling there's something beyond me, something beyond all understanding. And I am very glad, very grateful there is such a thing."

Is it the presence of directional sunbeams or sun patches (Boubekri, Hull, & Boyer, 1991), is it the dynamic character of daylight (e.g., Wang & Boubekri, 2011) or is it the intensity and spectral composition of daylight (e.g., Wirz-Justice at al., 1996). Moreover, daylight is highly correlated to for instance season (and subsequently to the amount of green nature in winter versus summer), weather type, latitude, and temperature. Not least, daylight is often accompanied by a view. In other words, the studies conducted in this dissertation form just the tip of the iceberg and more research is required to see which characteristics of daylight are important for psychological benefits.

To conclude, we found no short-term benefits of exposure to daylight without view content on mood, physiology, or self-regulatory performance. As we did not study long-term exposure to daylight versus electric light, possible benefits of daylight could still occur for these longer durations, possibly even without a view content. Two main explanations for the absence of short-term benefits of daylight have been presented. First of all, beneficial effects of daylight may not only depend on the light source itself, but also on additional benefits accompanying daylight entrance such as having a view including the sky, sun, and clouds. Second, since the valence of associations with daylight versus electric light did not mediate the effect on preference, potential psychological benefits of daylight may run through different pathways than for natural environments. We can only speculate on these other mechanisms. Possibly, rather than the instantaneous affective responses to natural environments, daylight could exhibit superior effects over electric light during long-term exposure. For instance by increasing the feeling of being connected with the outside world or through the dynamic nature of daylight in connection with the weather type and time of day.

We investigated effects of daylight versus electric light in research paradigms derived from restoration research. This gave us a number of insights, namely that people prefer bright over dark scenes, sunny over overcast weather, and daylight over electric light. A short exposure to daylight compared to electric light further did not prove to be restorative or instorative for mood, physiology, or self-regulatory performance. The study of health effects of natural versus urban environments could also benefit from research paradigms within the lighting domain.

7.4 Lessons to be learned from lighting research?

This dissertation has used insights from restoration research to look at the phenomenon of light. Cross-pollinations can also be searched in the opposite direction as knowledge about the salutogenic effects of nature could also benefit from a close inspection of the experimental paradigms used in the lighting domain. The evolutionary significance of nature has been stressed in restoration research, but the evidence base for this evolutionary basis is not very strong yet (see e.g., Joye & van den Berg, 2011). In contrast to natural environments, there is a strong evidence base for the evolutionary significance of daylight expressed for instance in markers of circadian timing (e.g., melatonin; Cajochen, Kräuchi, & Wirz-Justice, 2003). A more frequent use of biological markers to investigate short-term and long-term physiological responses to nature could empower claims made within restoration theory. Moreover, physiological parameters are sometimes included in the experimental set-up - as it was in this dissertation - but little research has focused on the exact psychological constructs underpinning these physiological outcomes.

Not only can we learn from research in the lighting domain, it is also important to realize the profound role that light plays in our daily life. We have already seen in Chapter Two that the weather type on images can have extensive effects on how the image is perceived, as well as on the preference for the displayed environments. This also has consequences for the study of restorative effects of nature. Experimental designs testing both exposure to real and mediated nature should take into account for instance the weather conditions and the time of day in which the experiment is conducted. Moreover, circadian timing not only influences outcomes of restoration research, but research in general investigating effects on for instance mood and cognitive performance.

The role of light in daily life dictates our circadian rhythm through various biological mechanisms. The main focus of our studies has been on psychological effects of the naturalness of the light source, but biological mechanisms are also central to human functioning. These rhythms are not only reflected in our sleep-wake cycle, but also in many diurnal patterns as for instance in subjective alertness (Akerstedt, Kecklund, & Hallvig, 2013), pain perception (Glynn & Lloyd, 1976), cognitive performance (Blatter & Cajochen, 2006), but also reward motivation and positive affect (Murray et al., 2009).

7.5 Theoretical contribution

In this dissertation, we tested for beneficial effects of daylight and nature through psychological pathways, and investigated whether the two natural phenomena shared psychological underlying mechanisms. For natural environments, an extensive evidence base is already present for these psychological mechanisms, whereas this evidence base is virtually non-existent for effects of daylight. In this section, we will revisit the outcomes discussed above and will indicate the theoretical contribution of these findings to the existing literature.

Even though psychological benefits of natural environments have already been widely established, this dissertation still contributes to the existing nature restoration literature in a number of areas. To start with, a striking overlap with effects of daylight was discussed in Chapter One. This review further indicated that exposure to daylight has important biological effects, as for instance circadian entrainment or acute effects on brain responses. In Chapter Two, we found that the brightness and weather type on photos influenced preference ratings, irrespective of the displayed environment. Together, these outcomes signal the importance of taking light variables into account when designing a nature intervention study

Novel insights were also provided by the association studies in Chapter Three. We were able to show that people have associations with natural environments and that these associations are generally more positively evaluated than the associations with urban environments. In turn, these associations predicted preference ratings. These results empirically prove the previously made theoretical assumption that learned associations are an important element of the restorative effects of nature (Tuan, 1974). Moreover, these outcomes preliminarily suggest that nature evokes more positive thoughts and these positive thoughts, in turn, can be restorative.

The predominant assertion in literature of natural environments exhibiting restorative effects was challenged by the outcomes of the effect studies in Chapter Five. When including control conditions, we found evidence for ‘instorative’ rather than restorative effects. Furthermore, novel findings include the effects found on Heart Rate Variability – an outcome that has received little attention up till now in this field of research. Two studies further tested a previously made theoretical link between ART and ego-depletion theory. We were able to show that self-regulatory performance improved on lower level cognitive tasks after a three-minute exposure to natural environments, but that effects were absent for higher order executive functioning tasks.

These outcomes suggest that existing theories in restoration literature need reconsideration. Not only evolutionary based preferences (PTE; Ulrich, 1983) or involuntary attention (ART; S.Kaplan, 1995) should be considered when theorizing about the beneficial effects of nature, but associations with natural environments and the positive emotions that nature evokes should be taken into account as well. Furthermore, theories should go beyond mere restorative effects of nature by incorporating possible revitalizing or buffering effects. Not only did these results challenge existing conceptions within nature restoration theory, but together with the results of the studies investigating ego-replenishing effects of daylight (discussed in Chapter Six) they also raised important questions for ego-depletion theory itself as we were not able to find evidence for an effective ego-depletion manipulation in the majority of studies.

The effect studies comparing beneficial effects of daylight to electric light after ego-depletion generated null results in Chapter Six. In our attempt to separate effects of daylight from view content, we uncovered an important characteristic of daylight. Namely, beneficial *psychological* effects of daylight may depend on characteristics beyond the mere spectral composition and intensity of the light. We hypothesized that they may be dependent on the one factor that we tried to single out; a view. Besides the practical implications of these findings -which will be discussed in more depth in the next section- they also have important theoretical implications. Developing a theory for the psychological benefits of daylight should take into account the dependency of these beneficial effects on view content. Moreover, contrary to our efforts to separate daylight from view content, future research might want to explicitly incorporate the view in the research design.

Whereas we found no evidence for beneficial effects of daylight versus electric light, we were able to show that people show a strong preference for daylight in three different ways. First, environments that were sunny and bright were rated more positively than environments that were overcast and darker in Chapter Two. Second, words related to daylight were scored higher on preference than words related to electric light (Chapter Three). Third, a room with daylight scored higher on preference than a room with electric light (Chapter Six). These outcomes revealed an important pathway through which daylight can have beneficial psychological effects, namely though preferential evaluations. The association studies in Chapter Four further show that -just as natural versus urban environments- people have more positive associations with daylight than with electric light. However, the fact that these associations did not mediate preference ratings was a first indication that mere daylight (without a view) might not exhibit its beneficial effects through the same psychological pathways as natural environments do. Thus, one of the main theoretical contributions of this dissertation is that combined rather than separate effects of daylight and a view are to be expected.

7.6 Societal and Practical Implications

In the first chapter, we found that there is a considerable overlap in salutogenic effects of nature and daylight. Because effects were reported in two different research domains - with different experimental traditions - we investigated both phenomena using the same research paradigms. Moreover, as daylight and view type often co-occur and can improve several health outcomes in a similar manner, we explicitly aimed at controlling for daylight variables when investigating for beneficial effects of nature and vice versa. We would recommend this research practice to scholars investigating effects of daylight and nature. A detailed description on how researchers have controlled for potential confounds would be welcome as well. The latter would simultaneously aid the design and performance of replication studies (Annerstedt & Währborg, 2011; Veitch & Galasiu, 2012). For nature studies, this could include weather type, time of day of the experiment or when visual stimuli were collected, and a description of the lighting situation. For daylight studies, natural elements in the proximity and view content should be described. In addition, it has been argued that there is a need for a more detailed report of the lighting conditions in lighting research as well. Currently, most studies in the lighting domain report lighting conditions in terms of the visual system, corrected for the spectral sensitivity of the cone receptor system (expressed in the $V\lambda$ curve). Importantly though, this curve does not adequately represent the action spectrum of the non-visual (ipRGC) system. There is a strong need for a more extended description of subjects and lighting conditions, including age and visual state of the subjects and spectral composition and/or irradiance measured at eyelevel (CIE, 2009; Veitch & Galasiu, 2012).

The studies reported in Chapter One all generally support salutogenic effects of both daylight and nature. However, in order to persuade clinicians to embrace these salutogenic effects and to incorporate them into health interventions, there is an additional need for a strong empirical basis using not only cross-sectional designs but also randomized (placebo) controlled clinical trials. We hope this dissertation has further pointed out the risk of confounds when focusing on only one of the two phenomena, while not controlling for the other and the need to report how possible confounds are controlled for. We believe the challenge that lies ahead exists not only in finding out more about the underlying psychological mechanisms and their possible interrelatedness, but also in raising awareness of these two natural phenomena and their salutogenic properties. Exposure to either daylight or nature need not cost much effort or time. Natural environments, for instance, have already been proposed as micro-restorative experiences (R. Kaplan, 1993). Moreover, they are both often freely and abundantly available, but their beneficial aspects could be exploited more by raising awareness in the general population, designers, and the medical domain alike.

One of the main findings of this dissertation was that no immediate psychological benefits were found for daylight over electric light with the same intensity and colour temperature, whereas this was the case for view content with natural environments compared to urban environments. Biological benefits may still be achieved by daylight simulations, with the right type of light presented at the right biological timing. However, when aiming for benefits through psychological pathways these simulations may not be enough, as a view to the outside may be of vital importance. It is not yet clear what the exact content of the view needs to be to become restorative. Possibly a view related to daylight characteristics –such as the sun and sky- would be enough. This view can provide humans with a distraction from their daily routines and informational cues about what is going on in the outside world. If the view extends beyond the sky, the type of content is of great importance, with beneficial effects for natural environments but not for urban environments.

The superior effects of view content on micro-restorative outcomes once again stress the importance of the architectural elements windows. Much research and design effort is put in realizing daylight harvesting systems and daylight simulation armatures. The outcomes in this dissertation do not discard the importance of these systems for human wellbeing, but they do point to the fact that merely simulating daylight will not necessarily result in micro-restorative experiences. Longer exposure durations could still be very beneficial, possibly through biological mechanisms. But, importantly, even a short exposure to natural environments could have immediate benefits. Thus, windows (bringing both daylight and a view) should always be preferred over daylight simulation. Moreover, in those cases in which no daylight entrance is possible it will be worth considering that besides simulating daylight, a simulated (or virtual) window view could be very beneficial as well. Indeed, studies with virtual windows have already reported beneficial effects on positive affect and physiological stress responses (e.g., de Kort et al., 2006; Valtchanov, Barton, & Ellard, 2010). Virtual reality can not only be used to create windows where no view is available, but also to progress restoration research as stimuli sets become highly controllable and easily adjustable (Depledge, Stone, & Bird, 2011). However, many challenges still lie ahead in the development of virtual windows, such as motion parallax (IJsselsteijn, Oosting, Vogels, de Kort, & van Loenen, 2008). Moreover, where daylight simulation might be less effective because of the lack of a view to the outside, beneficial effects of nature might be enhanced by incorporating daylight simulation to the virtual window.

7.7 Conclusion

Daylight is part of our natural environment. Natural view content has already been found to exhibit psychological benefits. In this dissertation, we looked both at the effects of daylight and nature on mood, physiology, and self-regulation and at the psychological mechanisms by which they work. The majority of the results found were replicated in at least one other study and consistent results were found for explicit preferences and associative patterns for both nature and daylight. The absence of implicit preferences for environments differing in naturalness, weather type, and brightness was also found in three consecutive studies. Beneficial effects of nature on positive affect and heart rate variability were reported for two studies. Only effects of nature on self-regulatory performance yielded mixed results. Furthermore, the outcomes of two studies concerning effects of daylight on mood, physiology, and self-regulation were mostly in line with each other, namely that daylight does not offer micro-restorative experiences.
Several theories have already been proposed to explain for these psychological benefits of nature. However, these theories do not offer a conclusive explanation yet for the beneficial effects of nature. In this dissertation, we found that learned associations through the experiences that people have had with natural environments could play an important role in affective responses to natural environments. We suggested that positive affect (generated though this positive associations) might be a candidate for further theoretical and empirical investigation. We also saw preliminary evidence pointing us to the possibility that weather type may exhibit very similar influences on human beings.

Daylight was clearly preferred over electric light. Yet it did not seem to offer the micro-restorative experiences that natural environments presented us. Associative patterns with daylight were not related to the higher preference ratings for these environments, indicating that learned associations with daylight could not explain potential psychological benefits of natural light. Moreover, daylight entrance is often accompanied by other characteristics such as sun patches and a view to the outside. These additional benefits of daylight might well be the requirements for daylight to become salutogenic.

The following quote by Peter Zumthor (2006b, pp. 89) illustrates the complexity of daylight and it's connectedness with perceiving the world, with having a view:

"I want to think about the artificial light in my buildings, in our cities and in our landscapes, and I catch myself forever returning, like a lover, to the object of my admiration: the light that meets the earth from afar, the untold numbers of bodies, structures, materials, liquids, surfaces, colors, and shapes that radiate in the light. The light that comes from outside the earth makes the air visible, I can see it."

The connectedness of daylight with the way we perceive the world and the views that we have has one important consequence, namely that the disentanglement of daylight and view content may not be possible, as part of the beneficial effects of daylight may run through offering human beings a view. A natural view, in turn, exhibits salutogenic effects. Synergetic - rather than separate - effects might be expected from natural views and daylight.

I once told a friend
that nothing really ends
no one can prove it
so I am asking you now
could it possibly be
(Deus - Nothing really ends)

References

Akerstedt, T. & Gillberg, M. (1990). Subjective and objective sleepiness in the active individual. *International Journal of Neuroscience, 52,* 29-37.

Akerstedt, T., Kecklund, G., & Hallvig, D. (2013). repeated sleepiness ratings throughout the day - A normative field study among 800 individuals across one working week. *Sleep medicine, 14,* e56.

Alimoglu, M.K. & Donmez, L. (2005). Daylight exposure and the other predictors of burnout among nurses in a university hospital. *International Journal of Nursing Studies, 42,* 549-555.

Ando, T. (2008). Retrieved from: http://www.clarkart.edu/exhibitions/ando/ando.html

Annerstedt, M. & Währborg, P. (2011). Nature-assisted therapy: Systematic review of controlled and observational studies. *Scandinavian Journal of Public Health, 39,* 371-388.

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

Appleton, J. (1975). *The experience of landscape*. London: Wiley.

Appleton, J. (1992). Prospects and refuges revisited. In J.L. Nasar (ed.), *Environmental Aesthetics: Theory, research, & applications*, (pp. 27-44). New York: Cambridge University Press.

Arns, M., van der Heijden, K.B., Arnold, L.E., & Kenemans, J.L. (2013). Geographic variation in the prevelance of Attention-Deficit/Hyperactivity Disorder: The Sunny Perspective. *Society of Biological Psychiatry.*

Ashby, F.G., Isen, A.M., & Turken, A.U. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review, 106,* 529-550.

Aspinwall, L.G. (1998). Rethinking the role of positive affect in self-regulation. *Motivation and Emotion, 22,* 1-32.

Avery D.H., Dahl K. (1993). Bright light therapy and circadian neuroendocrine function in seasonal affective disorder. In: J. Schulkin(ed.) *Hormonally induced changes in mind and brain*. San Diego: Academic Press.

Avery, D.H., Dahl, K., Savage, M.V., Brengelmann, G.K., Larsen, L.H., Kenny, M.A., ……, Prinz, P.N. (1997). Circadian temperature and cortisol rhythms during a constant routine are phase-delayed in hypersomnic winter depression. *Biological Psychiatry, 41,* 1109-1123.

Avery, D.H., Kizer, D., Bolte, M.A., & Hellekson, C. (2001). Bright light therapy of subsyndromal seasonal affective disorder in the workplace: morning vs. afternoon exposure. *Acta Psychiatrica Scandinavica, 103,* 267-274.

Barker, R.G. (1968). *Ecological Psychology: Concepts and methods for studying the environment of human behavior.* Chicago: University of Chicago Press.

Barton, J. & Pretty, J. (2010). What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. *Environmental Science & Technology, 44,* 3947-3955.

Bauer, D.J., Preacher, K.J., & Gil, K.M. (2006). Conceptualizing and testing random indirect effects and moderated mediation in multilevel models: new procedures and recommendations. *Psychological Methods, 11,* 142-163.

Baumeister, R.F. (1998). The Self. In D.T. Gilbert, S.T. Fiske, & G.Lindzey (eds.), *Handbook of Social Psychology* (pp. 680-740). McGraw-Hill, New York.

Baumeister, R.F., Vohs, K.D., & Tice, D.M. (2007). The strength model of self-control. *Current Directions in Psychological Science, 16,* 351-355.

Beauchemin, K. M., & Hays, P. (1996). Sunny hospital rooms expedite recovery from severe and refractory depressions. *Journal of Affective Disorders, 40,* 49-51.

Beauchemin, K. M., & Hays, P. (1998). Dying in the dark: sunshine, gender and outcomes in myocardial infarction. *Journal of the Royal Society of Medicine, 91,* 352-354.

Begemann, S.H.A., van den Beld, G.J., & Tenner, A.D. (1997). Daylight, artificial light and people in an office environment, overview of visual and biological responses. *International Journal of Industrial Ergonomics, 20,* 231-239.

Benedetti, F., Colombo, C., Barbini, b., Campori, E., & Smeraldi, E. (2001). Morning sunlight reduces length of hospitalization in bipolar depression. *Journal of Affective Disorders, 62,* 221-223.

Bentall, R.P., Kinderman, P., & Manson, K. (2005). Self-discrepancies in bipolar disorder: Comparison of manic, depressed, remitted and normal participants. *British Journal of Clinical Psychology*, *44*, 457-473.

van den Berg, A. E. (2005). *Health impacts of healing environments. A review of evidence for benefits of nature, daylight, fresh air, and quiet in healthcare settings.* Groningen: Foundation 200 years University Hospital Groningen.

van den Berg, A.E. & van den Berg, C.G. (2010). A comparison of children with ADHD in a natural and built setting. *Child: care, health, and development, 37,* 430-439.

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

van den Berg, A.E. & Custers, M.H.G. (2010). Gardening promotes neuroendocrine and affective restoration from stress. *Journal of Health Psychology, 16,* 3-11.

Berlyne, D.E. (1971). *Aesthetics and psychobiology*. New York: McGraw-Hill.

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

Berntson, G.G., & Cacioppo, J.T. (2004). Heart rate variability: Stress and psychiatric conditions. In: M. Malik, & A.J. Camm (eds). *Dynamic electrocardiography* (pp. 57–64.), New York: Blackwell Futura.

Berson, D.M., Dunn, F.A., & Takao, M. (2002). Phototransduction by retinal ganglion cells that set the circadian clock. *Science*, 295, 1070-1073.

Bilchick, K.C. & Berger, R.D. (2006). Heart rate variability. *Journal of Cardiovascular Electrophysiology, 17,* 691-694.

Blair, I.V. (2002). The malleability of automatic stereotypes and prejudice. *Personality and Social Psychology Review, 6,* 242-261.

Blascovich, J. & Mendes, W.B. (2000). The challenge and threat appraisals. The role of affective cues. In: J. Forgas (ed.), *Feeling and Thinking: The Role of Affect in Social Cognition,*
(pp. 59-82). Cambridge: Cambridge University Press.

Blatter, K. & Cajochen, C. (2006). Circadian rhythms in cognitive performance: Methodological constraints, protocols, theoretical underpinnings. *Physiology & Behavior, 90*, 196-208.

Bodin, M. & Hartig, T. (2003). Does the outdoor environment matter for psychological restoration gained through running? *Psychology of Sport and Exercise, 4*, 141-153.

Boeka, A. G. & Lokken, K. L. (2008). Neuropsychological performance of a clinical sample of extremely obese individuals. *Archives of Clinical Neuropsychology, 23*, 467-474.

Borkowski, J. G., & Burke, J. E. (1996). Theories, models, and measurements of executive functioning: An information processing perspective. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 235–261). Baltimore, MD: Paul Brookes.

Boubekri, M., Hull, R.B., & Boyer, L.L. (1991). Impact of window size and sunlight penetration on office workers' mood and satisfaction. *Environment and Behavior, 23,* 474-493.

Bowler, D.E., Buyung-Ali, L.M., Knight, T.M., & Pullin, A.S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *Public Health, 10,* 1-10.

Boyce, P., Hunter, C., & Howlett, O. (2003). *The benefits of daylight through windows.* Report, US Department of Energy.

Bradley, M.M., & Lang, P.J. (1994). Measuring emotion: The self-assessment manakin and the semantical differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25,* 49-59.

Brainard, G.C., Hanifin, J.P., Greeson, J.M., Byrne,B., Glickman, G., Gerner, E., & Rollag, M.D. (2001). Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. *The Journal of Neuroscience, 21*, 6405-6412.

Brosschot, J.F., Pieper, S., & Thayer, J.F. (2005). Expanding stress theory: Prolonged activation and perseverative cognition, *Psychoneuroendocrinology, 30,* 1043-1049.

Brosschot, J.F. & Thayer, J.F. (2003). Heart rate response is longer after negative emotions than after positive emotions. *International Journal of Psychophysiology, 50,* 181-187.

Cajochen, C., Kräuchi, K., & Wirz-Justice, A. (2003). Role of melatonin in the regulation of human circadian rhythms and sleep. *Journal of Neuroendocrinology, 15,* 432-437.

Canu, W. & Gordon, M. (2005). Mother nature as treatment for ADHD: Overstating the benefits of green. *American Journal of Public Health, 95,* 371.

Carver, C.S. (2006). Approach, avoidance, and the self-regulation of affect and action. *Motivation and Emotion, 30,* 105-110.

Chauvel, P., Collins, J.B., Dogniaux, R., & Longmore, J. (1982). Glare from windows: Current views of the problem. *Lighting Research and Technology, 14,* 31-46.

Cho, k. (2001). Chronic ‘jet lag’ produces temporal lobe atrophy and spatial cognitive deficits. *Nature Neuroscience, 4,* 567-568.

Chrousos, G.P. (2009). Stress and disorders of the stress system. *Nature Reviews Endocrinology, 5,* 374-381.

Clarkson, J.J., Hirt, E.R., Chapman, D.A., Jia, L. (2011). The impact of illusory fatigue on executive control: Do perceptions of depletion impair working memory capacity? *Social Psychological and Personality Science, 2,* 231-238.

Cohen, S. (1978). Environmental load and the allocation of attention. In: A.Baum, J.E.Singer, & S. Valins (eds.), *Advances in environmental psychology* (pp. 1-28). Hillsdale: Lawrence Erlbaum Associates.

Cohen, S., Glass, D.C., & Phillips, S. (1979). Environment and health. In: H. Freeman, S. Levine, & L.G. Reeder: *Handbook of medical sociology* (pp. 134-149). New Jersey: Prentice-Hall.

Cohen, S. & Spacapan, S. (1978). The aftereffects of stress: An attentional interpretation. *Environmental Psychology and non-verbal behavior, 3*, 43-57.

Collins, B.L. (1975). Windows and people: A literature Survey. *NBS Building Science Series, 70*.

Commission Internationale de l’Eclairage (CIE) (2009). *Ocular lighting effects on human physiology and behaviour* (CIE 158:2009). Vienna: CIE.

Converse, P.D., & DeShon, R.P. (2009). A tale of two tasks: Reversing the self-regulatory resource depletion effect. *Journal of Applied Psychology, 94,* 1318-1324.

Conway, A.R.A., Kane, M.J., Bunting, M.E., Hambrick, D.Z., Wilhelm, O., & Engle, R.W. (2005). Working memory span tasks: a methodological review and user’s guide. *Psychonomic Bulletin & Review, 12,* 769-786.

Cronbach, L.J., & Furby, L. (1970). How should we measure “change” – or should we? *Psychological Bulletin, 74,* 68-80.

Cummings, J.L., & Miller, B.L. (2007). *The Human Frontal Lobes*. New York: The Guilford Press.

Czeisler, C.A., Moore-Ede, M.C., & Coleman, R.H. (1982). Rotating shift work schedules that disrupt sleep are improved by applying circadian principles. *Science, 30,* 460-463.

Denissen, J. J., Butalid, L., Penke, L., & van Aken, M. A. (2008). The effects of weather on daily mood: A multilevel approach. *Emotion, 8,* 662-667.

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

DiBonaventura, M., & Chapman, G. B. (2008). Do decision biases predict bad decisions? Omission bias, naturalness bias, and influenza vaccination. *Medical Decision Making, 28*, 532-539.

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

Dijkstra, K., Pieterse, M., & Pruyn, A. (2006). Physical environment stimuli that turn health care facilities into healing environments through psychologically mediated effects: a systematic review. *Journal of Advanced Nursing, 56,* 166-181.

Duffy, S., & Verges, M. (2010). Forces of nature affect implicit connections with nature. *Environment and Behavior, 42,* 723-739.

Elias, M.F., Elias, P.K., Sullivan, L.M., Wolf, P.A., & D'Agustino, R.B. (2003). Lower cognitive function in the presence of obesity and hypertension: the Framingham heart study. *International Journal of Obesity, 27,* 260-268.

Ellenbogen, M.A., Schwartzman, A.E., Stewart, J., & Walker, C. (2002). Stress and selective attention: the interplay of mood, cortisol levels, and emotional information processing. *Psychophysiology, 39*, 723-732.

Ellet, L., Freeman, D., & Garety, P.A. (2008). The psychological effect of an urban environment on individuals with persecutory delusions: the Camberwell walk study. *Schizophrenia Research, 99,* 77-84.

Elliot, A.J. (2006). The hierarchical model of approach-avoidance motivation. *Emotion and Motivation, 30,* 111-116.

Fazio, R.H., & Olson, M.A. (2003). Implicit measures in social cognition research: their meaning and use. *Annual Review of Psychology, 54,* 297-327.

Federman, E. J., Drebing, C. E., Boisvert, C., Penk, W., Binus, G., & Rosenheck, R. (2000). Relationship between climate and psychiatric inpatient length of stay in veterans health administration hospitals. *American Journal of Psychiatry, 157,* 1669-1673.

Foo, J,Y,A., & Lim, C.S. (2006). Pulse transit time as an indirect marker for variations in cardiovascular related activity. *Technology and Health Care, 14,* 97-108.

Foster, R. G., Provencio, I., Hudson, D., Fiske, S., De Grip, W., & Menaker, M. (1991). Circadian photoreception in the retinally degenerate mouse. *Journal of Comparative Physiology 169*, 39-50.

Fredrickson, B.L. (2004). The broaden-and-build theory of positive emotions. *Philosophical Transactions of the Royal Society B: Biological Sciences, 359,* 1367-1377.

Fredrickson, B.L. & Joiner, T. (2002). Positive emotions trigger upward spirals toward emotional well-being. *Psychological Science, 13,* 172-175.

Fredrickson, B. L., & Levenson, R. W. (1998). Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. *Cognition and Emotion, 12,* 191-220.

Fredrickson, B., Mancuso, R.A., Branigan, C., & Tugade, M.M. (2000). The undoing effects of positive emotions. *Motivation and Emotion, 24,* 237-258.

Freedman, D.M., Dosemeci, M., & McGlynn, K. (2002). Sunlight and mortality from breast, ovarian, colon, prostate, and non-melanoma skin cancer: a composite death certificate based case-control study. *Occupational Environmental Medicine, 59,* 257-262.

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

Gaillot, M.T., & Baumeister, R.F. (2007). The physiology of willpower: Linking blood glucose to self-control. *Personality and Social Psychology Review, 11,* 303-327.

Gaillot, M.T., Baumeister, R.F., DeWal, C.N., Maner, J.N., Plant, E.A., Tice, D.M., …., & Schmeichel, B.J. (2007). Self-control relies on glucose as a limited energy source: Willpower is more than a metaphor. *Journal of Personality and Social Psychology, 92,* 325-336.

Gawronski, B., & Bodenhausen, G.V. (2006). Associative and propositional processes in evaluation: an integrative review of implicit and explicit attitude change. *Psychological Bulletin, 132,* 692-731.

Gibson, J.J. (1979). *The ecological approach to visual perception.* Boston: Houghton Mifflin.

Gifford, R. (2002). *Environmental Psychology: Principles and Practice.* Canada: Optimal Books.

Glynn, C.J. & Lloyd, J.W. (1976). The diurnal variation in the perception of pain. *Procedures of the Royal Society of Medicine, 69,* 369-372.

Goldberg, T.E., Greenberg, R.D., Griffin, S.J., Gold, J.M., Kleinman, J.E., Pickar, D., …, & Weinberger, D.R. (1993). The effect of clozapine on cognition and psychiatric symptoms in patients with schizophrenia. *British Journal of Psychiatry, 62,* 43-48.

Gordijn, E.H., Hindriks, I., Koomen, W., Dijksterhuis, A., & van Knipperburg, A. (2004). Consequences of stereotype suppression and internal suppression motivation: a self-regulation approach. *Personality and Social Psychology Bulletin, 30,* 212-224.

Grossarth-Marticek, R. & Eysenck, H.J. (1995). Self-regulation and mortality from cancer, coronary heart disease, and other causes: a prospective study. *Personality and Individual Differences, 19,* 781-795.

Haans, A. (*in press*). The natural preference in people's appraisal of light. *Journal of Environmental Psychology*

Haans, A. & Olijve, K.C.M. (2012). Sunlight versus electrical Light: A naturalness bias in people's appraisal of light. *Proceedings of Experiencing Light 2012.* Eindhoven.

Hagger, M.S. (2010). Self-regulation: an important construct in health psychology research and practice. *Health Psychology Review, 4*, 57-65.

Hagger, M.S., Wood, C., Stiff, C., & Chatzisarantis, N.L.D. (2010). Ego depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin, 136,* 495-525.

Hanyu, K. (1997). Visual properties and affective appraisals in residential areas after dark. *Journal of Environmental Psychology, 17*, 301-315.

Hanyu, K. (2000). Visual properties and affective appraisals in residential areas in daylight. *Journal of Environmental Psychology, 20,* 273-284.

Hartig, T., van den Berg, A., Hagerhall, C.M., Tomalak, M., Bauer, N., Hansmann, R., ..., & Waaseth, G. (2010). Health benefits of nature experience: Psychological, social and cultural processes. In: K. Nilsson, M. Sangster, C. Gallis, T. Hartig, S. de Vries, K. Seeland, & J. Schipperijn. *Forest, trees and human health.* Dordrecht: Springer Science Business and Media.

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

Hartig, T., Catalano, R., & Ong, M. (2007). Cold summer weather, constrained restoration, and the use of antidepressants in Sweden. *Journal of Environmental Psychology, 27,* 107-116.

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

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

Hartig, T., Kaiser, F.G., & Bowler, D. (1997). Further development of a measure of perceived environmental restorativeness. *Institute of Housing Research, Working paper (5).*

Hartig, T., Korpela, K. M., Evans, G. W., & Gärling, T. (1996). Validation of a measure of perceived environmental restorativeness (Göteborg Psychological Reports, 26:7). Göteborg: Göteborg University, Department of Psychology.

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

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

Häusser, J.A., Mojzisch, A., & Schuulz-Hardt, S. (2011). Endocrinological and psychological responses to job stressors: An experimental test of the Job Demand-Control Model. *Psychoneuroendocrinology, 36,* 1021-1031.

Heft, H. (2013). An ecological approach to psychology. *Review of General Psychology, 17,* 162-165.

Hietanen, J. K., Klemetillä, T., Kettunen, J. E., & Korpela, K. M. (2007). What is a nice smile like that doing in a place like this? Automatic affective responses to environments influence the recognition of facial expressions. *Psychological Research, 71,* 539-552.

Hietanen, J. K., & Korpela, K. M. (2004). Do both negative and positive environmental scenes elicit rapid affective processing? *Environment and Behavior, 36,* 558-577.

Hofmann, W., Vohs, K.D., & Baumeister, R.F. (2012). What people desire, feel conflicted about, and try to resist in everyday life. *Psychological Science, 23*, 582-588.

Holick, M.F. (2008). Vitamin D: a D-lightful health perspective. *Nutrition Reviews, 66*, 182-194.

Hoyer, J., Beesdo, K., Gloster, A.T., Runge, J., Höfler, M., & Becker, E.S. (2009). Worry exposure versus applied relaxation in the treatment of generalized anxiety disorder. *Psychotherapy and Psychosomatics, 78,* 106-115.

IJsselsteijn, W.A., Oosting, W., Vogels, I.M.L.C., de Kort, Y.A.W., & van Loenen, E. (2008). A room with a cue: The efficacy of movement parallax, occlusion, and blur in creating virtual windows. *Presence, 17,* 269-282.

Inzlicht, M. & Schmeichel, B.J. (2012). What is ego-depletion? Toward a mechanistic revision of the resource model of self-control. *Psychological Science, 7,* 450-463.

Jacobsen, T. (2010). Beauty and the brain: culture, history, and individual differences in aesthetic appreciation. *Journal of Anatomy, 216,* 184-191.

Jacobsen, T., Schubotz, R.I., Höfel, L., & Cramon, D.Y. (2006). Brain correlates of aesthetic judgment of beauty. *NeuroImage, 29,* 276-285.

Joye, Y. & van den Berg, A. (2011). Is love for green in our genes? A critical analysis of evolutionary assumptions in restorative environments research. *Urban Forestry and Urban Greening, 10,* 261-268.

Jung, C.M., Khalsa, S.B.S., Scheer, F.A.J.L., Cajochen. C., Lockley, S.W., Czeisler, C.A., Wright, K.P. (2010). Acute effects of bright light exposure on cortisol levels. *Journal of Biological Rhythms, 25,* 208-216.

Kaida, K., Takahashi, M., Haratani, T., Otsuka, Y., Fukasawa, K., & Nakata, A. (2006). Indoor exposure to natural bright light prevents afternoon sleepiness. *Sleep, 29,* 462-469.

Kaida, K., Takahashi, M., & Otsuka, Y. (2007). A short nap and bright light exposure improve positive mood status. *Industrial Health, 45,* 301-308.

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

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

Kaplan, S. (1987). Aesthetics, affect, and cognition. Environmental preferences from an evolutionary perspective. *Environment and Behavior, 19,* 3-32.

Kaplan, S. (1992a). Perception and landscape: conceptions and misconceptions. In J.L. Nasar (ed.), *Environmental Aesthetics: Theory, research, & applications*, (pp. 45-55). New York: Cambridge University Press.

Kaplan, S. (1992b). Where cognition and affect meet: a theoretical analysis of preference. In J.L. Nasar (ed.), *Environmental Aesthetics: Theory, research, & applications*, (pp. 56-63). New York: Cambridge University Press.

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

Kaplan, S., & Berman, M. G. (2010). Directed attention as a common resource for executive functioning and self-regulation. *Perspectives on Psychological Science, 5,* 43-57.

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

Kashdan, T.B., Weeks, J.W., & Savostyanova, A. (2011). Whether, how, and when social anxiety shapes positive experiences and events: A self-regulatory framework and treatment implications. *Clinical Psychology Review, 31,* 786-799.

Kauffman, J.M. (2009). Benefits of vitamin D supplementation. *Journal of American Physicians and Surgeons, 14,* 38-45.

Keep, P., James, J., & Inman, M. (1980). Windows in the intensive care unit. *Anaesthesia, 35,* 257-262.

Keller, M. C., Fredrickson, B. L., Ybarra, O., Côté, S., Johnson, K., Mikels, J., Conway, A., & Wager, T. (2005). A warm heart and a clear head: The contingent effects of weather on mood and cognition. *Psychological Science, 16,* 724-731.

Kent, S. T., McClure, L. A., Crosson, W. L., Arnett, D. K., Wadley, V. G., & Sathiakumar, N. (2009). Effect of sunlight exposure on cognitive function among depressed and non-depressed participants: a REGARDS cross-sectional study. *Environmental Health, 8,* 34-47.

Klimstra, T. A., Frijs, T., Keijsers, L., Denissen, J. J., Raaijmakers, Q. A., van Aken, M. A., ….., & Meeus, W. H. (2011). Come rain or come shine: Individual differences in how weather affects mood. *Emotion, 11,* 1495-1499.

Knopf, R. (1987). Human behavior, cognition, and affect in the natural environment. In D. Stokols & I. Altman (eds.), *Handbook of Environmental Psychology,* (pp. 783-825).Wiley, New York.

Konecni, V.J. (1979). Determinants of aesthetic preference and effects of exposure to aesthetic stimuli: social, emotional and cognitive factors. *Progress in Experimental Personality Research, 9*, 149–197.

Koole, S.L., & van den Berg, A.E. (2005). Lost in the wilderness: Terror management, action orientation, and nature evaluation. *Journal of Personality and Social Psychology, 88,* 1014-1028.

Koole, S.L., Jostmann, N.B., & Baumann, N. (2012). Do demanding conditions help or hurt self-regulation? *Social and Personality Psychology Compass, 6,* 328-246.

Kööts, L., Realo, A., & Allik, J. (2011). The influence of the weather on affective experience. An experience sampling study. *Journal of Individual Differences, 32,* 74-84.

Korpela, K. M., Klemetillä, T., & Hietanen, J. K. (2002). Evidence for rapid affective evaluation of environmental scenes. *Environment and Behavior, 34,* 634-650.

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

Krause, R., Bühring, M., Hopfenmüller, W., Holick, M. F., & Sharma, A. M. (1998). Ultraviolet B and blood pressure. *The Lancet, 352,* 709-710.

Krull, & MacKinnon (2001). Multilevel modeling of individual and group level mediated effects. *Multivariate behavioral Research, 36,* 249-277.

Küller, R., & Lindsten, C. (1992). Health and behavior of children in classrooms with and without windows. *Journal of Environmental Psychology, 12,* 305-317.

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

Kuo, F.E. & Taylor, A.F. (2004). A potential natural treatment for attention/deficit/hyperactivity disorder: Evidence from a national study, *American Journal of Public Health, 94,* 1580-1588.

Lakens, D., Semin, G. R., & Foroni, F. (2012). But for the Bad, There Would Not Be Good: Grounding Valence in Brightness Through Shared Relational Structures. *Journal of Experimental Psychology: General, 141*, 584-594.

Lambert, G. W., Reid, C., Kaye, D. M., Jennings, G. L., & Esler, M. D. (2002). Effect of sunlight and season on serotonin turnover in the brain. *Lancet, 360,* 1840-1842.

Landsdowne, A. T., & Provost, S. C. (1998). Vitamin D3 enhances mood in healthy subjects in winter. *Psychopharmacology, 135,* 319-323.

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D.H.J., Hawk, S.T., & van Knippenberg, A. (2010). Presentation and validation of the Radboud Faces Database. *Cognition, & Emotion, 24(8),* 1377-1388.

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

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., ..., & Meyer-Linderberg, A. (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature. 474,* 498-501.

Lee, J.J., Gino, F., & Staats, B.R. (*in press*). Rainmakers: Why bad weather means good productivity. *Journal of Applied Psychology.*

Lee, R.J. & Hernández-Andrés, J. (2005). Colors of the daytime overcast sky. *Applied Optics, 44,* 5712-5722.

Leger, D., Bayon, V., Elbaz, M., Philip, P., & Choudat, D. (2011). Underexposure to light at work and its association to insomnia and sleepiness: A cross-sectional study of 13296 workers of one transportation company. *Journal of psychosomatic research, 70,* 29-36.

Leppämäki, S., Partonen, T., & Lönnqvist, J. (2002). Bright-light exposure combined with physical exercise elevates mood. *Journal of Affective Disorders, 72,* 139-144.

Leproult, R., Colecchia, E.F., L'Hermite-Balériaux, M. & van Cauter, E. (2001). Transition from dim to bright light in the morning induices an immediate elevation of cortisol levels. *The Journal of Clinical Endocrinology & Metabolism, 86,* 151-157.

Lieverse, R., van Someren, E.J.W., Nielen, M.M.A., Uitdehaag, B.M.J., Smit, J.H., & Hoogendijk, W.J.G. (2011). Bright Light treatment in elderly patients with nonseasonal major depressive disorder. A randomized placebo-controlled trial. *Archives of General Psychiatry, 86,* 61-70.

Lindström, B. & Erikson, M. (2005). Salutogenesis. *Journal of Epidemiology and Public Health, 59,* 440-442.

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

Magnusson, A., & Boivin, D. (2003). Seasonal Affective Disorder: An overview. *Chronobiology International, 20,* 189-207.

Maller, C., Townsend, M., Pryor, A., Brown, P., & st Leger, L. (2005). Healthy nature healthy people: 'contact with nature' as an upstream health promotion intervention for populations. *Health Promotion International, 21,* 45-54.

Markus, T.A. (1967). The function of windows – a reappraisal. *Building Science, 2,* 97-121.

Martijn, C., Tenbült, P., Merckelbach, H., Dreezens, E., & de Vries, N.K. (2002). Getting a grip on ourselves: Challenging expectancies about loss of energy after self-control. *Social Cognition, 20,* 441-460.

Matthews, G., Jones, D.M., & Chamberlain, A.G. (1990). Refining the measurement of mood: the UWIST mood adjective checklist. *British Journal of Psychology, 81,* 17-42.

McEwen, B.S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load, *Annals of the New York Academy of Sciences, 840,* 33-44.

McGrath, J.J., Burne, T.H., Féron, F., Mackay-Sims, A., Eyles, D.W. (2010). Developmental vitamin D deficiency and risk of schizophrenia: a 10-year update. *Schizophrenia Bulletin, 36,* 1073-1078.

Meesters, Y., & Waslander, M. (2009). Burnout and light treatment. *Stress and Health, 26,* 13-20.

Meier, B. P., & Robinson, M. D. (2004). Why the sunny side is up. *Psychological Science, 15,* 243-247.

Meier, B.P., Robinson, M.D., Crawford, L.E., & Ahlvers, W.J. (2007). When "light" and "dark" thoughts become light and dark responses: Affect biases brightness judgments. *Emotion, 7,* 366-367.

Messner, C., & Wanke, M. (2011). Good weather for Schwartz and Clore. *Emotion, 11,* 436-437.

Millar-Craig, M.W., Bishop, C.N., Rafferty, E.B. (1978). Circadian variation of blood pressure. *Lancet*, *311, 795*-797.

Mitchell, R. (2012). Is physical activity in natural environments better for mental health than exercise in other environments? *Social Science and Medicine, in press.*

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

Monk, T.H. (1989). A visual analogue scale technique to measure global vigor and affect. *Psychiatry Research, 27,* 89-99.

Moore, E.O. (1981). A prison environment's effect of health care service demands. *Journal of Environmental Systems, 11,* 17-34.

Moritz, S., Birkner, C., Kloss, M., Jahn, H., Hand, I., Haasen, C., & Krausz, M. (2002). Executive functioning in obsessive-compulsive disorder, unipolar depression, and schizophrenia. *Archives of Clinical Neuropsychology, 17,* 477-483.

Münch, M., Linnart, F., Borisuit, A., Jaeggi, S.M., & Scartezzini, J. (2012). Effects of prior light exposure on early evening performance, subjective sleepiness, and hormonal secretion. *Behavioral Neuroscience, 126,* 196-203.

Muraven, M., Gagné, M., & Rosman, H. (2008). Helpful self-control: Autonomy support, vitality, and depletion. *Journal of Experimental Social Psychology, 44,* 573-585.

Muraven, M., Shmueli, D., & Burkley, E. (2006). Conserving self-control strength. *Personality Processes and Individual Differences, 91,* 524-537.

Murray, G., Nicholas, C.L., Kleiman, J., Dwyer, R., Carrington, M.J., Allen, N.B., & Trinder, J. (2009). Nature's clock and human mood: The circadian system modulates reward motivation. *Emotion, 9,* 705-716.

Nightingale, F. (1860). *Notes on nursing. What it is and what it is not.* Retrieved from http://digital.library.upenn.edu/women/nightingale/nursing/nursing.html.

Nikunen, H.J. & Korpela, K.M. (2009). Restorative environments – Does the focus of light have an effect on restorative experiences? *Journal of Light and Visual Environment, 33,* 37-45.

Nikunen, H.J. & Korpela, K.M. (2012). The effects of scene content and focus of light on perceived restorativeness, fear and preference in nightscapes. *Journal of Environmental Planning and management,* 1-16.

Nisbet, E.K. & Zelenski, J.M. (2011). Underestimating nearby nature. Affective forecasting errors obscure the happy path to sustainability. *Psychological Science, 22,* 1101-1106.

Nosek, B.A. (2005). Moderators of the relationship between implicit and explicit evaluation. *Journal of Experimental Psychology: General, 134,* 565-584.

Okubo, M., & Ishiwaka, K. (2011). Automatic semantic association between emotional valence and brightness in the right hemisphere. *Cognition & Emotion, 7,* 1273-1280.

Orbach, J., Ehrlich, D., & Heath, H.A. (1963). Reversibility of the Necker Cube: I. An examination of the concept of "satisfaction of orientation". *Perceptual and Motor Skills, 17,* 439-458.

van Os, J., Kenis, G., & Rutten, B.P.F. (2010). The environment and schizophrenia. *Nature, 468,* 203-212.

Osgood, (1957). *The measurement of meaning.* University of Illinois Press.

Ottoson, J., & Grahn, P. (2008). The role of natural settings in crisis rehabilitation: How does the level of crisis influence the response to experiences of nature with regard to measures of rehabilitation. *Landscape Research, 33,* 51-70.

Parsons, R. (1991). The potential influences of environmental perception on human health. *Journal of Environmental Psychology, 11,* 1-23.

Parsons, R., Tassinary, L.G., Ulrich, R.S., Hebl, M., & Grossman-Alexander, M. (1998). The view from the road: implications for stress recovery and immunization. *Journal of Environmental Psychology, 18,* 113-139.

Partonen, T., & Lönnqvist, J. (2000). Bright light improves vitality and alleviates distress in healthy people. *Journal of Affective disorders,* 57, 55-61.

Peters, M.L., Godeart, G.L.R., Ballieux, R.E., van Vliet, M., Willemsen, J.J., Sweep, F.C.G.J., & Heijnen, C.J. (1998). Cardiovascular and endocrine responses to experimental stress: effects of mental effort and controllability. *Psychoneuroendocrinology, 23,* 1-17.

Porteous, J.D. (1996). *Environmental Aesthetics: Ideas, Politics, and Planning.* London: Routledge.

Pressman, S.D. & Cohen, S. (2005). Does positive affect influence health? *Psychological Bulletin, 131,* 925-971.

Pretty, J. (2004). How nature contributes to mental and physical health. *Spirituality and Health International, 5,* 68-78.

Quirin, M., Kazen, M., Rohrman, S., & Kuhl, J. (2009). Implicit but not explicit affectivity predicts circadian and reactive cortisol: Using the implicit positive and negative affect test. *Journal of Personality, 77*, 401-426.

Rea, M.S., Bierman, A., Figueiro, M.G., Bullough, J.D. (2008). A new approach to understanding the impact of circadian disruption on human health. *Journal of Circadian Rhythms, 6*, 1-14.

Rechlin, T., Weis, M., Schneider, K., Zimmermann, U., & Kaschka, W.P. (1995). Does bright-light therapy influence autonomic heart-rate parameters? *Journal of Affective Disorders,*
34, 131-137.

Richter, P., Bouhuys, A.L., van den Hoofdakker, R.H., Beersma, D.G.M., Jansen, J.H.C., Lambers, P.A., …, & Bos, P. (1992). Imaginary versus real light for winter depression. *Biological Psychiatry, 31,* 534-536.

Riemersma-van der Lek, R.F., Swaab, D.F., Twisk, J., Hol, E.M., Hoogendijk, W.J.G., & van Someren, E.J.W. (2008). Effect of bright light and melatonin on cognitive and noncognitive function in elderly residents of group care facilities: A randomized controlled trial. *Journal of American Medical Association, 299,* 2642-2655.

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

Rosenthal, N. E., Sack, D. A., Gillin, J. C., Lewy, A. J., Goodwin, F. K., Davenport, Y., ….., & Wehr, T. A. (1984). Seasonal affective disorder: a description of the syndrome and preliminary findings with light therapy. *Archives of General Psychiatry 41*, 72-80.

aan het Rot, M., Benkelfat, C., Boivin, D.B., & Young, S.N. (2008). Bright light exposure during acute tryptophan depletion prevents a lowering of mood in mildly seasonal women. *European Neuropsychopharmacology, 18,* 14-23.

aan het Rot, M., Moskowitz, D.S., & Young, S.N. (2008). Exposure to bright light is associated with positive social interaction and good mood over short time periods: A naturalistic study in mildly seasonal people. *Journal of Psychiatric Research, 42,* 311-319.

Rozin, P. (2005). The meaning of “natural": Process more important than content. *Psychological Science, 16*, 653-658.

Rüger, M., Gordijn, M.C.M., Beersma, D.G.M., de Vries, B., & Daan, S. (2005). Time-of-day-dependent effects of bright light exposure on human psychophysiology: comparison of daytime and nighttime exposure. *American Journal of Physiology – Regulatory, Integrative and Comparative Physiology, 290,* 1413-1420.

Rüger, M., & Scheer, F. A. (2009). Effects of circadian disruption on cardiometabolic system. *Reviews in Endocrine and Metabolic Disorders, 10,* 245-260.

Ryan, R.M., & Deci, E.L. (2000). Self-determination Theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55,* 68-78.

Ryan, R. M., & Deci, E. L. (2008). From ego-depletion to vitality: Theory and findings concerning the facilitation of energy available to the self. *Social and Personality Compass, 22,* 702-717.

Ryan, R.M. & Frederick, C. (1997). On energy, personality, and health: Subjective vitality as a dynamic reflection of well-being. *Journal of Personality, 65,* 529-565.

Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., & Gagné, M. (2009). Vitalizing effects of being outdoors and in nature. *Journal of Environmental Psychology, 30,* 159-168.

Salmon, P. (2001). Effects of physical exercise on anxiety, depression, and sensitivity to stress: a unifying theory. *Clinical Psychology Review, 21,* 33-61.

Salovey, P., Rothman, A.J., Detweiler, J.B., & Stewart, W.T. (2000). Emotional states and physical health. *American Psychologist, 35,* 110-121.

Sauro, M.D., Jorgensen, R.S., & Pedlow, C.T. (2003). Stress, glucocorticoids, and memory: A meta-analytic review. *Stress, 6,* 235-245.

Schlager, D., Schwartz, J.E., & Bromet, E.J. (1993). Seasonal variations of current symptoms in a healthy population. *British Journal of Psychiatry, 163,* 322-326.

Schmeichel, B.J. (2007). Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *Journal of Experimental Psychology: General, 136,* 241-255.

Schmeichel, B.J., & Vohs, K. (2007). Self-affirmation and self-control: Affirming core values counteracts Ego depletion. *Journal of Personality and Social Psychology, 96,* 770-782.

Schmoll, C., Lascaratos, G., Dhillon, B., Skene, D., & Riha, R.L. (2011). The role of retinal regulation of sleep in health and disease. *Sleep Medicine Reviews, 15,* 107-113.

Scholten, L.M., & Midden, C.J.H. (1997). Milieubelastingen van verpakkingen: effecten van de ’natuurlijkheidsbias’ op consumentenoordelen. *Milieu: Tijdschrift voor de milieukunde, 12,* 167-174.

Schwarz, N., & Clore, G. L. (1983). Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. *Journal of Personality and Social Psychology, 45,* 513-523.

Segerstrom, S.C., & Solberg Nes, L. (2007). Heart rate variability reflects self-regulatory strength, effort, and fatigue. *Psychological Science, 18,* 275-281.

Seligman, M.E.P. & Csikszentmihalyi, M. (2000). Positive psychology. An introduction. *American Psychologist, 55,* 5-14.

Selye, H. (1950). Stress and the general adaptation syndrome. *British Medical Journal, 1,* 1383-1392.

Sloan, R.P., Shapiro, P.A., Bagiella, E., Boni, S.M., Paik, M., Bigger Jr, J.T., …., & Gorman, J.M. (1994). Effect of mental stress throughout the day on cardiac autonomic control. *Biological Psychology, 37,* 89-99.

Smith, A.W. & Baum, A. (2003). The influence of psychological factors on restorative function in health and illness. In J.Suls & K.A. Watson (eds.). *Social psychological foundations in health and illness* (pp. 431-457). Maiden: Blackwell Publishing.

Smolders, K.C.H.J., de Kort, Y.A.W., & Cluitmans, P.J.M. (2012). A higher illuminance induces alertness even during office hours: Findings on subjective measures, task performance and heart rate measures. *Physiology and Behavior, 107,* 7-16.

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

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

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

Steidle, A., Werth, L., & Hanke, E.V. (2011). You can't see much in the dark: Darkness affects construal level and psychological distance. *Social Psychology, 42,*

Strack, F., & Deutch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review, 8,* 220-247.

Straus, S.M.J.M., Bleumink, G.S., Dieleman, J.P., van der Lei, J., Stricker, B.H.Ch., & Sturkenboom, M.C.J.M. (2004). The incidence of sudden cardiac death in the general population. *Journal of Clinical Epidemiology, 57,* 98-102.

Streiner, D.L., & Norman, G.R. (1995). *Health measurement scales: a practical guide to their development and use, 2,* 28-53.

Suchy, Y. (2009). Executive functioning: Overview, assessment, and research issues for non-neuro-psychologists. *Annals of Behavioral Medicine, 37,* 106-116.

Tangney, J.P., Baumeister, R.F., & Luzio Boone, A. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality, 72,* 271 – 322.

Takano, T., Nakamura, K., & Watanabe, M. (2002). Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *Journal of Epidemiological Community Health, 56,* 913-918.

Task force of the European Society of cardiology and The North American Society of pacing and Electrophysiology (1996). Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. *European Heart Journal, 17,* 354-381.

Taylor, A.F., & Kuo, F.E. (2009). Children with attention deficits concentrate better after walking in the park. *Journal of Attention Disorders, 12,* 402-209.

Tenessen, C. M., & Cimprich, B. (1995). Views to nature: effects on attention. *Journal of Environmental Psychology, 15*, 77-85.

Terman, M. & Terman, J.S. (2005). Light therapy for seasonal and nonseasonal depression: Efficacy, protocol, safety, and side effects. *CNS Spectrums, 10*, 647-663.

Thapan, K., Arendt, J., & Skene, D.J. (2001). An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. *The Journal of Physiology, 535*, 261-267.

Thayer, J.F. & Brosschot, J.F. (2005). Psychosomatics and psychopathology: Looking up and down from the brain. *Psychoneuroendocrinology, 30,* 1050-1058.

Thayer, J.F., Hansen, A.L., Saus-Rose, E., & Helge Johnsen, B. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annuals of Behavioral Medicine, 37,* 141-153.

Thayer, R.E. (1989). *The Biopsychology of Mood and Arousal*. Oxford: Oxford University Press.

The Baumeister and Tice Social Psychology Lab. http://www.psy.fsu.edu/ ~baumeisterticelab /egodepletion.html, accessed online 01-03-2014.

Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J. & Depledge, M.H. (2011). Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. *Environmental Science & Technology, 45,* 1761-1772.

Tice, D.M., Baumeister, R.F., Shmueli, D. & Muraven, M. (2007). Restoring the self: Positive affect helps improve self-regulation following ego-depletion. *Journal of Experimental Social Psychology, 43,* 379-384.

Tomasello, M. (2000). *The cultural Origins of Human Cognition.* Boston: Harvard University Press.

Tooby, J. & Cosmides, L. (1990). The past explains the present. Emotional adaptations and the structure of ancestral environments. *Ethology and Sociobiology, 11,* 375-424.

Tuan, Y.F. (1974). *Topophilia: a study of environmental perception, attitudes, and values.* New Jersey: Englewood Cliffs.

Tuan, Y.F. (1977). Experience and appreciation. In *Children, nature, and the urban environment: Proceedings of a symposium fair, proceedings of a symposium-fair (pp 1-5)*. Upper Darby: USDA Forest Service General Technical Report NE-30.

Tuaycharoen, N., & Tregenza, P.R. (2005). Discomfort glare from interesting images. *Lighting Research and Technology, 37,* 329-341.

Tuaycharoen, N., & Tregenza, P.R. (2007). View and discomfort glare from windows. *Lighting Research and Technology, 39,* 185-200.

Turner, M.L., & Engle, R.W. (1989). Is working memory task dependent? *Journal of Memory and Language, 28,* 127-134.

Tyler, J.M., & Burns, K.C. (2008). After depletion: The replenishment of the self's regulatory resources. *Self and Identity, 7,* 305-321.

Ulrich, R. S. (1981). Natural versus urban scenes: Some psychophysiological effects. *Environment and Behavior, 13,* 523-556.

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman, & J. Wohlwill, eds., *Human Behavior and Environment* (pp. 85-125). New York: Plenum Press.

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

Ulrich, R. S. (2008). Biophilic theory and research for healthcare design. In S. Kellert, J. Heerwagen, & M. Mador (Eds.): *Biophilic Design: the theory, science, and practice of bringing buildings to life* (pp. 87-106). New Jersey: John Wiley, & Sons, Inc.

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

VandeWalle, G., Maquet, P., & Dijk, D. J. (2009). Light as a modulator of cognitive brain function. *Trends in Cognitive Science, 13,* 429-438.

Vandewalle G., Schwartz, Grandjean, Wuillaume, Balteau, Degueldre, Schabus, Phillips, Luxen, Dijk, D. J., & Maquet, P. (2010). Spectral quality of light modulates emotional brain responses in humans. *Proceedings of the National Academy of Sciences of the United States of America, 107,* 19549-19554.

Veitch, J.A. & Galasiu, A.D. (2012). *The physiological and psychological effects of windows, daylight, and view at home: Review and research agenda* (IRC-RR-325). Ottawa: NRC Institute for Research in Construction.

Veitch, J. A., & Gifford, R. (1996). Assessing beliefs about lighting effects on health, performance, mood, and social behaviors. *Environment and Behavior, 28,* 446-470.

Veitch, J. A., Hine, D. W., & Gifford, R. (1993). End users' knowledge, preferences, and beliefs for lighting. *Journal of Interior Design, 19*, 15-26.

Walch, J. M., Rabin, B. S., Day, R., Williams, J. N., Choi, K., & Kang, J. D. (2005). The effect of sunlight on postoperative analgesic medication use: a prospective study of patients undergoing spinal surgery. *Psychosomatic Medicine, 67,* 156-163.

Waldstein, S.R., Tankard, C.F., Maier, K.J, Pelletier, J.R., Snow, J., Gardner, A.W., Macko, R., & Katzel, L.I. (2003). Peripheral arterial disease and cognitive function. *Psychosomatic Medicine, 65,* 757-763.

Wallis, D.W., Penckofer, S., `& Sizemore, G.W. (2008). The "sunshine deficit" and cardiovascular disease. *Circulation, 118,* 1476-1485.

Wang, N., & Boubekri, M. (2011). Design recommendations based on cognitive, mood, and preference assessments in a sunlit workspace. *Lighting Research and Technology, 43,* 55-72.

Ward Thompson, C., Roe, J., Aspinall, P., Mitchell, R., Clow, A., & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape and Urban planning, 105,* 221-229.

Webb, A.R. (2006). Considerations for lighting in the built environment: Non-visual effects of light. *Energy and Buildings, 38,* 721-727.
Weinstein, N., Przybylski, A.K., & Ryan, R.M. (2009). Can nature make us more caring? Effects of immersion in nature on intrinsic aspirations and generosity. *Personality and Social Psychology Bulletin, 35,* 1315-1329.
Wells, M.W.P. (1965). Subjective responses to the lighting installation in a modern office building and their design implications. *Building Science, 1,* 57-68.
Wells, N.M. (2000). At home with nature: Effects of ”greenness” on children’s cognitive functioning. *Environment and Behavior, 32,* 775-795.
Wells, N.M. & Evans, G.W. (2003). Nearby nature: A buffer of lifse stress among rural children. *Environment and Behavior, 35,* 311-330.
White, M.P., Alcock, I., Wheeler, B.W., & Depledge, M.H. (2013). Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. *Psychological Science, 24,* 920-928.
White, M., Smith, A., Humphreys, K., Pahl, S., Snelling, D., & Depledge, M. (2010). Blue space: The importance of water for preference, affect, and restorativeness ratings of natural and built scenes. *Journal of Environmental Psychology, 30,* 482-493.
WHO (1948). Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, pp. 100) and entered into force on 7 April 1948.
Williams, P.G., Suchy, Y., & Rau, H.K. (2009). Individual differences in executive functioning: implications for stress research. *Annals of Behavioral Medicine, 37,* 126-140.
Wilson, L.M. (1972). Intensive care delirium. *Archives of Internal Medicine, 130,* 225-226.
Wilson, T.D., Lindsey, S., & Schooler, T.Y. (2000). A model of dual attitudes. *Psychological Review, 1,* 101-126.
Wirz-Justice, A., Benedetti, F. & Terman, M. (2009). *Chronotherapeutic interventions for Affective Disorders. A clinician’s manual for Light and Wake Therapy.* Basel: Karger.
Wirz-Justice, A., Graw, P., Kräuchi, K., Sarrafzadeh, A., English, J., Arendt, J., & Sand. L. (1996). ’Natural’ light treatment of seasonal affective disorder. *Journal of Affective Disorders, 37,* 109-120.
Wohlwill, J.F. (1983). The concept of nature: A psychologist’s view. In I. Altman & J.F. Wohlwill (Eds.), *Human behavior and the environment,* (pp. 1-34). New York: Plenum.
Wright, R.A., & Kirby, L.D. (2001). Effort determination of cardiovascular response: An integrative analysis with applications in social psychology. In: M.P. Zanna (ed.), *Advances in Experimental Psychology* (pp. 255-307). San Diego: Academic.
Wright, R.A., Stewart, C.C., & Barnett, B.R. (2008). Mental fatigue influence on effort-related cardiovascular response: Extension across the regulatory (inhibitory)/non-regulatory performance dimension. *International Journal of Psychophysiology, 69,* 127-133.

Zajonc, R. B. (1980). Feeling and thinking. Preferences need no inferences. *American Psychologist, 35,* 151-175.
Zumthor, P. (2006a). *Atmospheres.* Basel: Birkhäuser.
Zumthor, P. (2006b). *Thinking architecture.* Basel: Birkhäuser.

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I would like to thank my friends for their patience and understanding for my frequent cancellations, especially when nearing the deadline for my thesis. In particular, I would like to thank Lady. Your fresh ‘outsiders’ point of view helps me keep both feet on the ground. You’re always curious and interested and have always been there for me. Thank you for that.

Last, but not least, I would like to thank my family; mama, Sebastiaan, and Marit and Bram. I am happy and very grateful for your unconditional support and guidance. All four of you have been very committed to my research: you read my work, alerted me to relevant information, asked questions, and often functioned -without complaining- as test subjects.

Mama, you have been my rock, my tower of strength, and I owe you a lot. Your commitment to my research and career has kept me going. You have raised us to pursue our own goals and dreams and will support and be proud of us whichever path we wish to choose. Sebastiaan, you have helped me greatly by programming my experience sampling application. A study which in the end wasn't included in this thesis, but hopefully will provide new scientific insights very soon. Not only did you give 'technical' support, your enthusiasm for my topic of research and future career means a lot to me. Marit and Bram, you are big nature-lovers yourselves and have always shown interest and pride in my work and I have especially appreciated your encouragements when I was finishing this dissertation. Marit, whenever I felt down, you always advised me to 'practice what I preach' and take a walk in nature.

Life has not only centred around science and dissertations. As a family, we had dreams, hopes, and expectations, but also disappointments and obstacles. I am grateful that we are a team, in prosperity and adversity. Therefore, I would like to end with a musical quote (of which you have already found many more throughout this dissertation).

And tonight
We can truly say
Together we're invincible
(Muse, Invincible)

Femke Beute,
Eindhoven, July 2014

Summary

For centuries nature has been our habitat. Many aspects of this natural habitat still have pronounced influence on our health and wellbeing. In this dissertation, two important aspects of nature have been studied; views to nature and exposure to daylight. The main focus has been on positive effects of these two phenomena as well as on the underlying psychological pathways of these beneficial effects.

The first chapter of this dissertation presented a review of the evidence for beneficial health effects of nature and daylight. The main conclusion of this chapter was that natural views and daylight exposure rendered very similar beneficial effects on a variety of health outcomes, but both phenomena have been studied in two separate research fields. Not only did this separation oftentimes result in ignorance with respect to contributions of one phenomenon while studying the other, but there were also substantial differences in the experimental paradigms used, the outcome variables, and the proposed underlying mechanism. Therefore, it was as of yet unclear whether natural elements and daylight exhibit similar beneficial effects and whether they share psychological underlying pathways. For these reasons, the aim of this dissertation was twofold. First, we wanted to test whether daylight and natural environments share underlying psychological mechanisms. Second, beneficial effects of nature and daylight were studied separately, but within uniform research paradigms to establish whether their health-benefits overlap.

A first series of experiments investigated possible underlying psychological pathways. The focus was on preference and associative pathways. Preference ratings are important in view of the adaptive function of preferences, guiding humans toward healthy -and away from unhealthy- environments. Chapter One reported a consistent preference for environments that are natural, bright, and sunny as opposed to urban, dark, and overcast environments. These findings were found for explicit preference, but not for implicit preferences. Two studies also investigating implicit preference for environments differing in naturalness, brightness, and weather type did not yield any evidence for implicit preferences. Importantly, we were also not able to replicate earlier findings concerning implicit preferences for natural environments. Preference for daylight over artificial light was further reported in Chapters Four and Six and higher preference ratings for natural as opposed to urban environments

were reported in Chapters Three and Five. These higher preference ratings provided a first indication for possible restorative effects of daylight through psychological pathways.

Psychological mechanisms were further investigated in Chapters Three (for nature) and Four (for daylight). This time, the focus was on associative patterns, which are closely related to preference formation and have been previously theoretically linked to restorative potential. The series of experiments performed in these two Chapters aimed at testing whether and how associations differ between nature or daylight and their artificial counterparts. Results indicated that both daylight and natural environments generally evoked more positive associations than respectively electric light and urban environments. The valence of the associations generated with natural as opposed to urban environments mediated the preference ratings for these environments. The causal directionality of this relation was further investigated for natural environments by guiding the valence of associations. To this end, participants were instructed to generate either only positive or only negative associations and to suppress all oppositely valenced associations. The outcomes of these conditions rendered mixed results. Preference ratings for natural environments remained unaffected by the association instructions, whereas preference ratings for urban environments declined when generating only negative associations as compared to only positive associations.

Whereas natural environments and daylight both evoked more positive associations, the influence of these associations on preference formations differed between them. For natural environments, the valence of associations significantly mediated the effect of environment type on preference. However, for daylight the valence of associations did not mediate preference outcomes. Therefore, we did not guide the valence of associations with daylight versus electric light.

Not only did we investigate the relation between valence of associations and preference, we also studied the role of associations in restorative outcomes. For both natural environments (Chapter Three) and daylight (Chapter Four), little evidence for restorative effects of the manipulation was found. We hypothesized that the association generation task possibly interfered with the restoration process. On the other hand, in Chapter Three, we found that generating positive associations resulted in an improved restoration of positive affect. We postulated that natural environments generate more positive thoughts and that positive thoughts, in turn, can be restorative.

From the studies investigating psychological pathways for the effects of nature and daylight, we learned that they both generated more positive associations and higher preference ratings than electric light and urban environments. However, the relation between associations and preference ratings appeared to differ between the two phenomena, indicating that they could work through different psychological pathways.

These differences between daylight and nature proceeded when comparing the beneficial effects of nature and daylight on self-regulation, mood, and physiology. A uniform research paradigm was chosen to test these effects; ego-depletion. Chapter Five focused on the effects of nature, while controlling for daylight influences and Chapter Six investigated beneficial effects of daylight as compared to electric light while view content was kept constant.

In both chapters, the ego-depletion inductions were not always successful. Irrespective of this, Chapter Five reported consistent beneficial effects of natural environments on Heart Rate Variability and hedonic tone. By testing effects of nature after a depleting as well as a control task, we were further able to challenge the notion of restorative versus instorative effects. Contrary to the beneficial effects found for natural environments, no such effects were found for daylight. No difference in restoration outcomes were reported for daylight as compared to electric light in Chapter Six.

To conclude, we found that both daylight and nature generated higher preference ratings as well as more positive associations than their artificial counterparts. In a uniform research paradigm we established beneficial effects of nature, but not of daylight. In Chapter Seven, we postulated that the lack of evidence for beneficial effects of daylight could be due to the separation of daylight from view content. The psychological benefits of daylight may depend on exactly the factor we tried to single out; view content.

Samenvatting

Eeuwenlang hebben wij ons in natuurlijke omgevingen gevestigd. Veel aspecten van deze natuurlijke habitat hebben nog steeds een uitgesproken invloed op onze gezondheid en welzijn. In deze dissertatie zijn twee aspecten van natuur onderzocht; uitzicht op natuurlijke elementen en blootstelling aan daglicht. Hierbij is de aandacht met name gericht op zowel de positieve effecten van deze twee fenomenen als hun onderliggende psychologische mechanismen.

Het eerste hoofdstuk van dit proefschrift presenteerde een overzicht van de evidentie voor de heilzame effecten van natuur en daglicht op gezondheid. De hoofdconclusie van dit hoofdstuk was dat natuurlijke uitzichten en blootstelling aan daglicht vrijwel dezelfde positieve effecten hebben op verscheidene gezondheidsuitkomsten, maar dat de twee fenomenen wel in twee verschillende onderzoeksvelden onderzocht waren. Deze scheiding zorgde niet alleen voor onwetendheid over mogelijke bijdragen van het ene fenomeen wanneer het andere onderzocht werd, maar ook voor substantiële verschillen in de gebruikte onderzoeksmethodieken, de afhankelijke variabelen, en de voorgestelde onderliggende mechanismen. Hierdoor is het tot op heden niet duidelijk of daglicht en natuurlijke elementen inderdaad dezelfde heilzame werking hebben en of ze onderliggende psychologische paden delen. Om deze redenen was het doel van dit proefschrift tweeledig. Om te beginnen wilden we testen of daglicht en natuurlijke omgevingen psychologische onderliggende mechanismen delen. Ten tweede hebben we de effecten van daglicht en natuur apart bestudeerd, maar wel met uniforme onderzoek paradigma's om vast te stellen of hun gezondheid voordelen overlappen.

Een eerste serie van experimenten onderzocht mogelijke onderliggende psychologische paden. De focus was op preferentie en associatieve paden. Preferentie scores zijn belangrijk door hun adaptieve functie, waardoor ze mensen aan de ene kant naar gezonde omgevingen sturen en aan de andere kant wegleiden van ongezonde omgevingen. Het eerste hoofdstuk rapporteerde een consistente voorkeur voor natuurlijke, lichte en zonnige omgevingen over stedelijke, donkere en bewolkte omgevingen. Deze bevindingen golden voor expliciete voorkeur, maar niet voor impliciete voorkeur. In twee studies naar impliciete voorkeuren voor omgevingen verschillend in natuurlijkheid, lichtheid, en weertype werd geen bewijs gevonden voor de aanwezigheid van impliciete voorkeuren. Deze uitkomsten waren van groot belang, aangezien we hiermee eerdere bevindingen omtrent impliciete voorkeuren voor natuurlijke omgevingen niet konden repliceren. Een hogere voorkeur score voor daglicht dan voor kunstlicht werd gevonden in de Hoofdstukken Vier en Zes en ook voor natuurlijke dan voor stedelijke omgevingen in de Hoofdstukken Drie en Vijf. Deze hogere voorkeur scores waren de eerste indicatie voor mogelijke helende effecten van daglicht door psychologische paden.

Deze psychologische paden warden verder onderzocht in de Hoofdstukken Drie (natuur) en Vier (daglicht). In deze hoofdstukken was de focus op associatieve patronen gericht, welke sterk gerelateerd zijn aan de vorming van voorkeuren en eerder met de helende werking van natuur in verband zijn gebracht. De serie experimenten in deze twee hoofdstukken hadden als doel te testen hoe associaties verschillen tussen aan de ene kant natuur en daglicht en aan de andere kant hun kunstmatige tegenhangers. De uitkomsten duiden op algemeen positievere associaties met natuur en daglicht dan met respectievelijk stad en kunstlicht.

De valentie van de associaties die gegenereerd waren met natuurlijke versus stedelijke omgevingen medieerde de voorkeuren voor deze omgevingen. De causale richting van deze relatie werd verder onderzocht door de valentie van de te genereren associaties te sturen. Hiervoor werden de participanten gevraagd om alleen positieve of alleen negatieve associaties te genereren en om alle associaties met tegengestelde valentie te onderdrukken. Deze manipulaties resulteerde in wisselende uitkomsten. Voorkeur voor natuurlijke omgevingen bleef onaangetast door deze instructies, terwijl voorkeur scores voor stedelijke omgevingen negatiever werden wanneer alleen negatieve associaties bedacht mochten worden, vergeleken met wanneer alleen positieve associaties bedacht mochten worden.

Waar natuurlijke omgevingen en daglicht allebei positievere associaties opriepen, verschilde de invloed van deze associaties op voorkeur tussen hun. Voor natuurlijke omgevingen medieerde de associaties voorkeur formatie. Dit bleek echter niet het geval voor de vergelijking tussen daglicht en kunstlicht. Om deze reden hebben we de valentie van de associaties voor daglicht niet verder gestuurd.

We hebben niet alleen gekeken naar de relatie tussen valentie van de associaties en preferentie, we hebben ook gekeken naar de rol van deze associaties in helende effecten. Zowel voor natuur (Hoofdstuk Drie) en daglicht (Hoofdstuk Vier) vonden we weinig aanwijzingen voor helende effecten van onze manipulatie. Onze hypothese is dat de associatie-taak mogelijk de helende werking van onze manipulaties teniet deed. Aan de andere kant, in Hoofdstuk Drie vonden we wel dat het genereren van positieve associaties het herstel van positief affect faciliteerde. We veronderstelden dat natuurlijke omgevingen positievere gedachtes opwekt en dat deze positieve gedachtes op hun beurt helend kunnen werken.

Van de studies naar de psychologische paden voor de effecten van natuur en daglicht hebben we geleerd dat ze beiden meer positieve associaties en hogere voorkeur scores genereerden dan stedelijke omgevingen en kunstlicht. Echter, de relatie tussen associaties en voorkeur verschilde tussen de beide fenomenen, wat aanduidt dat ze mogelijk via verschillende psychologische paden werken.

Deze verschillen tussen daglicht en natuur werden voortgezet wanneer de herstellende effecten van natuur en daglicht op zelfregulatie, stemming, en fysiologie vergeleken werden. Een uniform onderzoek paradigma werd gekozen om deze effecten te testen; ‘ego-depletion’. Hoofdstuk Vijf richtte zich op de effecten van natuur, terwijl mogelijke invloeden van daglicht gecontroleerd werden en Hoofdstuk Zes onderzocht herstellende effecten van daglicht vergeleken met kunstlicht terwijl het type uitzicht gelijk werd gehouden.

In beide hoofdstukken waren de inducties van ‘ego-depletion’ niet altijd succesvol. Ongeacht hiervan rapporteerde Hoofdstuk Vijf consistente herstellende effecten van natuurlijke omgevingen op hartslag variabiliteit en positief affect. Door effecten van natuur te vergelijken voor participanten die wel of niet uitgeput waren, konden we verder ook de notie van herstellende versus bufferende (‘instorative) effecten uitdagen. In tegenstelling tot de helende effecten van natuur, werd er geen bewijs gevonden voor positieve effecten van daglicht vergeleken met kunstlicht in Hoofdstuk Zes.

Tot slot, we vonden dat zowel daglicht en natuur hogere voorkeur scores en positievere associaties opriepen dan hun artificiële tegenhangers. Gebruik makend van uniforme onderzoek paradigma’s hebben we herstellende effecten van natuur bewezen, maar niet van daglicht. In Hoofdstuk Zeven stelden we dat het uitblijven van evidentie voor herstellende effecten van daglicht zou kunnen komen door het scheiden van daglicht en uitzicht. De psychologische voordelen van daglicht hangt mogelijk af van juist datgeen dat we probeerden uit te sluiten; uitzicht.

Curriculum Vitae

Femke Beute was born in Apeldoorn (The Netherlands) on February 10th, 1982. After receiving her VWO diploma at the Comenius College in Uden in 2000, she started studying at the Eindhoven University of Technology. Here, she obtained her Bachelor's degree in Architecture, Building, and Planning. Subsequently, she received her Master of Science (Cum Laude) in Human Technology Interaction in 2010, with a graduation project focusing on individual differences in restorative behaviours.

Directly after finishing the Master Program, she started her PhD at Human Technology Interaction. Working as an environmental psychologist enables her to combine her background in both architecture and psychology. She has a warm interest in the positive effects of the physical environment on health and wellbeing. During her PhD, she investigated the psychological benefits of natural environments and daylight on wellbeing.

In her Postdoctoral research, she continues to study the health-protective effects of our environment with a special focus on effects of light through both psychological and biological pathways. The health outcomes she studies include, but are not limited to, seasonal and non-seasonal depression, burnout, and stress.

During her PhD, she started being an active co-convener of the Restorative Environments Network and her work has so far resulted in three publications and over 15 conference publications.

Appendix A

Summary Tables

Table 1. Overview of studies investigating effects of nature and daylight on stress.

Stress outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds
Physiology Nature	Ulrich et al., 1991	Experimental (120)	Watching nature vs. urban videos (10 min) *after* stressor. Nature videos: a forest / water stream with surrounding vegetation. No humans or animals. Urban videos: commercial streets (differing in traffic intensity) / outdoor traffic-free shopping malls (differing in amount of pedestrians). All: openness in foreground /middle ground.	Decrease skin-conductance, EMG, PTT, Heart rate **	In lab, excluding direct exposure to sunlight. Weather type and time of day for the videos were kept constant.
	Fredrickson & Levenson, 1998	Experimental (60)	Watching nature vs. urban videos (100 s) *after* stressor. Nature video: waves crashing on a beach / playing puppies. Other videos: sad scene from a movie / geometrical patterns.	Faster return to baseline heart rate & PTT **	In lab, excluding direct exposure to sunlight. Not all videos were taken outdoors. Weather type not reported.
	Laumann et al., 2003	Experimental (28)	Watching nature vs. urban videos (20 min) *after* mental fatigue induction. Nature video: waterside / coastline, including (distant) hills and cows. Some people were visible in the distance. Urban video: main pedestrian street and bus station.	Lower heart rate	In lab, excluding direct exposure to sunlight. All videos taken during sunny weather
	Parsons et al., 1998	Experimental (176)	Watching nature vs. urban videos (20 min) *before* stressor. Nature video: Roads / highways with predominantly natural vegetation along the roadside / roads along golf courses. Urban video: in and around cities, with predominantly man-made artifacts. Mixed video: Mix of commercial buildings and vegetation.	Lower skin conductance level	In lab, excluding direct exposure to sunlight. Weather type of videos not reported.
	Hartig et al., 2003	Quasi-experimental (112)	Several assessments of blood pressure during a walk (50 min) in a natural vs. urban environment *after* mental fatigue task. Natural site: wildlife preserve in canyon. Urban site: medium density office and retail area, surrounded by a judicial complex and hospital.	Lower blood pressure during first part of walk	Outside, direct exposure to daylight. Weather reported to be generally warm and clear.

Table 1 – continued

Stress outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Physiology (continued) Daylight	Rechlin et al., 1995	Experimental (48)	Heart Rate measured for in-patients (major depression) versus controls on 5th day of bright vs, dim light treatment. Bright light (> 2500 lx.) during day 1-14, dim light (< 200 lx.) during day 15-19, between 6:00 and 7:30 am. No additional information provided.	Higher heart rate variability (indicates more relaxation)	No information provided of the setting in which the bright light therapy was offered
Neurology Nature	Lederbogen et al., 2011	Experimental (23 / 32)	Stressor task under fMRI, contrasting groups with rural vs. urban upbringing. Urbanicity upbringing calculated by (up to age of 15): urbanicity score * amount of years living in that area. Urbanicity score: > 100.000 residents (=3), > 10.000 residents (=2), < 10.000 residents (=1).	Lower brain reactivity to stress	In fMRI scanner, no daylight entrance. No data included for time spent outdoors during upbringing
Cortisol Nature	Ward Thompson et al., 2012	Cross-sectional (25)	Relation amount of green space in living environment with cortisol secretion. Green space data derived from database (based on postcode); amount of public (not private) green spaces.	Steeper cortisol slope	Measurements were taken in the same (climatic) area, not controlled for average time spent outdoors.
Daylight	Jung et al., 2010	Experimental (20)	Exposure to bright vs. dim light on day 6 during rising or descending phase of cortisol using a constant routine procedure for 6.7 h.. Bright light intensity ~10.000 lx during fixed gaze and ~5000-9000 lx during free-gaze sessions. In dim light (day 1-5) ~3 lx during fixed and free-gaze sessions, using 4100 K armatures. Light measured in angle of gaze at 137 cm from ground.	Reduced cortisol production	Very controlled setting with no time cues and no contact with the outside world. No view outside.
	Leproult et al., 2001	Experimental (8)	Exposure to bright vs. dim light between 5:00 and 8:00 and 13:00 and 16:00 after sleep deprivation. Bright light; dynamic: 15 min 2000-2500 lx; 45 min 3000-4000 lx; 1 h 4500 lx; 45 min 3000-4000 lx; 15 min 2000-2500 lx. Illumination levels measured at eye level. Dim light: < 150 lx.	Early morning: increase cortisol production.	Controlled setting. Subjects could watch television, with unknown content.

Table 1 – continued

Stress outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Cortisol (continued) Daylight	Rüger et al., 2005	Experimental (12)	Exposure to bright vs. dim light from 12:00 – 16:00. Bright light (5000 lx at eye level, in gaze direction), Dim light (< 10 lx). Whole retina light exposure, pupils not dilated. Spectral distribution of light source included in the article.	No effect light on cortisol production.	Controlled setting. Subjects could watch television, with unknown content.

* Changes in positive and negative affect will be reported in the section on mood.
** EMG = Electromyography (tension in muscles), PTT = Pulse transit time (correlated to blood pressure)

Table 2. Overview of studies investigating effects of nature and daylight on mood.

Mood outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Mood Nature	Berman et al., 2008	Experimental (38/12)	Walking (study 1, n=38, ~50 min) or viewing pictures (study 2, n=12, 350 s) *after* mental fatigue induction. Study 1: ~50 min walk in park (screened from traffic) vs. central Ann Arbor (high in traffic). Participants walked in both environments, counterbalanced. Study 2: pictures of natural or urban environments.	Improved mood after walking in nature, no reliable changes in mood after viewing pictures.	Walking outside: different seasons, season entered in analysis. Pictures: differed in weather type and time of day.
	Hartig et al., 2003	Experimental (112)	Going for a walk (50 min) in a natural vs. urban setting *after* a mental fatigue task. Natural site: wildlife preserve in canyon. Urban site: medium density office and retail area, surrounded by a judicial complex and hospital.	Happiness increased and anger / aggressiveness decreased.	Outside, direct exposure to daylight. Weather reported to be generally warm and clear.
	Hartig et al., 1996	Experimental (102/18)	Watching pictures of natural vs. urban settings *after* mental fatigue induction (study 1) and after no induction (study2) Nature: dirt path through forest, no humans present. Urban: central Stockholm, densely built, some nature elements present, as well as humans and traffic.	Decrease in sadness and anger/aggression. Differences in hedonic tone, activation, and relaxation (study 2).	In lab, no direct exposure to sunlight. Pictures were taken during clear or mostly clear sky, at the same time of day.
	Ulrich et al., 1991	Experimental (120)	Watching nature vs. urban videos (10 min) *after* stressor. Nature videos: a forest / water stream with surrounding vegetation. No humans or animals. Urban videos: commercial streets (differing in traffic intensity) / outdoor traffic-free shopping malls (differing in amount of pedestrians). All pictures matched on openness.	Decrease in anger / aggression; decrease in fear; increase in positive affect.	In lab, excluding direct exposure to sunlight. Weather type and time of day for the outdoor videos were kept constant.
	Fredrickson & Levenson, 1998	Experimental (60)	Watching nature vs. urban videos (100 s) *after* stressor. Nature: waves crashing on a beach / playing puppies. Others: sad scene from a movie / geographical patterns.	More positive mood while watching the movie.	In lab, excluding direct exposure to sunlight. Weather type of outdoor videos not reported.
	Fredrickson & Levenson, 1998	Experimental (60)	Watching nature vs. urban videos (100 s) *after* stressor. Nature: waves crashing on a beach / playing puppies. Others: sad scene from a movie / geographical patterns.	More positive mood while watching the movie.	In lab, excluding direct exposure to sunlight. Weather type of outdoor videos not reported.

Table 2 – continued

Mood outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Mood Daylight	Kaida et al., 2007	Quasi-experimental (16)	Exposure to daylight vs. dim light or taking a nap *after* carrying out a set of tasks and having lunch. Between 12:40 and 13:10; control condition (<100 lx, day 1); daylight through window (> 2000 lx measured at eye-level, day 2); 20 min nap (day 3).	Improved pleasantness.	In lab, natural light entered through window. View content of window not reported.
	aan het Rot et al., 2008	Cross-sectional (48)	Experience sampling methodology with light measured at wrist. Light measured at wrist every 2 min for a 20-day period. Bright light defined as light > 1000 lx.	More positive affect when exposed to bright light (> 1000 lx).	Measured during different seasons. Naturalness of the environments not reported.
	Hubalek et al., 2010	Cross-sectional (23)	Light measurements during day, diary filled out during the evening. Light measured at eye-level; Illuminance (CIE spectral luminous efficiency function for photopic vision) and irradiance of the blue spectrum component.	No relation between light exposure and mood.	No data recorded on exposure to natural environments during the day.
	Denissen et al., 2008	Cross-sectional (1233)	Internet survey measuring mood combined with meteorological data. Weather data of German Weather Institute, based on day and postcode.	Random effects weather indices on mood; negative effect sunlight on negative affect and tiredness; positive effect sunlight on positive affect.	No data collected on amount of nature in direct environment.
	Kööts et al., 2011	Cross-sectional (110)	Experience sampling data combined with meteorological data. Temperature, relative humidity, and barometric pressure data obtained from the weather station of the University of Tartu.	Higher positive affect when more sunlight.	Naturalness environments not recorded.

Table 2 – continued

Mood outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Mood (continued) Daylight	Partonen & Lönnqvist, 2000	Quasi-experimental (145)	Bright light (A) vs. no extra light (B) exposure at work or at home (ABAB design). Participants were instructed to sit at 70 cm from the light device where illumination was ~ 2500 lx. (6500 K) at eye-level.	Improvement of vitality & decrease in depressive symptoms.	No data collected on naturalness of the environment in which the bright light therapy took place (differed per participant).
	Avery et al., 2001	Experimental (30)	Bright light vs. no extra light exposure for people with subsyndromal SAD at work. First week: no light treatment. Second and third week: bright light (2500 lx at 60 cm distance), either 2 hours in the morning (between 7:00 and 12:00) or 2 hours in the afternoon (between 12:00) and 17:00.	Lower depression, better mood, more energy, higher alertness, and higher productivity reported.	Bright light therapy at work, the environment was different for each participant. Naturalness of the environments not reported.
Neurology Daylight	VandeWalle et al., 2010	Experimental (17)	fMRI during emotion processing with colored light exposure. Exposure to 12 times 40 s monochromatic blue (473 nm) and 12 times 40 s green (527 nm) light, alternating. Light measurements calibrated beforehand, spectra checked at the level of the diffuser. Irradiance estimated to be 7 x 10^6 – 3 x 10^{13} photons per cm^2 per sec.	Blue light increased brain responses in amygdale and hypothalamus; affecting the emotion processing in brain.	Conducted in fMRI, no exposure to natural content.
Serotonin	Lambert et al., 2002	Cross-sectional (101)	Blood serotonin levels assessed and compared to meteorological data. Weather data obtained from the Australian Commonwealth Bureau of Meteorology database.	Higher amount of sunshine related to higher concentration of serotonin.	Exposure to natural environments prior to the study not recorded.
	aan het Rot et al., 2008	Experimental (49)	Women with subsyndromal SAD received tryptophan depletion (lowers mood) and bright or dim light therapy. Bright (3000 lx) vs. dim (10 lx) from ceiling-mounted lights, during the whole test day. Intensities were measured at ceiling level (~25-30% lower at eye level, 4100 K).	Effects of tryptophan depletion were overcome by exposure to bright light.	In controlled lab, no windows. A tv/vcr combination was present, with unknown content.

Table 3. Overview of studies investigating effects of nature and daylight on Executive Functioning.

Executive functioning outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Ego-depletion Nature	Beute & de Kort, 2013b	Experimental (90)	Watching natural vs. urban pictures (240 s) after ego-depletion. Nature: heath- and woodland, no humans present. Urban: central Eindhoven, no humans in foreground.	Ego-replenishing effects of nature; better performance on stroop task.	In lab setting, excluding exposure to sunlight. Time-of-day, weather type, season, and lightness of the pictures were kept constant.
Executive functioning Nature	Hartig et al., 2003	Experimental (112)	Going for a walk (50 min) in a natural vs. urban setting after a mental fatigue task. Natural site: wildlife preserve in canyon. Urban site: medium density office and retail area, surrounded by a judicial complex and hospital.	Improved performance on NCPC.*	Outside, direct exposure to daylight. Weather reported to be generally warm and clear.
	Berman et al., 2008	Experimental (38/12)	Walking (study 1, n=38, ~50 min) or viewing pictures (study 2, n=12, 350 s) after mental fatigue induction. Study 1: ~50 min walk in park (screened from traffic) vs. central Ann Arbor (high in traffic), within design, counterbalanced. Study 2: pictures of natural or urban environments.	Improved performance on BDS, and ANT.*	Walking outside: different seasons, season entered in analysis. Pictures: differed in weather type and time of day.
	Laumann et al., 2003	Experimental (28)	Watching nature vs. urban videos (20 min) *after* mental fatigue induction. Nature video: waterside / coastline, including (distant) hills and cows. Some people were visible in the distance. Urban video: main pedestrian street and bus station.	Increased performance on network orienting task.	In lab, excluding direct exposure to sunlight. All videos taken during sunny weather.
	Kuo & Sullivan (2001)	Experimental (145)	Amount of greenness in view of housing estate residents. Naturalness of the view was assessed using standardized sets of photographs.	Better performance on BDS.*	Study conducted during different seasons, nothing reported on the orientation / daylight entrance.
	Tennessen & Cimprich, 1996	Quasi-experimental (72)	Amount of nature in view of dormitory rooms. Naturalness of the view was assessed by 6 raters based on photos made on site.	Performed better on NCPC and SDMT.*	Performed in dormitory rooms. No data on amount of daylight or weather type.

Table 3 – continued

Executive functioning outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Daylight	Phipps-Nelson et al., 2009	Experimental (16)	Exposure to bright vs. dim light after sleep-deprivation. Bright light (*M* = 1056 lx), dim light (*M* = 3.3 lx), measured at forehead participant, in angle of gaze. Modified constant routine (prolonged exposure to < 5 lx light; 5 h sleep), bright or dim light exposure between 12:00 and 17:00 on day 2.	Better performance on PVT.*	Very controlled setting, no time cues, no windows. Exposure to natural content (in lab) not reported.
	Smolders et al., 2012	Experimental (32)	Exposure to bright vs. dim light (60 min) during the day. After baseline with 200 lx (at workplane, 4000 K) either bright light (1000 lx at eyelevel) or dim light (200 lx at eyelevel) exposure. Reflection indices of room and spectral composition included in article.	Better performance on PVT.*	In lab setting, exposure to natural content (in lab) not reported.
	Münch et al., 2012	Experimental (29)	Exposure to daylight vs. electrical light (6 h). Light exposure during afternoon and evening (starting 5 hours after habitual waking time). Exposure to electrical light (*M* = 176 lx at eye level, 3700 K) or daylight though harvesting system (~1000 lx, additional electric light when levels < 1000 lx).	Better performance on 2-back and 3-back task on second day.	In lab setting, daylight through daylight harvesting systems, excluding a view to the outside. Exposure to natural content (in lab) not reported.
Vitality Nature	Ryan et al., 2009	Experimental / Cross-sectional (97-138)	Walking in nature vs. walking indoors (study 2, 15 min) and experience sampling methodology (studies 4 and 5). Study 2: walk outdoors (tree-lined path along a river) or indoors (underground tunnels, little living things). Study 4&5: Diary method, naturalness measured semi-objectively with checklist including natural and man-made objects.	Higher vitality when imagining being in nature (study 2) or when actually in nature (study 4&5).	Study 2: walking outdoors vs. walking in nature resulted in a confound of daylight exposure. Study 4&5: Being outside in nature highly correlated with daylight exposure.

Table 3 – continued

Executive functioning outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Vitality (continued) Daylight	Leppämäki et al., 2002	Experimental (80)	Exercising without additional light vs. exercising with bright light exposure. Exercise in normal illumination (400 – 600 lx; 6000 K) or bright light (2500-4000 lx; 6000 K), measured at eye-level. Sessions in November – January, morning or early afternoon (~1 h, 2-3 times per week).	Increasing vitality and alleviating depressive symptoms.	Experiment conducted in gym, unknown whether any nature content was available but both groups exercised in the same room.
Neurology Daylight	VandeWalle et al., 2006	Experimental (16)	Cognitive performance in fMRI during exposure to bright vs. no additional light (21 min). One eye was exposed to bright white light (> 7000 lx), spectrum of the light included in supplements of the article.	Increase in thalamic activity.	In fMRI scanner, no view to the outside / nature available.

Table 4. Overview of studies investigating effects of nature and daylight on health.

Health outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
General health Nature	van Dillen et al., 2012	Cross-sectional (1641)	Green space defined as the amount of green area and streetscape greenery at the residence. Naturalness environment based on amount of nature within 500 m radius of residence. Five categories: < 37.5 m^2; 37.5-75 m^2; 75-112.5 m^2; 112.5 – 150 m^2; > 150 m^2.	Both measures were significantly related to general health, physical health, and mental health.	Not controlled for time spent outdoors (exposure to sunlight).
	Maas et al., 2006	Cross-sectional (250782)	Amount of green space surrounding the residence. Naturalness derived from National Land Cover Classification database, which defines the dominant type of land use per area (25 x 25 m). Amount of nature in 1 and 3 km radius was calculated.	Both geographical areas were positively related to general health.	Not controlled for time spent outdoors (exposure to sunlight).
	Moore, 1981	Quasi-experimental (2648)	Comparison between two cell blocks in prison. Open (with open and natural view) cell blocks compared to closed cell blocks (with adjacent closed galleries).	Less incidences of sick call.	Only the open cell blocks had a window to the outside enabling daylight entrance. Possible differences in light levels not reported.
Longevity Nature	Takano et al., 2002	Cross-sectional (3144)	Proximity of parks and trees for elderly citizens. Residential characteristics measured by a scale of nine items, including the presence of a nearby park.	More parks and trees in the proximity found related to longevity after 5 years.	Not controlled for time spent outdoors (exposure to sunlight).
Subjective health Nature	Kaplan, 1993	Cross-sectional (168 & 615)	Amount of nature in view for sedentary office workers. Naturalness of the view was assessed with a checklist containing built and natural elements.	Better reported general health.	Orientation and amount of daylight entrance for the different office workers not reported.
Sleep quality Daylight	Hubalek et al., 2010	Cross-sectional (23)	Light measurements during day, diary filled out during the evening. Light measured at eye-level; Illuminance (CIE spectral luminous efficiency function for photopic vision) and irradiance of the blue spectrum component.	Better sleep quality.	No data recorded on exposure to natural environments during the day.

Table 4 – continued

Health outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Sleep quality (continued) Daylight	Riemersma-van der Lek et al., 2008	Experimental (189)	Bright vs. dim light exposure in elderly care facility. Bright light condition: Lights installed in common rooms. Lights were on between 9:00 and 18:00, ~1000 lx at eye level in gaze direction. Dim light condition: no additional lights installed.	Lower cognitive decline and depressive symptoms, and increased sleep quality.	Naturalness in the environment of the different care facilities not reported, but pre- and post measures were taken.
Additional effects of physical exercise Nature	Bodin & Hartig, 2003	Quasi-experimental (12)	Running in natural vs. urban environment (1 h). Park route: in nature reserve, in pine-birch forest and along a lake, contained some built elements. Urban route: along medium-density, mid-rise apartments and office buildings, some greenery present in roadside.	Trend for beneficial effects running in nature on emotional recovery (though non-significant).	Groups of participants ran at the same time in the environments, adequately controlling for the effect of daylight exposure.
	Mitchell, 2012	Cross-sectional (1860)	Being physically active in nature compared to other environments. Data of Scottish Health Survey, including items being physically active in nature vs. other environments.	Lower risk for mental health problems.	Other environments could be an urban environment or indoors. No data available for the exposure to sunlight.
Additional effects of physical exercise Daylight	Leppämäki et al., 2002	Experimental (80)	Exercising without normal light settings vs. exercising with bright light exposure. Exercise in normal illumination (400 – 600 lx; 6000 K) or bright light (2500-4000 lx; 6000 K), measured at eye-level. Sessions in November – January, morning or early afternoon (~1 h, 2-3 times per week).	Increasing vitality and alleviating depressive symptoms.	Experiment conducted in gym, unknown whether any nature content was available but both groups exercised in same room.
Recovery in hospital Nature	Ulrich, 1984	Cross-sectional (46)	Patient rooms with a natural vs. urban view. Retrospective data, comparing two different wings. Natural: view to trees. Urban: view to brick wall.	Shorter length of stay, less negative comments nurses, less pain medication.	Nothing reported on amount of daylight entrance. Brick wall could also lower the amount of daylight entrance.

Table 4 – continued

Health outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
Recovery in hospital (continued) Daylight	Walch et al., 2005	Cross-sectional (89)	Bright vs. dim patient rooms. Light intensity is mean of: direct (at window), reflective (reflecting from patients eye), and ambient (reflected off interior surfaces) light. Light measured twice daily (~9:30 & ~15:30). Dim (50410 lx/h): east side (blocked sunlight by adjacent building, 25 m). Bright (73537 lx/h): west side.	Less experienced stress, and less pain medication.	Adjacent building not only blocked sunlight, but also the view. View content of the bright rooms not reported.
	Beauchemin & Hays, 1998	Cross-sectional` (628)	Bright vs. dim rooms in cardiac intensive care unit. Retrospective data, comparing data of patients staying in northerly oriented rooms (dim) to southerly oriented rooms (bright). Light measured on one day in spring (morning) and one day in autumn (afternoon). Spring: bright = 1200-1300 lx, dim = 200-400 lx. Autumn: bright = 2500 lx (linds half down), dim = 200 lx.	Shorter length of stay for females, lower mortality rates.	View type of the patient rooms not reported.
Cardiovas-cular disease Daylight	Krause et al., 1998	Experimental (18)	Sunbathing with UVA vs. UVB radiation for people with untreated mild hypertension. UVB (94.5 % UVB) vs. UVA (.05 % UVB) irradiation three times per week for 6 weeks in February – March. Treatment started with 6 min at .7 of minimal erythmal dose, increasing (if tolerated) to 10 %.	In the UVB group, a decrease in blood pressure was reported.	Sunbathing occurred indoors. No effects of nature to be expected.
	Straus et al., 2004	Cross-sectional (4892)	Seasonal variation in sudden cardiac death. Data based on Integrated Primary Care Information project. Investigating instances of sudden cardiac death per month.	Seasonal difference in sudden cardiac deaths; lowest number in August, peak in October.	No data available for the amount of nature in proximity.
Cancer Daylight	Freedman et al., 2002	Cross-sectional (6365 – 153511)	Residential exposure to sunlight (based on region of residence). Based on national database, comparing deaths from certain types of cancer with residential (based on place of birth) and occupational (based on usual occupation reported on death certificate) sunlight exposure.	Lower amount of deaths for several types of cancer.	Amount of nature in environment of residence and occupation not reported.

Table 4 – continued

Health outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
General mental health Nature	White et al., 2013	Cross-sectional (12818)	Green space derived from database. Data from the British Household Panel Survey combined with Generalised Land Use Database for amount of green in the environment for Urban residential areas. Amount of greenspace defined by percentage of green space and gardens.	Higher general health and life satisfaction.	No data included regarding exposure to sunlight.
	Roe & Aspinall, 2011	Quasi-experimental (123 / 24)	Walking in a rural setting (study 1, 1 h) and walking in a rural vs. urban setting (study 2) for people with and without mental health problems. Study 1: walk in woods and open countryside, for all abilities. Study 2: both studies on flat terrain. Rural walk: in a park. Urban park: Stirling town center with greenery and historic interest along the route.	Rural: beneficial (hedonic tone, efficacy, stress-reduction) effects, more pronounced for people with mental health problems. Urban: also restorative for people with mental health problems.	In both studies, exposure to daylight is present. Similar weather conditions reported (fair, no rain).
Persecut-ory Delusions Nature	Ellett et al., 2008	Experimental (60)	Participants with persecutory delusions and a control group walked in an urban environment (10 min). Urban area: walk in a busy shopping street. Other half did mindfulness task.	Higher levels of anxiety, negative beliefs about others, jumping to conclu-sions, and paranoia. Clinical group scored different than control group on all measures.	Indoor vs. outdoor activity, no data on exposure to sunlight or view content in the therapy room.
ADHD Nature	Taylor & Kuo, 2009	Experimental (25)	Children with ADHD walking in urban park, downtown area, and residential area (20 min). Urban park, residential area, and downtown area. All well quiet, well maintained, flat terrain, and minimal traffic intensity.	Improvement in performance on Digit Span Backward task.	All walks were outdoors, all walks during warm weather.

Table 4 – continued

Health outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
ADHD (continued) Nature	van den Berg & van den Berg, 2010	Quasi-experimental (12)	Visiting nature vs. a town (~1h). Natural: open spot in wooded area. Town: a square in a quiet neighborhood in nearby town. Settings were comparable in openness and quietness.	Improved cognitive performance (Test of Everyday Attention for Children).	Visits to urban vs. natural setting on two consecutive days. Weather type not reported.
Daylight	Arns et al., 2013	Cross-sectional (84545)	Difference in solar intensity per region. Solar intensity defined as horizontal irradiation, expressed in kilowatt hours / m^2 / day.	Decreased prevalence of ADHD.	Amount of nature in proximity of residence not reported.
(Seasonal) Depression Nature	Hartig et al., 2007	Cross-sectional (Swedish population)	Meteorological data for the 3 summer months (cold weather was formulated as a constraint on restoration in nature). Temperatures were derived from the Swedish Meteorological and Hydrological Institute. Mean monthly temperature of Sweden was compared to the monthly doses of anti-depressants dispensed.	Increased use of antidepressants in cold summers.	Weather data is used to predict opportunities for nature restoration. Direct effects of sunlight exposure can also be an important factor.
Daylight	Wirz-Justice et al., 1996	Quasi-experimental (28)	Walk outdoors vs. electrical light (1 h / .5 h daily, resp.). Three week therapy protocol, starting at the onset of winter depression. Outdoor group: instructed to go outdoors regularly, as early as possible, in sunshine. Most participants walked. Electrical light group: Light box therapy between 6:00 – 9:00. The average light intensity at .8 m was 2800 lx.	Higher decrease in depression scores.	The walk was outside, type of setting in which participants were walking (and the amount of nature) not reported and different between participants.
	Lieverse et al., 2011	Experimental (89)	Bright vs dim light (60 min). Exposure during morning, for 3 weeks. Bright: pale-blue light (7500 lx). Dim: red light (50 lx).	Increased sleep efficiency, decreased depression ratings, lower cortisol, and steeper melatonin production.	Amount of nature in the proximity of participants' homes is not reported, but pre- and post measures were taken.

Table 4 – continued

Health outcome Content	Author / date	Study type (n)	Nature / Light Interventions /predictors	Effects found for nature / light	Control for confounds?
(Seasonal) Depression (continued) Daylight	Beauchemin & Hays, 1996	Cross-sectional (174)	Bright vs. dim hospital rooms. Retrospective data. On a cloudy morning in February; dim room = 200 lx, bright room = 500 lx. Half overcast day; dim = 300 lx, bright = 1700 lx. Bright day; dim = 300, bright = 5000.	Shorter length of stay.	View of all rooms is described, not specifically indicating the amount of naturalness.
	Benedetti et al., 2001	Cross-sectional (602)	Morning (East; E) vs. afternoon daylight (West; W) entrance . Retrospective data. Bright day in May, at 9:00; E = 15500 lx, W = 1400 lx, and at 17:00; E = 2700 lx, W = 3000 lx. With a partly overcast sky, at 9:00; E = 1500 lx, W = 150 lx, and at 17:00; E = 200 lx, W = 1500 lx. On a cloudy day, at 9:00; E = 650 lx, W = 150 lx, and at 17:00; E = 140 lx, W = 600 lx.	Shorter length of stay for bipolar patients in east rooms, but marginally significant shorter stay for unipolar depressed patients in west room.	View content of windows not reported.