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Salutogenic Effects of the Environment: Review of Health Protective Effects of Nature and Daylight

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Both nature and daylight have been found to positively influence health. These findings were, however, found in two separate research domains. This paper 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, the paper points 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 between 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.

Keywords: daylight, health, nature, restoration, salutogenesis

Can this earth be so green and wonderful!
And the sky shine so blue and clear!
We stand and marvel. It's hard to believe that this world can truly be ours . . .
(H.M. Vesaas)

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; other factors, such as a view of nature, are seen as containing health protective qualities. In this paper we will discuss two environmental factors that have been found to exhibit these health protective qualities—daylight and nature.

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Beneficial effects of natural environments have been found for stress, mental fatigue, and self-regulation failure. We will closely inspect how viewing nature can help overcome these very prominent threats to mental and physical health in our present-day society. In addition, we will point to literature which indicates that exposure to daylight can have very similar beneficial effects. 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.

Our aim in writing this paper was to examine the range of health outcomes that have been related to exposure to both nature and daylight, and to explore and systemise the various underlying mechanisms of beneficial effects that have been suggested in the literature. To this end we have performed an extensive search of relevant publications in scientific domains including medical and psychiatric sciences, epidemiology, clinical, social, environmental and health psychology, architecture and landscape architecture, targeting studies that report effects of exposure to nature or daylight. Our aim was to cover the most important classes of health effects and mechanisms. This paper does not present a meta-analysis of effects of daylight and nature on health, nor does it present a systematic review according to the Cochrane method; hence it cannot claim to be comprehensive on the level of individual studies. We did not employ rigid inclusion criteria with regard to research designs as this would inevitably have resulted in omitting crucial papers because of the plurality in research traditions between the different research domains. In bringing together empirical findings on health outcomes from these different research domains, we reveal the overlap in beneficial health effects of both phenomena.

We focused mainly on effects of passively viewing either real or mediated nature (slideshows and videos). There is also a large body of research looking at active nature participation as wilderness experience and horticulture therapy. We only included studies investigating effects of actively interacting with nature when a control condition also involving physical activity was included, because physical exercise can be beneficial for health on its own (Thompson Coon et al., 2011). In considering effects of daylight we will also report on studies using electric bright white light, as long as the studies were conducted during the biological day. There is a large body of evidence suggesting melatonin suppressing and alerting effects of bright light exposure during the biological night. As we are only interested in effects of daytime light, we will not report on these effects (for an overview, see e.g. Boyce, Hunter, & Howlett, 2003; CIE, 2009).

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 separately from each other. One disadvantage of this detachment is that in some studies restorative outcomes of one phenomenon potentially confound the other. The present paper urges scholars to critically reassess their previous findings for possible confounds or motivate them to reconsider the design of future studies. More importantly, however, we hope to learn more about potential underlying mechanisms and ways to explore those further. Below, 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 take a look at the proposed underlying pathways for beneficial effects of nature and daylight.

PATHWAYS DESCRIBED IN THE LITERATURE

The effects of nature on health are attributed to underlying psychological pathways. Psycho-evolutionary theory argues that evolution has favored those individuals who had an adaptive response to unthreatening natural environments that contained elements beneficial for well-being (stress reduction and restoring energy) as well as for survival (i.e. low risk, food and water available; Ulrich et al., 1991). According to Ulrich and colleagues (1991), a pre-cognitive emotional response exists which subsequently influences attention, physiological responding, and behavior. Viewing unthreatening nature should therefore help people become restored from stress by reducing negative affect, increasing positive affect, and decreasing physiological arousal (Ulrich et al., 1991). 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.

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 labeled attention fatigue. ART distinguishes between two types of attention: voluntary and involuntary. Voluntary attention, also called directed attention, is under conscious control, and prolonged exertion of this control requires effort. Over time, the resource necessary to control attention will become depleted resulting in directed attention fatigue. This state is characterised by fatigue, an inability to concentrate, and irritability (S. Kaplan, 1995). The conceptualisation 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 soft fascination, in particular, 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.

Whereas proposed underlying mechanisms for the 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 (Kauffman, 2009), but also to improved mood via the production of serotonin (Landsdowne & Provost, 1998).

A second pathway for daylight to affect health is through the circadian system. Retinal ganglion cells with a direct connection to the suprachiasmatic nucleus (SCN) in which our biological clock resides are particularly sensitive to light with wavelengths within the blue spectrum (Brainard et al., 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 to the night-dark cycle. Moreover, bright light induces direct responses in alertness-related subcortical structures (hypothalamus, brainstem, thalamus) limbic areas (amygdale and hippocampus), and even in cortical areas (Vandewalle, Maquet, & Dijk, 2009). Furthermore, effects on brain serotonin turnover have been proposed to run through retinal light exposure (aan het Rot, Benkelfat, Boivin, & Young, 2008a). This implies that, in addition to entraining the biological clock, light shows immediate effects on alertness, cognitive performance, and even affective responses (Vandewalle et al., 2009).

These first pathways for the effects of daylight on health pertain to purely biological mechanisms, but psychological mechanisms have also been proposed (e.g. Boyce et al., 2003). It is therefore possible that—much like nature—daylight positively influences well-being 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 the supplementary materials, we present overview tables of all individual studies with study type (broadly categorised as cross-sectional, quasi-experimental, and experimental designs), sample size, intervention type, and study outcome. Furthermore, we report whether and how possible confounds were controlled in each study.

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), as well as our physiological status—often labeled 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). It is exactly this prolonged activation of the autonomic nervous system 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 recover from stress, such as for instance engaging in social interaction, exercise, or meditation. We will now discuss how nature and daylight can help recover from stress.

Nature and Stress Reduction

A recent fMRI study demonstrated that living in urban areas changes brain responses to stress in a negative way compared to dwelling in a small town or rural area (Lederbogen et al., 2011). This study indicated that stress induction produced higher brain activity in brain areas related to stress and negative affect among people who grew up in a highly urbanised area. Not all studies provide insight on whether the negative effects of cities are due to a lack of nature or the presence of other urban factors and stressors. There are, however, also urban studies demonstrating restorative effects of nature. An exploratory study in a deprived area of Scotland revealed that more green in the neighborhood was related to a steeper cortisol slope (indicating a more healthy cortisol secretion system), together with lower levels of self-reported stress (Ward Thompson et al., 2012).

The stress-reducing potential of nature was reported by, among others, Ulrich and colleagues (1991) who had 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 stressful movie 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 have also found that watching nature can lower physiological arousal (Laumann, Gärling, & 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. They found that 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 psycho-evolutionary theory. 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 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 natural content: the first one showed waves breaking on a beach, the other portrayed a playful puppy.

There is also evidence suggesting an immunising 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, 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).

Daylight and Stress Reduction

There are only indirect indications that light too has stress-reducing effects. Exposure to bright electric light has been found to improve heart rate variability in healthy subjects (Rechlin, Weis, Schneider, Zimmermann, & Kaschka, 1995). Increased heart rate variability has been related to increased activation of the parasympathetic nervous system (Bilchick & Berger, 2006), indicating potential stress-reducing effects of bright light. Furthermore, light has been found to influence cortisol production, but in different 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 night-time or morning bright light acutely suppressed cortisol production in an alternative study (Jung et al., 2010) or showed no effect on cortisol at all (Rüger, Gordijn, Beersma, de Vries, & Daan, 2005).

Summary

Both 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. 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 the attractiveness of these environments, in particular, 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 and 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 the case, for instance, in the study by Hartig and colleagues (2003).

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 nature and light influence cortisol production, a hormone related to stress, although mixed results were found for the effects of light on cortisol. These differences have 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.

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. see 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. 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 ones such as anger (Pressman & Cohen, 2005), and 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. According to the Broaden-and-build theory (Fredrickson & Joiner, 2002), positive emotions broaden our mindset, 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.

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 been reported as well (Hietanen & Korpela, 2004). However, note that these rapid affective responses to natural versus urban environments were not replicated in a recent study (Beute & de Kort, 2013).

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; Ulrich et al., 1991). Hartig and colleagues (2003) compared mood effects of walking in a natural environment to 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 but 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 nature video reported lower levels of fear and anger/aggression and higher levels of positive affect than participants watching urban settings.

Daylight and Mood

Through evolution, we have developed a diurnal rhythm of being active during the day and resting during the night. Daylight, therefore, has evolutionary relevance, and Ulrich (2008) argues that under certain circumstances positive responses to nature may be enhanced by daylight. People do indeed prefer sunny and light environments to overcast and dark environments (Beute & de Kort, 2013).

The mood-enhancing effects of daylight exposure have been investigated in a number of studies. Exposure to daylight for 30 minutes (appr. 3,000 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 (> 1,000 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, 2008b). Technically, the device cannot distinguish between electric and natural light sources, but light levels over 1,000 lux very likely represent daylight exposure. Furthermore, mood in general was also better in summer than in winter. No relation was found, however, between an aggregate (not momentary) daily light dosage and pleasure and arousal in the general population (Hubalek, Brink, & Schierz, 2010).

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, found mixed results. More sunshine has been found to be 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, 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 we reported earlier, sunlight on the skin promotes the synthesis of vitamin D, which has been linked to the production of serotonin

(Landsdowne & Provost, 1998). 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 to be 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, 1998). Besides effects on serotonin production by sunlight touching the skin, it has also been proposed that retinal exposure to bright light can increase brain serotonin production (aan het Rot et al., 2008a).

The mood-enhancing effects of light appear to extend beyond natural lighting. The use of bright electric light exposure has also 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 (appr. 2,500 lux, 6,500 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 synchronisation 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., 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 the later section on mental health). 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, 2004). Furthermore, people generally associate light with positive affect and dark with negative affect (Meier, Robinson, Crawford, & Ahlvers, 2007). 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.

Summary

The literature reports that both daylight and nature can positively influence mood. 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.

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 the positive influence of nature or to a detrimental effect of urban environments albeit that again some studies have used a baseline comparison. 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.

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.

SELF-REGULATION AND EXECUTIVE FUNCTIONING

The lion's share of behaviors that we engage in are automatic and require little conscious thought. When we overrule our inclinations or feelings, we need to exert (conscious) control over thoughts and behaviors. This process has been labeled 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 diseases (Williams & Thayer, 2009), stressing the importance of having high self-control. Self-regulation, however, does not come without a cost. Executive functioning requires much energy (Suchy, 2009) and has been found to rely on a limited resource (Baumeister, 1998; Kaplan & Berman, 2010). Depletion of this resource has been labeled ego-depletion within the self-control strength model (Baumeister, 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 & Frederick, 1997, p. 530). Subjective vitality is related to both physical and psychological well-being 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 & Frederick, 1997). Ego-depletion can be overcome by increasing vitality, and people who feel vital will replenish their resources faster (Muraven, Gagné, & Rosman, 2008). 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 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 this goal, this would provide individuals with a free and generally available source for recovery. Indeed, there are indications in the literature that this could be the case, as discussed in the next section.

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.

Recently, a study was carried out that tested nature's effects in such an ego-replenishment paradigm (Beute & de Kort, 2011). Between two ego-depleting tasks, participants were either exposed to no images, urban pictures, or natural pictures. In a fourth condition (the control condition) participants were not depleted in the first task. Comparing performance to that in the control condition, Beute and de Kort report a decline in performance for participants watching urban images or no images, whereas participants who watched natural pictures performed as well as those who had not been depleted. These results suggest ego-replenishing effects of nature.

As mentioned earlier, the theoretical link between ego-depletion and restorative effects of nature has only been made recently (Kaplan & Berman, 2010). Consequently, only few 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 provide support for the 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 environment compared to those who walked in 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 improved after watching pictures of natural environments, but not 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 quite a body of experimental research supporting the idea that nature helps recover from attention fatigue.

In addition to experimental explorations, cross-sectional and quasi-experimental research has been employed to test the beneficial effects of nature. Experience sampling studies produced evidence that being in nature can increase subjective vitality (Ryan et al., 2009). More specifically, 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 (1995) found that students living in dorms with more natural views performed better on executive functioning tasks.

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), 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. First these were 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 on vigilance 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, & Scartezzini, 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 were 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., 2009). 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.

Summary

Both daylight and nature may influence health by helping overcome or even preventing depletion of self-regulation resources. 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, and so far one study has demonstrated ego-replenishment by nature. 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—has been demonstrated to improve vitality, a concept closely related to executive functioning, and to enhance performance on 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.

Some additional evidence for possible beneficial effects of nature and daylight on executive functioning is provided by the fact that both nature and daylight have been found to influence heart rate variability (cf. Beute & de Kort, 2013, and Rechlin et al., 1995) which, in turn, has been found to be related to self-regulation strength (Segerstrom & Nes, 2007). In the next section, we will further discuss the effects of nature and daylight on physical health.

PHYSICAL AND MENTAL HEALTH

Nature and Health

Epidemiological research has illustrated a positive association between amount of green space in the proximity of the home and health (Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006), between the amount of accessible green space and longevity (Takano, Nakamura, & Watanabe, 2002), and between the amount of urban green space and mental health and well-being (White, Alcock, Wheeler, & Depledge, 2013). Maas and colleagues found that people with a higher percentage of green space in the proximity of their home reported better 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 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 (e.g. see Thompson Coon et al., 2011). Being physically active is often seen as a secondary benefit of nature exposure (Ward Thompson & Aspinall, 2011).

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 mindset in relation to personal projects for both groups, but beneficial effects were greater for people with mental health problems compared to healthy individuals. A second study, investigating the effects of natural environments compared to urban environments, revealed 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 exhibited beneficial effects as well.

Three studies have 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. Furthermore, playing in green settings was related to fewer symptoms (Taylor & Kuo, 2011). 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 describes a relation between nature and health.

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). The 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). 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, however, 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 et al., 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; Kauffman, 2009; Wallis, Penckofer, & Sizemore, 2008).

Effects of light on the circadian rhythm can result in both positive and negative health outcomes. Negative effects often pertain to the shifting 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 synchronised 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 (Rüger & Scheer, 2009). Moreover, light exposure has been related to sleep quality through the biological clock (Hubalek et al., 2010; Riemersma-van der Lek et al., 2008). Conversely, diseases to the eye reducing retinal phototransduction 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 labeled Seasonal Affective Disorder (SAD; Rosenthal et al., 1984). Even in the general population, negative effects such 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 recommended 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 et al., 1996). Wirz-Justice and colleagues (1996) found that a one-hour walk per day outdoors also 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., 2008b). Unfortunately, Wirz-Justice's study could not rule out that the effects were (partly) due to physical exercise per se. More importantly, the 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 very 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 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).

Summary

Nature and daylight can influence both mental and physical health on many outcomes including depression, longevity, and general health. 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. 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). 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 the 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.

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 et al., 2003; Kaida et al., 2007) as well as the community level (e.g. Maas et al., 2006; Freedman et al., 2002). 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).

Commonalities have been found, in particular, in the effects of both phenomena on mood, activation of the parasympathetic nervous system, (lower level) self-regulation, recovery and mental health. Higher light levels have been associated with better mood (Kaida et al., 2007; Kööts et al., 2011; Partonen & Lönnqvist, 2000; aan het Rot et al., 2008b), as have natural environments (Ulrich et al., 1991; Fredrickson & Levenson, 1998; Hartig et al., 2003). Furthermore, both bright light and natural environments have been found to increase vitality (Ryan et al., 2009; Partonen & Lönnqvist, 2000). Natural environments speed up cardiovascular recovery after stress induction (Fredrickson & Levenson, 1998; 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., 2008; 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 indicates 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 rooms. 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 both the nature and the urban conditions walked outside in the same weather conditions. Similarly, laboratory experiments investigating the effects of bright light exposure have often ruled out the effects of view content.

In future studies, we would recommend explicitly controlling for possible confounds of one phenomenon, when investigating the other, and to include a more detailed description of how the authors have controlled for potential confounds. 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 eye level (CIE, 2009; Veitch & Galasiu, 2012).

A challenge in comparing the effects of daylight and views of nature that we have 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 yet seem to have reached this status.

There are some methodological issues in both fields that impede drawing the causal inferences needed to implicate them as a therapeutic intervention. First of all, there is a need for controlled randomised trials (Annerstedt & Währborg, 2011; Veitch & Galasiu, 2012). Second, clinical trials often include a placebo condition, which can be difficult to implement in research investigating the effects of light and nature (Bowler, Buyung-Ali, Knight, & Pullin, 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, urban environments, in particular, used in research vary substantially in attractiveness and content. 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 the beneficial effects of nature on health has recently come in for criticism, mostly aimed at the relative lack of evidence for this claim (Joye & van den Berg, 2011). Moreover, the high level of segregation between research on the effects of light and the effects of nature on health and well-being, and even within the field of lighting 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 draw conclusions about the hypothesised 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 the 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 the stress-reducing effects of daylight.

Two elaborate 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, 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 that herein lies the challenge for future research, as very similar effects of both phenomena have been found on mood, (lower level) self-regulation, and the cardiovascular system. Daylight is part of our natural environment. And even though many research challenges can be identified, the studies reported here 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 randomised (placebo) controlled clinical trials. We hope this paper 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 a lot of 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.

REFERENCES

Annerstedt, M., & Währborg, P. (2011). Nature-assisted therapy: Systematic review of controlled and observational studies. *Scandinavian Journal of Public Health*, *39*, 371–388.

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*, *74*, 585–590.

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.

Baumeister, R.F. (1998). The self. In D.T. Gilbert, S.T. Fiske, & G. Lindzey (Eds.), *Handbook of social psychology* (pp. 680–740). New York: McGraw-Hill.

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.

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.

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

Beute, F., & de Kort, Y.A.W. (2011). Vitalize me! Overcoming ego-depletion by viewing bright and sunny nature. *The 9th Biennial Conference on Environmental Psychology*, September, Eindhoven.

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.

Bilchick, K.C., & Berger, R.D. (2006). Heart rate variability. *Journal of Cardiovascular Electrophysiology*, *17*, 691–694.

Blascovich, J., & Mendes, W.B. (2000). 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.

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.

Brainard, G.C., Hanifin, J.P., Greeson, J.M., Byrne, B., Glickman, G., Gerner, E. et al. (2001). Action spectrum for melatonin regulation in humans: Evidence for a novel circadian photoreceptor. *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.

CIE (Commission Internationale de l'Eclairage) (2009). *Ocular lighting effects on human physiology and behaviour (CIE 158:2009)*. Vienna: CIE.

Cohen, S., Janicki-Deverts, D., Doyle, W.J., Miller, G.E., Frank, E., Rabin, B.S. et al. (2012). Chronic stress, glucocorticoid receptor resistance, inflammation, and disease risk. *Proceedings of the National Academy of Sciences, USA*, *109*, 5995–5999.

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.

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.

Ellett, 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.

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.

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.

Gaillot, M.T., Baumeister, R.F., DeWal, C.N., Maner, J.N., Plant, E.A., Tice, D.M. et al. (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.

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

Hietanen, J.K., & Korpela, K.M. (2004). Do both negative and positive environmental scenes elicit rapid affective processing? *Environment and Behavior*, *36*, 558–577.

Hubalek, S., Brink, M., & Schierz, C. (2010). Office workers' daily exposure to light and its influence on sleep quality and mood. *Lighting Research and Technology*, *42*, 33–50.

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. et al. (2010). Acute effects of bright light exposure on cortisol levels. *Journal of Biological Rhythms*, *25*, 208–216.

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, S. (1995). The restorative benefits of nature: Toward an integrative framework. *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., & Kaplan, R. (1982). *Cognition and environment: Functioning in an uncertain world*. New York: Praeger.

Kauffman, J.M. (2009). Benefits of vitamin D supplementation. *Journal of American Physicians and Surgeons*, *14*, 38–45.

Keller, M.C., Fredrickson, B.L., Ybarra, O., Côté, S., Johnson, K., Mikels, J. et al. (2005). A warm heart and a clear head: The contingent effects of weather on mood and cognition. *Psychological Science*, *16*, 724–731.

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.

Krause, R., Bühring, M., Hopfenmüller, W., Holick, M.F., & Sharma, A.M. (1998). Ultraviolet B and blood pressure. *Lancet*, *352*, 709–710.

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.

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.

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

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P. et al. (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature*, *474*, 498–501.

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 induces an immediate elevation of cortisol levels. *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.

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.

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-Sim, A., & Eyles, D.W. (2010). Developmental vitamin D deficiency and risk of schizophrenia: A 10-year update. *Schizophrenia Bulletin*, *36*, 1073–1078.

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., & Wänke, M. (2011). Good weather for Schwartz and Clore. *Emotion*, *11*, 436–437.

Moore, E.O. (1981). A prison environment's effect on health care service demands. *Journal of Environmental Systems*, *11*, 17–34.

Münch, M., Linhart, 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.

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.

Phipps-Nelson, J., Redman, J.R., Dijk, D., & Rajaratnam, S.M.W. (2003). Daytime exposure to bright light, as compared to dim light, decreases sleepiness and improves psychomotor vigilance performance. *Sleep*, *26*, 695–700.

Pressman, S.D., & Cohen, S. (2005). Does positive affect influence health? *Psychological Bulletin*, *131*, 925–971.

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.

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 the 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. et al. (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. (2008a). 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. (2008b). 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.

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., & 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.

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.

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.

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., & 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.

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.

Suchy, Y. (2009). Executive functioning: Overview, assessment, and research issues for non-neuropsychologists. *Annals of Behavioral Medicine*, *37*, 106–116.

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.

Taylor, A.F., & Kuo, F.E. (2009). Children with attention deficits concentrate better after walking in the park. *Journal of Attention Disorders*, *12*, 402–409.

Taylor, A.F., & Kuo, F.E. (2011). Could exposure to everyday green spaces help treat ADHD? Evidence from children's play settings. *Applied Psychology: Health and Well-Being*, *3*, 281–303.

Tennessen, 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.

Thayer, J.F., & Brosschot, J.F. (2005). Psychosomatics and psychopathology: Looking up and down from the brain. *Psychoneuroendocrinology*, *30*, 1050–1058.

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.

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). Hoboken, NJ: John Wiley & Sons.

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.

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.

Vandewalle, G., Maquet, P., & Dijk, D.J. (2009). Light as a modulator of cognitive brain function. *Trends in Cognitive Sciences*, *13*, 429–438.

Vandewalle, G., Schwartz, S., Grandjean, D., Wuillaume, C., Balteau, E., Degueldre, C. et al. (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.

van Os, J., Kenis, G., & Rutten, B.P.F. (2010). The environment and schizophrenia. *Nature*, *468*, 203–212.

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.

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.

Wallis, D.W., Penckofer, S., & Sizemore, G.W. (2008). The "sunshine deficit" and cardiovascular disease. *Circulation*, *118*, 1476–1485.

Ward Thompson, C., & Aspinall, P. (2011). Natural environments and their impact on activity, health, and quality of life. *Applied Psychology: Health and Well-Being*, *3*, 230–260.

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.

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.

Williams, P.G., Suchy, Y., & Rau, H.R. (2009). Individual differences in executive functioning: Implications for stress regulation. *Annals of Behavioral Medicine*, *37*, 126–140.

Williams, P.G., & Thayer, J.F. (2009). Executive functioning and health: Introduction to the special series. *Annals of Behavioral Medicine*, *37*, 101–105.

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. et al. (1996). "Natural" light treatment of seasonal affective disorder. *Journal of Affective Disorders*, *37*, 109–120.