Article

Environment and Behavior
2020, Vol. 52(3) 248–274

DOI: 10.1177/0013916518800798
journals.sagepub.com/home/eab
SAGE

Health Benefits of Walking in Nature: A Randomized Controlled Study Under Conditions of Real-Life Stress

Gunnthora Olafsdottir[1,2,3], Paul Cloke[2], André Schulz[1], Zoé van Dyck[1], Thor Eysteinsson[4], Björg Thorleifsdottir[4], and Claus Vögele[1]

Abstract

We investigated the effects of recreational exposure to the natural environment on mood and psychophysiological responses to stress. We hypothesized that walking in nature has restorative effects over and above the effects of exposure to nature scenes (viewing nature on TV) or physical exercise alone (walking on a treadmill in a gym) and that these effects are greater when participants were expected to be more stressed. Healthy university students (N = 90) were randomly allocated to one of three conditions and tested during an exam-free period and again during their exam time. Mood and psychophysiological responses were assessed before and after the interventions, and again after a laboratory stressor. All interventions had restorative effects on cortisol levels ($p < .001$), yet walking in nature resulted in lower cortisol levels than did nature viewing

[1]University of Luxembourg, Esch-sur-Alzette, Luxembourg
[2]University of Exeter, Exeter, U.K.
[3]Icelandic Tourist Board, Reykjavík, Iceland
[4]University of Iceland, Reykjavik, Iceland

Corresponding Author:
Gunnthora Olafsdottir, Icelandic Tourist Board, Geirsgata 9, 101 Reykjavík, Iceland.
Email: gunnthora@ferdamalastofa.is

($p < .05$) during the exam period. Walking in nature improved mood more than watching nature scenes ($p < .001$) or physical exercise alone ($p < .05$).

Keywords
restorative environments, natural environments, stress, walking, mental and physical health, psychophysiology, psychological wellbeing, environmental psychology

Introduction

Through the centuries, human beings have been drawn to nature to relax, recuperate, and find temporary freedom from the stressors of everyday life (Herzog, Black, Fountaine, & Knotts, 1997; Home, Hunziker, & Bauer, 2012; Knopf, 1987). These ventures are based on the age-old belief in the salubrious effects of exposure to nature (Parsons, 1991; Ulrich, 1979). Stress relief, escaping from civilization, clearing the head, reflecting on important life issues, experiencing beauty, and connecting with nature are among the dominant self-reported motives (Driver, 1976; Knopf, 1987). The single most important self-reported benefit of exposure to both nature-rich urban places and wilderness areas, however, is stress mitigation (Ulrich et al., 1991). Investigations of the causal mechanisms underlying such mediated health effects of the natural environment are apposite, significant, and pressing, especially in the light of the fact that stress is generally recognized as the most severe health problem in the 21st century (Kudielka & Wüst, 2010; Tyrväinen et al., 2014).

Restorative effects of nature exposure have been psychologically and physiologically accounted for in terms of "reduction in cognitive fatigue, decreased stress levels, increased focus, increased positive affect, decreased negative affect, and decreased sympathetic nervous system activity" (Valtchanov, Barton, & Ellard, 2010, p. 503). These results are interpreted in the context of the two dominating theories of nature restoration: (a) attention restoration theory (ART) that focuses on the detrimental factors of mental fatigue on our capacity to direct attention and associates the restorative effect of being in nature with its potential to conjure up soft fascination, which is the remedy needed to rest and recover (S. Kaplan, 2001; R. Kaplan & Kaplan, 1989; S. Kaplan & Talbot, 1983) and (b) the psychophysiological stress reduction framework, which posits an immediate positive *affective* and *stress-releasing* response to nature as a non-threatening environment (Ulrich, 1981, 1983, 1984; Ulrich et al., 1991). Both theories are based in part on the assumption of the innate affiliation to nature, and presume that nature can promote faster and more complete restoration than other environments for mentally fatigued and stressed individuals (Hartig, Mitchell, de Vries, & Frumkin, 2014; R. Kaplan & Kaplan, 1989; Ulrich, 1981).

Correlational and experimental findings over the past 30 years provide evidence for these restorative effects of nature (Health Council of the Netherlands, 2004; James, Banay, Hart, & Laden, 2015; Kondo, Fluehr, McKeon, & Branas, 2018). In the context of exercise, some experimental findings based on evidence at psychological (Pretty, Griffin, Sellens, & Pretty, 2003), physiological (Gladwell et al., 2012; Park, Tsunetsugu, Kasarani, Kagawa, & Miyazaki, 2010), and biochemical (Li et al., 2011) levels indicate that exercise with nature exposure (i.e., green exercise) is more beneficial than the same exercise in built-up places (Pretty et al., 2003). Nevertheless, a recent review shows that the evidence linking restorative physiological changes in response to nature exposure via exercise (walking or running) in comparison to other environments is sparse (Gladwell, Brown, Wood, Sandercock, & Barton, 2013). Reviews of the health benefits of passive and active activities in nature versus indoor, built (and synthetic) urban environments conclude that—in comparison—nature is associated with improved mental health and well-being (Bowler, Buyung-Ali, Knight, & Pullin, 2010; Ohly et al., 2016; Thompson-Coon et al., 2011). In a systematic review, including studies using several physiological parameters (blood pressure [BP], heart rate [HR], heart rate variability [HRV], cortisol, noradrenaline, and adrenaline; Bowler et al., 2010), there was not enough evidence to suggest a differential effect in favor of the natural environment due to a lack of studies of comparable design (Bowler et al., 2010; see also the review by Hartig et al., 2014). Nevertheless, some studies suggest differences in the effects of nature versus urban environments on physiological stress responses (Brown, Barton, & Gladwell, 2013; Gladwell et al., 2012; Gladwell et al., 2013; Laumann, Garling, & Stormark, 2003; Li et al., 2011; Park et al., 2010; Pretty, Peacock, Sellens, & Griffin, 2006; Ulrich, 1981; Ulrich et al., 1991). Brown and colleagues (2013), for example, investigated the effects of viewing images containing nature scenes compared with scenes from the built environment before exposure to a laboratory mental stressor. Although cardiovascular responses to the stressor did not differ between conditions, cardiac-vagal activity as indexed by HRV was higher during recovery in the nature-scene viewing condition.

Although such results are promising, it appears that the current evidence is often limited by the use of picture viewing (Brown et al., 2013; Gladwell et al., 2012; Laumann et al., 2003; Parsons, 1991; Pretty et al., 2006; Ulrich, 1981; Ulrich et al., 1991) rather than real-life situations, thereby lacking ecological validity. It has been argued that using passive viewing of images as a condition rather than real exposure to nature allows for the exclusion of any confounding effects of exercise, which is often part of nature experience and has itself inherent health benefits (Brown et al., 2013). Nevertheless, it seems important to use a research design that allows for the systematic investigation of the differential effects of all the components involved in nature exposure in a real-life setting. The first aim of the current study, therefore, was to compare the effects of nature exposure on mood and psychophysiological stress responses, and to disentangle the effects associated with recreational nature exposure from those linked with exercise (walking) by comparing three conditions: walking in nature, watching a video of the same nature scenes, and walking on a treadmill in a gym.

Another shortcoming of the current literature on the effects of nature exposure on stress and well-being is the predominant use of laboratory stressors. The specific purpose of laboratory stress paradigms is to elicit psychophysiological responses to emotional or behavioral challenges independent of basic reflexes so as to evaluate the role of the central nervous system in disturbances of stress regulation and the involvement of stress mechanisms in physical and mental disorders. There are several features of mental stress testing in the laboratory that make it an attractive research paradigm, including ease of application, high degree of standardization, and the possibility to monitor psychophysiological stress responses using sophisticated physiological measurements (Steptoe & Vögele, 1991). Nevertheless, in daily life people rarely confront a single stressor and usually face a myriad of stressors from many sources and of varying duration. Especially chronic stress forces a person to continually adapt to changing circumstances in the medium- and long-term, although "chronic" is a poorly defined construct. In a meta-analysis investigating the link between acute stress responsivity to laboratory stressors and changes in various chronic psychosocial stress conditions (e.g., job stress, general life stress), there were no associations between chronic psychosocial stress and stress reactivity or recovery as assessed by parameters of sympathetic and parasympathetic nervous system activity (Chida & Steptoe, 2009). The use of laboratory stressors in lieu of real-life stress is, therefore, doubtful.

A second aim of the current study was, therefore, to extend the current literature on the potential stress-buffering effects of nature exposure by including a more chronic life stress (academic examination period), in addition to a standardized laboratory stressor. Participants attended the psychophysiological experiment twice, that is, under academic stress (*exam* period) and no-stress conditions (*no exam* period). This repeated measurement design allowed for the investigation of differential and interaction effects of both types of stressors on psychophysiological reactivity in relation to the three treatment conditions. We hypothesized that (a) exposure to nature in the context of leisure walking has restorative effects on mood and psychophysiological stress responses under chronic and acute stress conditions over and above the effects of passive exposure to nature scenes or physical exercise alone, and (b) that the restorative effects of nature exposure would be more pronounced during the exam period when the participants were expected to be more stressed. We did not expect to find differences between exercise and passive viewing of nature scenes as both interventions have been shown to be effective.

Method

Sample and Research Design

The study used a mixed factorial design. It was carried out in Reykjavik with prior ethics approval from the Ethics Review Panel of the University of Luxembourg and the National Bioethics Committee in Iceland. Overall, 90 volunteers were recruited from the local universities. Advertisements describing the study were sent by email to all students via student unions. Permission was sought from the university authorities to advertise on university websites and to put printed copies on advertisement boards. The same advertisement was posted in supermarkets and on student campuses and (a small version) published in a local newspaper. The advertisement invited students to contact the Principal Investigator (PI) for more information. Eligibility for participation was assessed via telephone screening of study volunteers. Eligible participants were randomly allocated to one of three 40-min (±5 min) activities: (a) walking in nature, representing direct exposure to nature (nature), (b) walking (on a treadmill) in a gym representing the same physical activity intensity without nature exposure (gym), and (c) watching nature video-recording on TV in a laboratory setting (video), representing exposure to the same natural environment without the physical effort of walking (Figure 1). The sample size was based on power analysis, assuming an alpha level of significance of 5%, and test power above 90% (91.88%). Exclusion criteria were as follows: (a) self-reported current and regular exercise in nature or non-nature environments, (b) self-reported current ill health and/or diagnosed chronic conditions that preclude participation in physical exercise and/or a stress test, including substance abuse, and (c) skin problems and known allergic reactions to electrodes. Data were collected in two waves: from January to

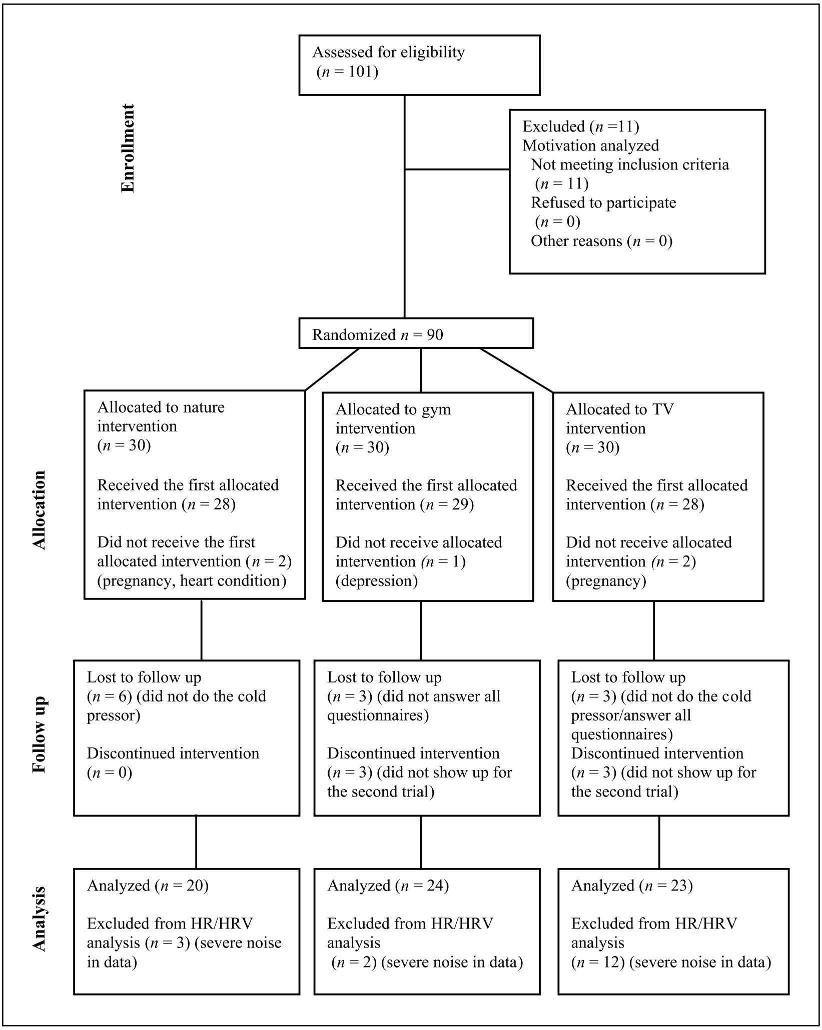

Figure 1. Consort flowchart.
Note. HR = heart rate; HRV = heart rate variability.

March 2014, that is, a period when students were not taking exams, and again from April to May 2014 during the exam period. To ensure that this operationalization of chronic life stress was valid, participants were asked to provide information on the date of their next examination. There were no significant differences in mean days until the next exam between the

Figure 2. (a) the nature-setting in May (upper left), (b) the nature-setting in February (upper right), (c) the gym-setting (lower left), (d) the video-setting (lower right).
Source. Author (All figures in color on-line only).

groups. Individual experimental sessions took place in the afternoon for reasons of standardization concerning the circadian rhythm of cortisol secretion and other dependent variables. Six participants dropped out before the second measurement. Their data along with responses from 12 participants who did not complete all measurements and five others with health-related issues not known during recruitment (pregnancy, depression, heart condition) was excluded from the analysis. The final sample consisted of 67 eligible participants (age 20-33 years; M = 24.39 years, SD = 2.61 years) with 20 participants in the nature group (15 females), 24 in the gym group (16 females), and 23 in the video group (15 females). The test power for the final sample was 83%. Mean body mass index (BMI) for the gym group was 22.37 kg/m^2 (SD = 2.96), 24.22 kg/m^2 for the nature group (SD = 2.96), and 25.19 kg/m^2 for the video group (SD = 4.56). There were no significant differences in BMI between the groups.

Study Settings

The nature walk took place in a conserved and by far the largest recreational area of Reykjavík city (Figure 2a). The majority of the 32 km^2 are covered with woodland of 26 different species predominated with the Sitka Spruce (*Picea sitchensis)*. The experiment took place on a 4.08 km sign-posted and easy circle trail (elevation 37 m) through the woodland. From time to time, during the walk the environment surrounding the trail opens up to open green spaces, moss-covered lava, and surrounding mountains. Mid-way, after 2.13 km into the trail, the outskirts of the city, Faxafloi bay and the mountains can be seen in the far distance. For the latter half, from 2.3 km onwards, the environment is again limited to greenery, lava, and the sky. We selected this trail, as people tend to like easily accessible environments characterized by trees and water (Ulrich, 1979, 1986) that can be walked in a relatively short period of time (40 ± 5 min). Compared with previous studies (Li et al., 2011; Park et al., 2010), we chose a trail with a longer walking time to improve ecological validity and also because the length of the walk could be easily matched in a gym setting without being out of place. Moreover, the route was also chosen as the only sign-posted route within the recreational area that does not involve crossing the main road, and starts and ends at a parking lot where the study's mobile laboratory could be placed. This way the laboratory marked the start and finish of the walk and the psychophysiological measurements could be done immediately before and after the individual walks in nature. As the experiment took place in the last months of the Icelandic winter (February-March) and again at the beginning of spring (April-May), all participants in the outdoor setting encountered snow during the first period, but none during the second (Figure 2b). In February/March, the average temperature, wind factor, and cloud coverage was higher than in April/May (5.1°C vs. 4.6°C; 6.3 m/sec vs. 4.2 m/sec; 5.6 of 8 vs. 7 of 8 parts, respectively), but precipitation and hours of sunshine were lower (0.7 mm vs. 1.6 mm; 0.7 hr vs. 8.5 hr of sunshine).

The indoor walking exercise took place at a gym selected because of its easily accessible location, modern man-made infrastructure, and its goal of promoting exercise for health and well-being; this compared better to the nature walk intervention than a conventional body-building gym (Figure 2c). All participants in the gym group used the same treadmill (Cybex 750T) in the main equipment room, surrounded by other equipment and customers. For participants in both the gym and the nature walk group, there was a possibility of encountering other people during their respective 40-min walk. These are ecological conditions normal to these settings in the early afternoon. Participants were instructed not to engage in any interaction with others during their 40-min walk.

The video nature viewing took place under laboratory conditions at the University of Iceland (Figure 2d). A small room within the laboratory was furnished with a comfortable armchair that was situated in front of a 55″

color TV set. Following the recommendations of the Society for Motion Picture and Television Engineers (SMPTE), we chose a viewing angle of 43° (recommended range 61.8° to 33.3°; SMPTE standard EG-18-1994). Accordingly, the chair for viewers was placed 128 cm from the screen.

The video recording was obtained from the same trail the participants allocated to the nature group walked. The recording took place in December, and again in March, 2 weeks prior to each viewing so that the sights and sounds of nature matched the season and to ensure similar exposure to nature as the nature group. For the first shooting in December, the footage consisted of a simulated walk with an adapted steadicam-like mechanism and approximately 2 min x 40 min in AVCHD 25M bit/sec in 1920 x 1080 50i shot on a Sony CX730. In interesting places, static, detailed, and panoramic shots were included to simulate a rest (e.g., on a bench). The simulated walk resulted in a lot of perturbations due to icy, slippery parts of the path and walking movement while recording the video. We, therefore, recorded a second video with a SONY FS700 NXCAM Codec and 1920 x 1080 50i to obtain more high quality pictures with a fixed camera position (panoramic movement, details, or panoramas). This shooting also generated a video of approximately twice the duration of the walk (80 min). Sound setup included two crossed Sennheiser shotgun microphones in 90° XY setup to get the best possible stereo recording for the sound ambience.

The settings for the video recording in March were the same as in December, that is, a Sony FS700 NXCAM, however, with a modified sound setup including a Rode NT1000 with Sennheiser shotgun in MS-Stereo recording. This resulted in 100 min of footage including details, panoramas, and walks to simulate the movement between the different points of interest. The footage was taken in 25 fps and played back in 100% speed. Some special settings and panoramas (e.g., moving clouds) were shot in time-lapse (10x) to better capture the image of the moving clouds on the beautiful landscape. Both video footages (i.e., winter and spring) were edited to each match a 40-min walk, resulting in two 40-min video clips.

Experimental Stressor

The Socially Evaluated Cold-Pressor Test (SECPT; Schwabe, Haddad, & Schächinger, 2008) was used to induce acute stress. This is a well-established and standardized method eliciting significant cardiovascular (HR) and endocrinological stress responses (e.g., cortisol). The test involves immersing the nondominant hand and wrist in cold water (0ºC-3ºC) for 3 min while being monitored and videotaped for the mock purpose of later analysis of facial expressions. The socially evaluative component (experimenter, fake video recording) is required to provoke cortisol responses (Schwabe, Haddad, & Schächinger, 2008). Its focused experimental setup allows for a precise timing of evoked physiological stress responses.

Physiological Measures

Cortisol assays. To assess hypothalamic pituitary adrenocortial (HPA) axis activity, cortisol was sampled and assayed from participants' saliva. Saliva samples were collected using salivettes (Sarstedt ref: 51.1534.500) and frozen at −20°C immediately after the sessions. Salivary samples were assayed twice at the Department of Clinical Biochemistry at the National University Hospital of Iceland, with the highly standardized nonisotopic and automatic electrochemiluminescence sandwich immunoassay (Mathew, Biju, & Thapalia, 2005) using kits provided by Roche Diagnostic GmbH, Mannheim, Germany (Elecsys®).

Cardiac data. HR and HRV were derived from the monitored electrocardiogram (ECG). For this measurement, we followed the standard methodological procedures (Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology [TFESC and NASPE], 1996). ECG was monitored with three electrodes (two active and one ground) placed on the individual's chest using a single standard lead I (Einthoven) configuration. ECG was recorded with a NeXus-32 biofeedback system with a sampling rate of 1,024 Hz. The spectral analysis of the manually confirmed RR-interval series was carried out using a Fast Fourier Transformation (FFT; 5 Hz resampling, Hanning window, triangular weighting). We followed the recommendations by the TFESC and NASPE and defined the high frequency (HF) band as 0.15 Hz to 0.4 Hz, and the low frequency (LF) band as 0.04 Hz to 0.15 Hz. HRV was expressed in terms of HFnu (normalized power in the high-frequency band [0.15 Hz-0.4 Hz]) as time-domain derived HRV parameters (e.g., Root Mean Square of the Successive Differences [RMSSD]) would have been inappropriate as trials differed in duration.

Psychological Measures

Mood was assessed using the Positive and Negative Affect Scale, a self-report questionnaire that consists of two 10-item scales to measure both positive and negative affect (Positive and Negative Affect Schedule [PANAS]; Crawford & Henry, 2004; Watson, Clark, & Tellegen, 1988). In this questionnaire, participants evaluate 20 mood-related adjectives according to their current perceived mood and rate them on a 5-point scale from 1 = *very slightly or not at all* to 5 = *extremely*. Questions 1, 3, 5, 9, 11, 12, 14, 16, 17, 19 refer to positive affect (PA) whereas 2, 4, 6, 7, 8, 10, 13, 15, 18, 20 refer to negative affect (NA). The score of the negative items are reversed in the analysis, and the total NA state score is found by adding up the sum of the NA items and PA items for PA. The total state score for each can range from 10 to 50. Higher scores indicate higher levels of NA and PA. Mean scores for PA is 33.3 (*SD* ± 7.2) and 17.4 (*SD* ± 6.2) for NA (Watson et al., 1988). The questionnaire was administered three times during the trial (quantified as NA and PA). The PANAS is a widely used instrument to reflect perceived stress, as its NA state scale is sensitive for state anxiety, which represents one important affective component of acute stress perception (Rossi & Pourtois, 2012). Furthermore, the PANAS allows for the assessment of possible effects of nature walking on PA.

Qualitative Information

A research diary was kept to record qualitative information on environmental conditions of each experimental trial, recording factors of the weather (nature group) that was substantiated with the quantitative measures of the Icelandic Met Office. Six randomly selected participants from each of the three groups were interviewed after the experimental sessions about their experience of the interventions. Results of these qualitative data are reported elsewhere (Olafsdottir, Cloke, & Vögele, 2017).

Experimental Procedure

Participants were instructed not to arrive hungry or thirsty at the study setting, and to refrain from smoking, eating, and drinking 1 hr prior to their individual afternoon appointments. The conditions in situ were kept as controlled as possible. On assessment days, the PI walked the nature route 1 hr prior to the experiment to ensure that conditions were safe and suitable for participants. The order and sequence of measurements within each trial was always the same (Figure 3). *Before the intervention*, and after receiving informed consent, ECG was recorded under resting conditions for 10 min. Thereafter, saliva was sampled for cortisol and the PANAS administered. Thereafter, the study participant performed the intervention alone. For the nature walk, participants were introduced to the route in the park's user-friendly trail map. They were thoroughly informed about the route's conditions (e.g., elevations, slippery in places in winter), the signposts and

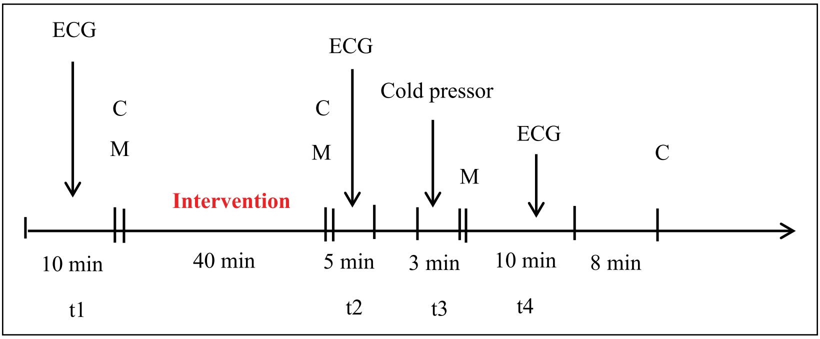

Figure 3. The trial sequence of the study.
Note. ECG = electrocardiogram; C = saliva collection for cortisol analysis; M = mood; t1–t4 = ECG measurement points.

instructed to keep a comfortable walking speed, not a speed that makes one sweat, but allows one to enjoy the walk and the setting. Participants were informed that in good weather conditions the route could be walked in 40 min ± 5 min. More clothes (parka, hat, mittens) were offered as needed, to ensure comfort en route.

In the gym, participants were guided to the equipment hall. After familiarization with the equipment, the clock on the treadmill was visibly set to 40 min. Volunteers were asked to step on the treadmill, switch it on and select a speed for walking, similar to the walking speed used on a leisurely walk outside. The speed was supposed to be comfortable walking speed for the individual that would not break a sweat. It could be adjusted by the participant whenever needed but kept within the range of 2.6 km/hr to 4.6 km/hr, which accommodated different levels of fitness and stride length.

Participants in the video group were invited to enter a small room within the laboratory and sit down in front of the TV. Before the video was switched on, participants were instructed to watch the video from start to finish and then re-enter the laboratory for measurements.

Post-intervention measurements started immediately after the intervention. Cortisol was sampled while the participant was reconnected with the ECG device for a 5-min recording period. The PANAS was then repeated. Next the stressor (SECPT) was introduced. A pre-adjusted video camera was brought into the room along with a bucket of water. The video recording started and participants were instructed to immerse their nondominant hand up to and including the wrist in the cold-water bath for 3 min and face the camera, but allowed to remove it prematurely if feeling very uncomfortable. Then, the video camera was switched off, and participants were handed a towel to dry their hand and to speed recovery. The PANAS was then answered for the third time. ECG was recorded throughout the procedure and for 10 min after the stressor. The third saliva sample was collected 18 min after removing the hand from the water, as previous studies on SECPT effects on cortisol responses indicated the peak of cortisol release between 15 and 20 min after SECPT termination (Lass-Hennemann et al., 2010; Schwabe, Haddad, & Schächinger, 2008). Participants were then debriefed and given time to recover after the procedure (Figure 3).

Data Analysis

To evaluate the effects of exposure to nature on cortisol levels under chronic and acute stress conditions, a 3 x 3 x 2 mixed-design analysis of variance (ANOVA) was conducted, with Group (nature, video, gym) as the between-subject factor, and Time (baseline, after intervention, after SECPT) and Period (no exams, exams) as the within-subject factors. The effects of exposure to nature on cardiovascular data were analyzed using two separate 3 x 4 x 2 mixed-design ANOVAs, with Group (nature, video, gym) as the between-subject factor, Time (baseline [t_1], after intervention [t_2], during SECPT [t_3], follow-up [t_4]) and Period (no exams, exams) as the within-subject factors, and with HR and HFnu as dependent variables. Because of equipment failure, ECG data of 17 participants had to be excluded from analyses, resulting in a final sample of 50 participants for ECG analyses (nature: $n = 17$; gym: $n = 22$; video: $n = 11$). To assess the effects of exposure to the natural environment on psychological measures, we calculated two separate 3 x 3 x 2 mixed-design ANOVAs, with Group (nature, video, gym) as the between-subject factor, Time (baseline, after intervention, after SECPT) and Period (exams, no exams) as the within-subject factors, and with NA and PA as dependent variables. Significant effects and interactions were assessed with additional *t* tests as post hoc comparisons with Bonferroni or Games-Howell corrections, depending on homogeneity of variance, as determined by Levene's test for equality of variances. Effects of potential baseline differences were controlled for by introducing baseline levels as covariates. In these cases, the initial 3 x 3 x 2 ANOVA model for cortisol and psychological measures was modified into a 3 x 2 x 2 analysis of covariance (ANCOVA), whereas the 3 x 4 x 2 ANOVA for cardiovascular data was changed into a 3 x 3 x 2 ANCOVA (identical factors, excluding "baseline" from factor "time"). All results are expressed as mean ± standard deviation. A value of $p < .05$ was considered statistically significant. Statistical software SPSS version 22.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

Preliminary analyses using sex as a grouping factor revealed no significant differences between men and women in any of the dependent variables. Results are, therefore, reported for both men and women together.

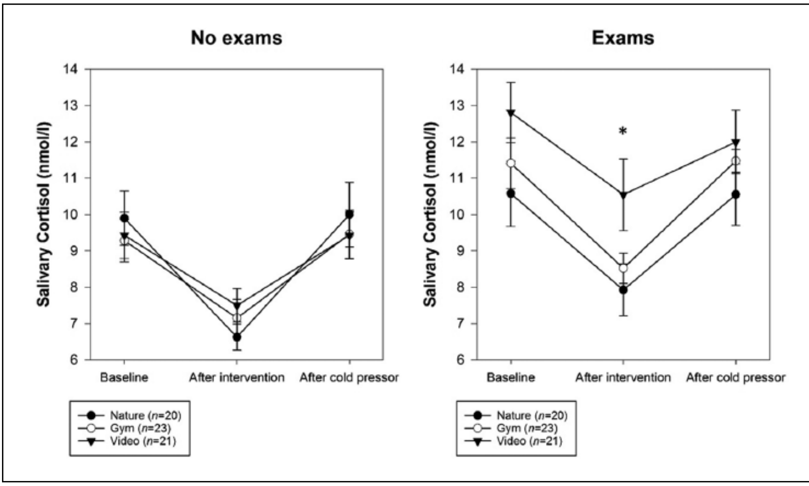

Figure 4. Mean cortisol levels during the no examination and examination period, in the nature-, gym- and video-group, respectively.
Note. Data are expressed as mean ± Standard Error of the Mean (SEM).
$^*p < .05$ nature versus video.

Results

Physiological Measures

Cortisol. Analysis of cortisol levels showed significant main effects for Period $F(1, 61) = 32.91, p < .001, \eta^2 = .35$ and Time $F(1, 122) = 36.41, p < .001, \eta^2 = .37$, together with a significant Period x Group interaction, $F(2, 61) = 3.44, p = .038, \eta^2 = .10$. Mean cortisol levels were significantly higher during the examination period than during the no examination period ($p < .001$). During both sessions, salivary cortisol significantly decreased after the intervention (baseline vs. after intervention: $p < .001$) and returned to its initial level after the SECPT (after intervention vs. after SECPT: $p < .001$). There were no significant differences in cortisol levels between the three groups during the no examination period (all ps $> .05$). During the examination period, participants in the nature group had significantly lower cortisol levels compared with the video group after the intervention ($p = .046$), and this difference remained significant after controlling for baseline cortisol levels ($p = .044$). No other group differences were found (all ps $> .05$). Mean cortisol levels are shown in Figure 4.

HR and HRV. In the analyses of HR as a dependent variable, there was a significant main effect for Time, $F(3, 141) = 57.16, p < .001, \eta^2 = .55$, a

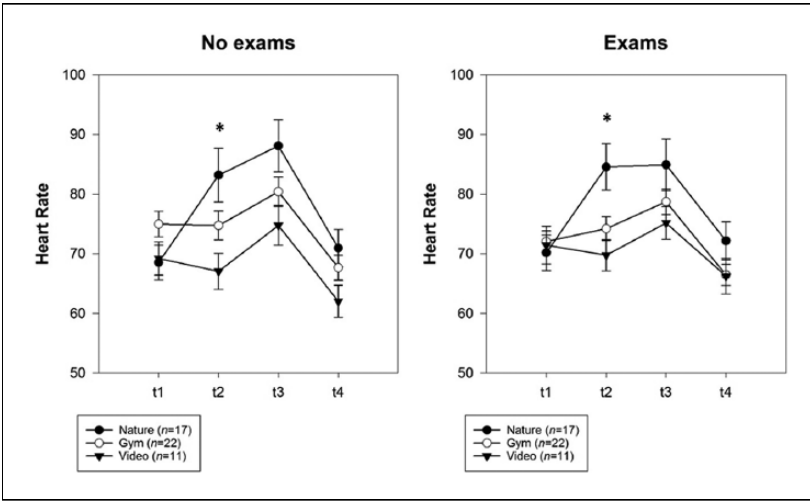

Figure 5. Mean heart rate (expressed as beats per minute) during no exam and exam period, in the green exercise group, gym group, and video group, respectively.
Note. Data are expressed as mean ± Standard Error of the Mean (SEM). Measurement points: t1 = baseline; t2 = after intervention; t3 = during SECPT; t4 = follow-up. SECPT = Socially Evaluated Cold-Pressor Test.
$^{*}p < .05$ nature versus video.

significant Time x Group interaction, $F(6, 141) = 9.24$, $p < .001$, $\eta^2 = .28$, and a significant interaction between Period and Time, $F(3, 141) = 3.94$, $p = .013$, $\eta^2 = .08$. No other main effects or interactions emerged (all Fs < 1.65, all ps > .15). Groups did not differ in baseline HR levels (all ps > .05). After the intervention, mean HR in the nature group was significantly higher compared with mean HR in the video group (no exams: $p = .017$; exams: $p = .011$), even after controlling for baseline values (no exams: $p < .001$; exams: $p < .001$). No significant differences were found between the nature group and the gym group (no exams: $p = .244$; exams: $p = .064$) or between the gym group and the video group (no exams: $p = .135$; exams: $p = .378$). There were no significant group differences during the SECPT and at follow-up (all ps > .05). Mean HR data are depicted in Figure 5.

In the analyses of HFnu, a significant Time x Group interaction, $F(6, 141) = 2.73$, $p = .015$, $\eta^2 = .10$ occurred. No other main effects or interactions were found (all Fs < 2.21, all ps > .09). There was no significant difference in HFnu between the three groups at baseline and after intervention (all ps > .05).

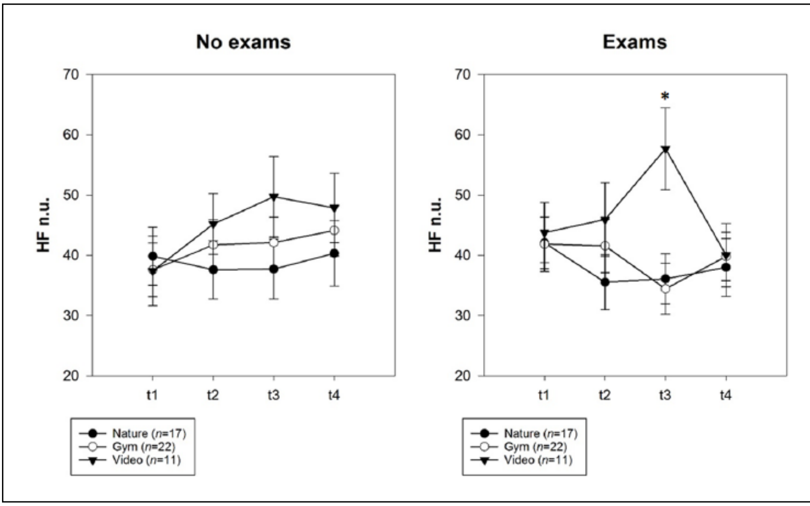

Figure 6. Mean HFnu during no examination and examination period in the nature-, gym- and video-group, respectively.
Note. Data are expressed as mean ± Standard Error of the Mean (SEM). Measurement points: t1 = baseline; t2 = after intervention; t3 = during SECPT; t4 = follow-up. HF = high frequency; SECPT = Socially Evaluated Cold-Pressor Test.
*$p < .05$ video versus nature and gym.

During the examination period, participants in the video group showed significantly higher HFnu during the SECPT compared with the nature group ($p = .037$) and the gym group ($p = .025$), even after controlling for baseline HFnu values (video vs. nature: $p = .007$; video vs. gym: $p = .001$). No other group differences were found during the examination period or during the no examination period (all *p*s > .05). Mean HFnu data are shown in Figure 6.

Psychological Measures

When NA was entered as a dependent variable, results showed significant main effects for Period, $F(1, 63) = 14.91$, $p < .001$, $\eta^2 = .19$ and Time, $F(2, 126) = 36.78$, $p < .001$, $\eta^2 = .37$, and a significant Period x Time interaction, $F(2, 126) = 10.80$, $p < .001$, $\eta^2 = .15$. There were no main or interaction effects for Group (all *F*s < 2.28, all *p*s > .11). NA was higher during the examination period compared with the no examination period at baseline ($p < .001$) and after the intervention ($p = .001$), but not at follow-up ($p = .364$). NA scores decreased significantly from baseline to after intervention across groups (no exams and exams: $p < .001$). No significant

Table 1. Means and Standard Deviations for Positive and Negative Affect Scores During No Examinations and Examination Period, in the Nature Group, Gym Group, and Video Group, Respectively.

		No exams			Exams		
		Baseline	After intervention	Follow-up	Baseline	After intervention	Follow-up
Negative affect	Nature	13.11 (2.32)	11.17[a] (2.43)	12.56 (2.31)	15.83 (3.94)	11.78[a] (3.30)	12.00 (2.03)
	Gym	15.13 (5.35)	12.96[a] (3.06)	13.42 (3.22)	17.21 (5.73)	14.50[a] (4.15)	14.08 (4.39)
	Video	14.61 (3.50)	11.39[a] (1.80)	13.43 (4.44)	18.57 (6.49)	13.78[a] (3.83)	14.13 (4.30)
Positive affect	Nature	31.10 (5.97)	36.80[bc] (9.38)	34.90 (8.60)	31.30 (5.89)	37.50[bc] (8.37)	34.75 (8.77)
	Gym	30.08 (6.53)	29.96 (6.50)	32.92 (5.21)	29.88 (6.41)	29.88 (6.42)	32.50 (5.10)
	Video	32.04 (5.47)	26.04 (7.57)	30.96 (6.53)	32.13 (5.49)	26.57 (7.57)	31.43 (5.98)

Note. The values in parentheses are *SD*s.
[a]Significant at the $p < .001$ level in comparison with baseline negative affect (NA).
[b]Significant at the $p < .05$ level in comparison with the gym group.
[c]Significant at the $p < .001$ level in comparison with the video group.

changes in NA were found from after intervention to follow-up (no exams: $p = .515$; exams: $p = .933$).

The analyses of PA showed a significant main effect for Time, $F(2, 126) = 5.55$, $p = .005$, $\eta^2 = .08$ and a significant Time x Group interaction, $F(4, 63) = 7.75$, $p < .001$, $\eta^2 = .20$. There was no difference in PA between the three groups at baseline (all ps $> .05$). After the intervention, participants from the nature group reported significantly higher PA scores compared with the gym group (no exams: $p = .016$; exams: $p = .004$) and the video group (no exams and exams: $p < .001$). These differences remained significant after controlling for baseline values (all ps $< .05$). No significant group differences were found for PA at follow-up (all ps $> .05$). Mean NA and PA scores are shown in Table 1.

Discussion

To the best of our knowledge, this is the first study to apply an ecologically valid research design (a) to test whether walking in nature promotes more restorative effects on mood and psychophysiological stress responses under chronic and acute stress conditions compared with exercise alone and (b) to disentangle the effects of walking and nature exposure by including all three conditions, that is, walking in nature, walking on a treadmill, and nature viewing. We expected participants to be more stressed during the examination period, and to benefit more profoundly when psychologically more stressed, as has been previously suggested (Ulrich, 1981, 1983). We tested these questions by measuring changes in endocrine markers of stress (cortisol) and indices of cardiac autonomic nervous system function (HR and HRV

[HFnu]) as well as psychological affect, when life was relatively relaxed and again during the examination period.

A first finding of this study concerns higher baseline cortisol levels during the examination period compared with the no examination period. This is in line with previous study findings on examination stress (Ignacchiti, Sesti-Costa, Marchi, Schedraoui-Silva, & Mantovani, 2011) and suggests higher stress levels during the examination time. Nevertheless, the order of no-examination and examination periods in the current study was fixed, so this effect may have also been affected by seasonal variations, which primarily show winter to summer decreases in cortisol levels (Hadlow, Brown, Wardrop, & Henley, 2014; Hansen, Garde, Skovgaard, & Christensen, 2001; King et al., 2000), probably associated with increased daylight exposure. As we found higher cortisol levels even under conditions of increased daylight hours (from 4.25 hr in January to 17.73 hr in May; Saemundsson, 2013), it seems likely that the observed increase in cortisol levels was due to examination stress, which may have overridden any seasonal effects of reduced cortisol.

All interventions had the power to significantly decrease cortisol levels during both life-stress periods, and there was no difference between the stress-buffering effects on either chronic or acute stress when life was relatively relaxed. Yet, when the individuals were under more stress, walking in nature (nature group) resulted in the largest decrease in cortisol levels, and passive viewing of nature scenes (video group) the least. This difference remained significant even after controlling for initial baseline differences, indicating that walking in nature may reduce stress levels to a greater extent when experiencing higher real-life stress levels than just viewing nature. Nevertheless, there was no statistically significant difference in average cortisol levels between participants walking in nature or walking in the gym. There was no significant difference in mean HR between the groups immediately after the interventions although there was a trend for higher HR in the nature group compared with the gym group despite being given the same instructions concerning exercise intensity. The nature walk may, therefore, have been more challenging than the gym walk in terms of physical effort. Moreover, after the intervention, participants in the nature group had significantly higher HR levels than the video group (both periods), and a tendency for lower parasympathetic activity (as indicated by the HF spectral component of HRV) than the other groups although these differences did not reach statistical significance. HR reflects both effects of sympathetic and parasympathetic activity. Given that the HF spectral component was reduced, it is likely that the increase in HR in the nature group was primarily due to decreased parasympathetic activity together with a simultaneous increase in sympathetic activity (Dong, 2016; Karemaker, 1999). HR was lowest after the intervention in those who passively viewed nature.

Previously, nature viewing has been shown to result in significant reductions in HR (Gladwell et al., 2012; Laumann et al., 2003; Ulrich et al., 1991) and higher HFnu (Gladwell et al., 2012) and higher RMSSD as indicators of parasympathetic activity after exposure to acute stress (Brown et al., 2013), indicating faster recovery. The cold pressor test (without the social component) increases HR in healthy participants (Jarvis, Okada, Levine, & Fu, 2015; Mourot, Bouhaddi, & Regnard, 2009; Sinha & Dubey, 2016) and decreases HFnu (Aimie-Salleh & Malarvili, 2011). In the current study, this was the case in both trial periods except for the video group. HFnu was higher in the video group during the SECPT but significant only in the chronic stress condition (exam period), suggesting that passive exposure to nature may help individuals to cope with acute stress under such circumstances. There were no differences between intervention groups in HR or HRV during the period following the laboratory stressor (SECPT), which contrasts with the findings by Brown et al. (2013) who found increased RMSSD during recovery from acute mental stress after passive viewing of nature scenes. Yet, the stressors used were different. Brown et al. (2013) used a task inducing mental load (i.e., mental arithmetic), whereas the cold pressor task used in the current study involves both physical and mental stress.

In summarizing the results on physiological responses, walking (regardless of environment/per se) seems to be most effective in buffering HPA axis activation when under high and low chronic (life stress) but not acute stress. Passive viewing of nature scenes, however, seems more effective in increasing cardiac-vagal activation when faced with an acute stressor.

The current findings on cortisol are comparable with some extent to what Park and colleagues (2010) found in their 24 experiments of 15 to 20 min forest walks and views in Japan, although there are differences in research design. As was the case with their results obtained from studies in forest environments, the current findings on cortisol were not reflected in the changes that occurred in cardiac-autonomic responses. Our protocol did not allow for any resting period after the walks or viewings before the ECG was recorded, as has been the case in the studies that demonstrated decreased sympathetic and increased parasympathetic activation after active nature exposure (Li et al., 2011; Park et al., 2010). This may be the reason why exercise with or without nature exposure did not lead to such outcomes in the present study.

Mean HR after the intervention was higher in the nature group compared with the gym group, although this difference was not statistically significant. In spite of being given the same instructions concerning exercise intensity, this may be an indication that the nature walk may have been physically more challenging than the gym walk. Previous studies have shown that self-selection of speed leads to slower walking inside than outside (Ceri & Hassmen, 1991), and when exposed to nature, perception of effort is reduced and mood enhanced (Akers et al., 2012).

All interventions resulted in significant reductions in NA for both periods. Participants across all groups reported significantly higher NA during the examination period, but only the nature group reported significant increases in PA after the intervention in both periods. This finding indicates that participants in the nature group felt better after the activity, which is in line with previous study findings of the positive impact of nature exposure on mental health over and above urban environments (Thompson-Coon et al., 2011). The current findings add, however, to the current literature in that they show that individuals do not have to be under high life stress to benefit psychologically from exposure to nature. According to Ulrich (1979, 1981), individual stress reduction occurs affectively and physiologically as the result of a perception of an unthreatening environment. Physiological stress responses are mobilized by perceived physical or psychological threats (the fight-flight response; Cannon, 1936) that put demands on the organism (Selye, 1955, 1979), which the brain discerns as an emergency and seeks to deal with immediately. Yet, as demonstrated by a large body of research on stress appraisal over the last five decades, individuals have the capacity to respond very differently to a given stress situation, depending on their cognitive appraisal. Such appraisal processes can easily destabilize allostatic balance and sustain a stressful situation by engaging with particular situations as an emergency, or worrying about things that might or might not happen (Sapolski, 2004; Selye, 1979). As Ulrich (1981) argues, the key to stress release is to refrain or distance oneself from negative thoughts and appraise the situation as unthreatening. The current findings in terms of increased PA and reduced NA and reduced cortisol seem to indicate that walking in nature is beneficial for this process, especially under conditions of chronic or longer-lasting real-life stress.

There are several limitations to this study. First, participants were introduced to the study's settings and more thoroughly to the experimental procedure immediately before the experiment. This might have been a cause for stress as most of the study volunteers had never been physically present in these settings, although they were aware of their existence and none had participated in an experiment of this sort before. Different results may have been demonstrated if we had followed Park and colleagues' (2010) approach and introduced the setting and procedure on the day before the experiment and put them up in a guesthouse the night before with controlled food and beverage intake. Second, the fixed order of non-examination and examination periods might have affected some of the current findings. Nevertheless, and as discussed in the previous paragraph, it is unlikely that seasonal effects would have confounded the findings on cortisol. Third, and also with regard to the cortisol data, 10 min of pre-experimental rest may have been too short to obtain a meaningful baseline. Nevertheless, the current study was primarily designed to assess cortisol responses to an acute stressor. Future studies should also address the impact of nature walking on other indices of HPA axis activity, such as diurnal cortisol rhythmicity. Fourth, the weather in the nature setting varied and was at times challenging although the forest provided some shelter from the wind and rain. The conditions on the ground also varied. During the first period, the ground was covered with snow and sometimes slippery in places. This may have somewhat reduced participants' enjoyment of the nature walk—although they were warned—as they tried to tackle the inconvenience of a challenging environment. However, it needs to be stated that no one fell or reported injuries. On the contrary, the research diary revealed that most people enjoyed the walk and returned from it feeling better as indicated by the changes in NA and PA. Fifth, both the nature setting and the gym were open for the public while the study was carried out, which meant that other people were present, which may have affected the results. Sixth, we did not control for exercise intensity between the nature and the gym walking groups (e.g., setting the treadmill at a 1% incline to represent outdoor walking, measuring exercise intensity) other than (a) instructing participants to walk at a leisurely pace that they felt comfortable with and (b) setting the pace of the treadmill (gym group) to a level to match the distance to be covered on the nature walk (approx. 4 km) in 40 min. More controlled conditions would have been desirable in terms of methodological rigor, thereby improving internal validity; however, increased levels of standardization usually reduce ecological validity and, therefore, impede the generalizability of results. Nevertheless, future studies should assess perceived exertion and measure exercise intensity as objectively as possible, for example, by including accelerometer/pedometer data. Seventh, it should be stressed that the HR and HRV findings should be regarded with caution due to the missing ECG data and small sample size (N = 50). Finally, a 40-min intervention may have been too short to induce more significant changes in stress responses. Yet, it is longer than the 10 to 30 min interventions used in previous studies investigating the effects of nature exposure on stress responses (see, for example, Brown et al., 2013; Li et al., 2011; Park et al., 2010; Ulrich et al., 1991). Furthermore, studies on the health effects of nature exposure have shown that even short visits to nature (30 min) can decrease cortisol levels and perceived stress (Tyrväinen et al., 2014), and the biggest impact on mental well-being seems to occur during the first 5 min (Barton & Pretty, 2010).

Although there are exceptions (Brown et al., 2013), previous studies investigating the effects of nature exposure on stress responses tended to monitor responses to a single laboratory stressor, and then monitor recovery after exposure to nature (Ulrich et al., 1991). The current study, however, extends this approach by assessing the effects of nature exposure on both chronic, general life stress and acute stress. The results suggest that periodic passive or active nature exposure or exercise alone (walking) might generally be beneficial in reducing stress levels. Although our hypotheses can only be partially confirmed, we found a tendency in favor of nature exposure in all parameters investigated. The results indicate that—when under high periodic life stress—stress responses can be mitigated more effectively by a 40-min walk in nature, than by physical exercise alone or by watching nature scenes (in this order). When life stress was more profound, the video group showed significantly higher HFnu reflecting cardiac-vagal activation *during* acute stress, which suggests that relaxed, passive nature viewing may help people deal with acute stress more readily than physical exercise with or without nature exposure.

Overall, the findings have important implications for local authorities to advocate the therapeutic agency of nature walks and views and to provide the public with easy access to nature-rich places where people can relax either passively by viewing nature or actively by walking in nature.

Acknowledgments

We thank the Department of Physiology, University of Iceland, for housing the fieldwork in Iceland. Much gratitude is also extended to Sveinbjörn Yngvi Gestsson, Sascha Helsper, Logi Jónsson, Lilja Guðrún Steinsdóttir, Anna Guðmundsdóttir, Ágústa Johnson, Hreyfing ehf, Helgi Gíslason, Reykjavik Forestry Association, Jón Sigurdsson, Nicole Knoblauch, Elizabeth Cook, and the National University Hospital of Iceland for supporting this research. Unnur Valdimarsdottir, University of Iceland, and Marcia Worrell, Roehampton University, had input at the development stage of the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was funded by the Fonds National de la Recherche Luxembourg (AFR ref. 3965162) and the University of Luxembourg (Internal Research Funding F3R-INS-PUL-13BREA/BREATH).

ORCID iDs

Gunnthora Olafsdottir https://orcid.org/0000-0002-4250-6822

André Schulz https://orcid.org/0000-0002-9381-2651

References

Aimie-Salleh, N., & Malarvili, M. B. (2011). Study of relationship between heart rate variability and autonomic function using cold pressor test for Malaysian population. *IEEE Colloquium on Humanities, Science and Engineering Research*, *5-6*, 351-354. doi:10.1109/CHUSER.2011.6163749

Akers, A., Barton, J., Cossey, R., Gainsford, P., Griffin, M., & Micklewright, D. (2012). Visual color perception in green exercise: Positive effects on mood and perceived exertion. *Environmental Science & Technology*, *46*, 8661-8666. doi:10.1021/es301685g

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. doi:10.1021/es903183r

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health*, *10*, Article 456. doi:10.1186/1471-2458-10-456

Brown, D. K., Barton, J. L., & Gladwell, V. F. (2013). Viewing nature scenes positively affects recovery of autonomic function following acute-mental stress. *Environmental Science & Technology*, *47*, 5562-5569. doi:10.1021/es305019p

Cannon, W. (1936, May). The role of emotion in disease. *Annals of Internal Medicine*, *9*(11), 1453-1465.

Ceri, R., & Hassmen, P. (1991). Self-monitored exercise at three different RPE intensities in treadmill vs. field running. *Medical Science in Sport and Exercise*, *23*, 732-738.

Chida, Y., & Steptoe, A. (2009). Cortisol awakening response and psychosocial factors: A systematic review and meta-analysis. *Biological Psychology*, *80*, 265-278. doi:10.1016/j.biopsycho.2008.10.004

Crawford, J. R., & Henry, J. D. (2004). The positive and negative affect schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology*, *43*, 245-265. doi:10.1348/0144665031752934

Dong, J. G. (2016). The role of heart rate variability in sports physiology (review). *Experimental and Therapeutic Medicine*, *11*, 1531-1536. doi:10.3892/etm.2016.3104

Driver, B. L. (1976). Quantification of outdoor recreationists' preferences. In B. Smissen & J. Myers (Eds.), *Research: Camping and environmental education* (HPEP Series No. 11, pp. 165-187). University Park: Pennsylvania State University.

Gladwell, V. F., Brown, D. K., Barton, J. L., Tarvainen, M. P., Kuoppa, P., Pretty, J., . . . Sandercock, G. R. H. (2012). The effects of views of nature on autonomic control. *European Journal of Applied Psychology*, *112*, 3379-3386. doi:10.1007/s00421-012-2318-8

Gladwell, V. F., Brown, D. K., Wood, C., Sandercock, G. R., & Barton, J. L. (2013). The great outdoors: How a green exercise environment can benefit all. *Extreme Physiology & Medicine*, *2*, Article 3. doi:10.1186/2046-7648-2-3

Hadlow, N. C., Brown, S., Wardrop, R., & Henley, D. (2014). The effects of season, daylight saving and time of sunrise on serum cortisol in a large population. *Chronobiology International*, *31*, 243-251. doi:10.3109/07420528.2013.844162

Hansen, Å. M., Garde, A. H., Skovgaard, L. T., & Christensen, J. M. (2001). Seasonal and biological variation in urinary epinephrine, norepinephrine, and cortisol in healthy women. *Clinica Chimica Acta*, *309*, 25-35. doi:10.1016/S0009-8981(01)00493-4

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health*, *35*, 207-228. doi:10.1146/annurev-publhealth-032013-182443

Health Council of the Netherlands. (2004). *Nature and health: The influence of nature on social, psychological and physical well-being*. The Hague: Health Council of the Netherlands/Dutch Advisory Council for Research on Spatial Planning, Nature and the Environment. Retrieved from http://www.gezondheidsraad.nl/sites/default/files/Nature_and_health.pdf

Herzog, T. R., Black, A. M., Fountaine, K. A., & Knotts, D. J. (1997). Reflection and attentional recovery as distinctive benefits of restorative environments. *Journal of Environmental Psychology*, *17*, 165-170. doi:10.1006/jevp.1997.0051

Home, R., Hunziker, M., & Bauer, N. (2012). Psychosocial outcomes as motivations for visiting nearby urban green spaces. *Leisure Science*, *34*, 350-365. doi:10.1080/01490400.2012.687644

Ignacchiti, M. D. C., Sesti-Costa, R., Marchi, L. F., Schedraoui-Silva, S., & Mantovani, B. (2011). Effect of academic psychological stress in post-graduate students: The modulatory role of cortisol on superoxide release by neutrophils. *Stress*, *14*, 290-300. doi:10.3109/10253890.2010.545459

James, P., Banay, R. F., Hart, J. E., & Laden, F. (2015). A review of the health benefits of greenness. *Current Epidemiology Reports*, *2*, 131-142. doi:10.1007%2Fs40471-015-0043-7

Jarvis, S. S., Okada, Y., Levine, B. D., & Fu, Q. (2015). Central integration and neural control of blood pressure during the cold pressor test: A comparison between hydrochlorothiazide and aliskiren. *Physiological Reports*, *3*(9), e12502. doi:10.14814/phy2.12502

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

Kaplan, S. (2001). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*, 169-182. doi:10.1016/0272-4944(95)90001-2

Kaplan, S., & Talbot, J. F. (1983). Psychological benefits of a wilderness experience. In I. Altman & J. F. Wohlwill (Eds.), *Human behavior and the environment: Advances in theory and research 6* (pp. 163-204). New York, NY: Plenum Press.

Karemaker, J. M. (1999). Autonomic integration: The physiological basis of cardiovascular variability. *Journal of Physiology*, *517*(Pt. 2), Article 316. doi:10.1111/j.1469-7793.1999.0316t.x

King, J. A., Rosal, M. C., Ma, Y., Reed, G., Kelly, T.-A., Stanek, E. J., & Ockene, I. S. (2000). Sequence and seasonal effects of salivary cortisol. *Behavioral Medicine*, *26*(2), 67-73. doi:10.1080/08964280009595753

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

Kondo, M., Fluehr, J., McKeon, T., & Branas, C. (2018). Urban green space and its impact on human health. *International Journal of Environmental Research and Public Health*, *15*(3), Article 445. doi:10.3390/ijerph15030445

Kudielka, B. M., & Wüst, S. (2010). Human models in acute and chronic stress: Assessing determinants of individual hypothalamus-pituitary-adrenal axis activity and reactivity. *Stress*, *13*, 1-14. doi:10.3109/10253890902874913

Lass-Hennemann, J., Deuter, C. E., Kuehl, L. K., Schulz, A., Blumenthal, T. D., & Schachinger, H. (2010). Effects of stress on human mating preferences: Stressed individuals prefer dissimilar mates. *Proceedings of the Royal Society, Series B: Biological Sciences*, *277*, 2175-2183. doi:10.1098/rspb.2010.0258

Laumann, K., Garling, T., & Stormark, K. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology*, *23*, 125-134. doi:10.1016/S0272-4944(02)00110-X

Li, Q., Otsuka, T., Kobayashi, M., Wakayama, Y., Inagaki, H., & Katsumata, M. (2011). Acute effects of walking in forest environments on cardiovascular and metabolic parameters. *European Journal of Applied Physiology*, *111*, 2845-2853. doi:10.1007/s00421-011-1918-z

Mathew, B. C., Biju, R. S., & Thapalia, N. (2005). An overview of electrochemiluminescent (ELC) technology in laboratory investigations. *Kathmandu University Medical Journal*, *3*(1), 91-93.

Mourot, L., Bouhaddi, M., & Regnard, J. (2009). Effects of the cold pressor test on cardiac autonomic control in normal subjects. *Physiological Research*, *58*, 83-91.

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention restoration theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, *19*, 305-343. doi:10.1080/10937404.2016.1196155

Olafsdottir, G., Cloke, P., & Vögele, C. (2017). Place, green exercise and stress: An exploration of lived experience and restorative effects. *Health & Place*, *46*, 358-365. doi:10.1016/j.healthplace.2017.02.006

Park, B., Tsunetsugu, Y., Kasarani, T., Kagawa, T., & Miyazaki, Y. (2010). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine*, *15*, 18-26. doi:10.1007/s12199-009-0086-9

Parsons, R. (1991). *Recovery from stress during exposure to videotaped outdoor environments* (Doctoral dissertation). University of Arizona, Tucson.

Pretty, J., Griffin, M., Sellens, M., & Pretty, C. (2003). *Green exercise: Complementary roles of nature, exercise and diet in physical and emotional well-being and*

implications for public health policy [CES occasional paper]. Colchester, UK: University of Essex.
Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2006). The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research*, *15*, 319-337. doi:10.1080/09603120500155963
Rossi, V., & Pourtois, G. (2012). Transient state-dependent fluctuations in anxiety measured using STAI, POMS, PANAS or VAS: A comparative review. *Anxiety Stress Coping*, *25*, 603-645. doi:10.1080/10615806.2011.582948
Saemundsson, T. (Ed.). (2013). *Almanak fyrir Ísland* [The calendar for Iceland], 177. Reykjavik: University of Iceland.
Sapolski, R. M. (2004). *Why zebras don't get ulcers: The acclaimed guide to stress, stress-related diseases, and coping* (3rd ed.). New York, NY: St. Martin's Griffin.
Schwabe, L., Haddad, L., & Schächinger, H. (2008). HPA axis activation by a socially evaluated cold-pressor test. *Psychoneuroendocrinology*, *33*, 890-895.
Selye, H. (1955). Stress and disease. *Science*, *122*, 625-631. doi:10.1126/science.122.3171.625
Selye, H. (1979). *The stress of my life*. New York, NY: Van Nostrand.
Sinha, B., & Dubey, D. K. (2016). Blood pressure variability and baroreflex sensitivity of a healthy male during cold pressor test that induced development of neurocardiogenic syncope. *Journal of Basic and Clinical Physiology and Pharmacology*, *27*, 437-443. doi:10.1515/jbcpp-2015-0004
Steptoe, A., & Vögele, C. (1991). The methodology of mental stress testing in cardiovascular research. *Circulation*, *83*(Suppl. 4), II14-II24.
Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology. (1996). Heart rate variability: Standards of measurement, physiological interpretation and clinical use. *Circulation*, *93*, 1043-1065. doi:10.1161/01/CIR.93.5.1043
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. doi:10.1021/es102947t
Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. *Journal of Environmental Psychology*, *38*, 1-9. doi:10.1016/j.jenvp.2013.12.005
Ulrich, R. S. (1979). Visual landscapes and psychological well-being. *Landscape Research*, *4*(1), 17-23. doi:10.1080/01426397908705892
Ulrich, R. S. (1981). Natural versus urban scenes: Some psycho-physiological effects. *Environment & Behavior*, *13*, 523-556. doi:10.1177/0013916581135001
Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the natural environment* (pp. 85-125). New York, NY: Plenum Press.
Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, *224*, 420-421. doi:10.1126/science.6143402

Ulrich, R. S. (1986). Human responses to vegetation and landscapes. *Landscape and Urban Planning*, *13*, 29-44. doi:10.1016/0169-2046(86)90005-8

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. doi:10.1016/S0272-4944(05)80184-7

Valtchanov, D., Barton, K. R., & Ellard, C. (2010). Restorative effects of virtual nature settings. *Cyberpsychology, Behavior, and Social Networking*, *13*, 503-512. doi:10.1089=cyber.2009.0308

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS Scales. *Journal of Personality and Social Psychology*, *47*, 1063-1070.

Author Biographies

Gunnthora Olafsdottir, PhD, is the director of research at the Icelandic Tourist Board and a visitor research fellow at University of Exeter and University of Luxembourg. Her research interests include restorative environments, human-nature relations, and human health and well-being in the context of leisure and tourism.

Paul Cloke, PhD, is a professor of human geography at University of Exeter and the founding editor of the international and multidisciplinary academic *Journal of Rural Studies*, published by Elsevier Science. He has research interests in social and cultural geographies of rurality, nature-society relations, ethics and care, and landscapes of spirituality.

André Schulz, PhD, is a research scientist at University of Luxembourg with research interests in the psychoneuroendocrinology of stress and interoception.

Zoé van Dyck, PhD, is a research associate at University of Luxembourg. Her research interests include cardiovascular and respiratory systems, human behavior, treatment, and clinical psychology.

Thor Eysteinsson, PhD, is director of Department of Physiology and professor of neurophysiology at the Faculty of Medicine, University of Iceland. His work focuses primarily on electrophysiology and eye research.

Björg Thorleifsdottir is an assistant professor of physiology at University of Iceland with primary research interests in biorhythms and sleep.

Claus Vögele, PhD, is a professor of health and clinical psychology at the University of Luxembourg. His main research areas include biological psychology, psychophysiology, and behavioral medicine where he examines psychocardiology, human behavior/decision-making and its neurobiological correlates, emotion regulation, interoception, and stress.