MASTER

Benefits of viewing nature versus urban slideshows for people experiencing stress
an ecological momentary intervention study

Bäbler, L.M.

Award date:
2017

BENEFITS OF VIEWING NATURE VERSUS URBAN SLIDESHOWS FOR PEOPLE EXPERIENCING STRESS

AN ECOLOGICAL MOMENTARY INTERVENTION STUDY

by

Linda Bäbler
ID: 0826701

in partial fulfilment of the requirements for the degree of

Master of Science

in Human-Technology Interaction

Eindhoven University of Technology

Eindhoven, 10.01.2017

Supervisors:

Dr. Ir. F. (Femke) Beute

Prof. Dr. W.A. (Wijnand) IJsselsteijn

Abstract

Previous research has found evidence for the restorative potential of nature exposure with regard to stress, mood and well-being. While the beneficial effects of real as well as mediated nature in the form of images and videos has been investigated in depth, research about nature interventions provided by the means of mHealth applications are scarce. The aim of the present ecological momentary intervention study was thus to investigate the influence of regularly watching nature slideshows on a mobile device over a period of six days on a variety of psychological variables including stress, mood, worry, rumination and well-being as well as the physiological variables of heart rate and heart rate variability. The effectiveness of the nature slideshows in mitigating stress and improving well-being was compared to watching urban slideshows or no slideshows at all. It was hypothesized that participants in the nature slideshow condition would experience lower stress, worry and rumination as well as better mood and well-being than participants in the urban slideshow or the control condition. Furthermore, it was predicted that physiological measures would improve significantly during and after watching nature slideshows, in comparison to before-slideshow measurements. The results showed that, contrary to expectations, regularly watching nature slideshows over a period of six days was not associated with significant improvements with regard to the psychological variables assessed. Instead, it was found that (a) participation in the experiment was associated with an increase in stress and decline in well-being over the course of the experiment for all participants, irrespective of experimental condition, and that (b) being assigned to one of the slideshow treatment conditions and consequently being required to regularly watch slideshows further contributed to the workload experienced. With regard to the physiological data collected, there was evidence that the mere act of taking a break to watch a slideshow was already beneficial in terms of physiological restoration, irrespective of treatment condition. The outcomes indicate that mediated nature interventions that were found to have restorative properties in the laboratory might not be as easily transferable into everyday settings as hypothesized. Instead, the results of the present study suggest that the requirements for stress-reducing interventions are different for real-life environments, compared to laboratory contexts.

Keywords: 741 social sciences (NUR code), environmental psychology, nature, health, mHealth, stress, heart rate variability, ecological momentary intervention

Acknowledgments

This thesis would not have been possible without the help of the many people that have supported me throughout the process of designing, executing and writing my research. First and foremost, I would like to express my sincere gratitude to my primary supervisor Dr. Ir. Femke Beute for her continuous support and guidance, her effort and time as well as the encouragement that she gave me. Without her expertise and knowledgeable input, this thesis would not have been achievable. My gratitude also goes to my second supervisor Prof. Dr. Wijnand IJsselsteijn for his guidance and support, not only during the present work, but also during prior projects. His advice and feedback was of immense value to me and has greatly helped me sharpen my critical thinking. I am very grateful for the support that I have received and I couldn't have wished for better and more patient supervisors.

I would also like to thank Prof. Dr. Ir. Yvonne de Kort for her valuable feedback on early drafts of my thesis and Prof. Dr. Chris Snijders for his advice on statistics and his tips and tricks with Stata. Many thanks also to Ing. Martin Boschman and Ing. Aart van der Spank for their technical support and help with the experimental setup. In addition, I would like to acknowledge my pilot testers who have helped me greatly with identifying issues with the experiment.

Many thanks also to my friends for their encouragement and for the interesting and stimulating discussions. Special thanks go to Roy for his moral support, his assistance with testing and his advice on the appropriate use of the Dutch language. Many thanks also to Philipp for his feedback on the draft versions of my thesis and to Mart for his help with testing and Bluetooth debugging. I would also like to thank Gemma for her input and advice and for being a great office neighbor.

Finally, I would like to thank my parents for supporting me throughout my studies, for always believing in me and for encouraging me to follow my dreams.

Contents

List of figures

List of tables

List of abbreviations

ACS-90	Action Control Scale
ACS-90 AOD	Hesitation versus initiative subscale of the ACS-90
ACS-90 AOF	Preoccupation versus disengagement subscale of the ACS-90
ANOVA	Analysis of Variance
ANS	Autonomic Nervous System
App	Application
ART	Attention Restoration Theory by Kaplan (1995)
BDI-II	Beck Depression Inventory II
BFI	Big Five Inventory
BPM	Beats Per Minute
CBS	Centraal Bureau voor de Statistiek (Statistics Netherlands)
CI	Confidence Interval
EMA	Ecological Momentary Assessment
EMI	Ecological Momentary Intervention
ESM	Experience Sampling Method
fMRI	Functional Magnetic Resonance Imaging
FSQ	Five-Shot Questionnaire
HF power	High frequency band (0.15–0.4 Hz), a marker of parasympathetic activity
HPA axis	Hypothalamic-Pituitary-Adrenocortical Axis
HR	Heart Rate
HRV	Heart Rate Variability
IBI	Interbeat Interval, alternative term for R-R interval
KSD	Karolinska Sleep Diary
LF power	Low frequency band (0.04–0.15 Hz), a marker of sympathetic activity
LF/HF ratio	Ratio of the LF and the HF band, an index of sympathovagal balance
LOT-R	Life Orientation Test Revised
M	Mean
MCTQ	Munich ChronoType Questionnaire

mHealth	Mobile Health
MLM	Multilevel Model
MSSD	Mean squared differences of successive N-N intervals, a marker of parasympathetic activity
N	Number
N-N interval	Alternative term for R-R interval
NN50	Number of interval differences of successive N-N intervals greater than 50 milliseconds, a marker of parasympathetic activity
pNN50	Percentage of interval differences of successive N-N intervals greater than 50 milliseconds, a marker of parasympathetic activity
PNS	Parasympathetic Nervous System
PSS-10	10-item version of the Perceived Stress Scale
PSWQ	Penn State Worry Questionnaire
RMSSD	Square root of the mean squared differences of successive N-N intervals, a marker of parasympathetic activity
R-R interval	Interval between two consecutive R-peaks of the QRS complex
SAM axis	Sympathetic-Adrenal-Medullary Axis
SCL-90-R	Symptom Checklist 90 Revised
SCL-90-R DEP	Depression subscale of the Symptom Checklist 90 Revised
SCL-90-R SOM	Somatic complaints subscale of the Symptom Checklist 90 Revised
SD	Standard Deviation
SDNN	Standard deviation of the N-N intervals, measure of total variance
SE	Standard Error
SNS	Sympathetic Nervous System
SRT	Stress Reduction Theory by Ulrich (1983)
UMACL	UWIST Mood Adjective Checklist
VLF power	Very low frequency band (0–0.04 Hz or 0.003– 0.04 Hz)
VPC	Variance Partition Coefficient

1 Introduction

Stress in our modern day society is a ubiquitous phenomenon and we all can relate to feeling stressed from time to time. While the term 'stress' has mostly negative connotations, from an evolutionary perspective, stress has a very important function: it serves as an alarm system, drawing our attention to potentially threatening aspects in the environment (Kemeny, 2003; McEwen & Wingfield, 2003; Nesse, Bhatnagar, & Young, 2007). In earlier days, this threat might have taken the form of a wild animal ready for attack, asking for immediate action. In modern days, however, stress is more likely to appear in the shape of deadlines, time pressure or social conflicts, potentially leaving us in a constant state of alert. While our bodies are well equipped to handle short periods of stress, previous research has recognized that prolonged or chronic stress can be very damaging to our health and well-being (Cohen, Janicki-Deverts, & Miller, 2007; McEwen & Wingfield, 2003). More specifically, stress was found to be associated with a wide range of illnesses, particularly diseases of cardiovascular (Brotman, Golden, & Wittstein, 2007; McEwen & Seeman, 1999; Miller & O'Callaghan, 2002; Thayer, Yamamoto, & Brosschot, 2010), cognitive (Hammen, 2005; Marin et al., 2011; McEwen, 2012; Sauro, Jorgensen, & Teal Pedlow, 2003), metabolic (Joseph & Golden, 2016; Kyrou & Tsigos, 2009; Peckett, Wright, & Riddell, 2011; Vegiopoulos & Herzig, 2007; Wardle, Chida, Gibson, Whitaker, & Steptoe, 2011), inflammatory, allergic and autoimmune nature (Dhabhar, 2014; Morey, Boggero, Scott, & Segerstrom, 2015; Segerstrom & Miller, 2004; Sternberg, 2001; Stojanovich, 2010).

In the light of these negative implications of stress for health and well-being, it is important to ask how stress can be reduced. Experimental research in the field of environmental psychology suggests that nature environments and green spaces have beneficial effects with regard to stress reduction and recovery (Beute & de Kort, 2014; Berto, 2014; Bowler, Buyung-Ali, Knight, & Pullin, 2010; Bratman, Hamilton, & Daily, 2012; Haluza, Schönbauer & Cervinka, 2014; Mantler & Logan, 2015; Velarde, Fry, & Tveit, 2007). However, while exposure to nature appears to be a potential remedy for stress, not everyone has access to or enough time to travel to nature environments in stressful situations. In order to treat symptoms of stress or prevent stress altogether, an alternative idea is to bring nature into the environment of the stressed individual. Given the widespread use of mobile devices such as smartphones and tablets (Liu, 2015), an interesting approach to the treatment of stress grounded in the theory of environmental psychology is to allow individuals to explore nature environments in a digital fashion, for example through the means of visualizations or artificial environments (de Kort, Meijnders, Sponselee, & IJsselsteijn, 2006; Valtchanov, Barton, & Ellard, 2010). Of particular interest for the design of nature interventions aimed at reducing stress are insights from the field of mobile health (mHealth), a rapidly developing healthcare discipline which studies the use of mobile computing and communication technology to provide healthcare services and interventions (Free et al., 2010). Mobile devices such as smartphones or tablets have the advantage that they are portable and have wireless networking capabilities, thereby offering immediate access to health-related information and providing support situationally when needed (Free et al., 2010; Free et al., 2013; Strecher, 2007). In addition, mobile devices allow for the continuous collection of environmental parameters such as time and location information and can be connected to sensors for the purpose of physiological data tracking (Beute, de Kort, & IJsselsteijn, 2016; Dobkin & Dorsch, 2011; Luxton, McCann, Bush, Mishkind, & Reger, 2011; Marzano et al., 2015). Mobile devices are thus highly versatile tools that provide novel opportunities for the development of healthcare services, particularly applications supporting health behavior change and the management of chronic diseases and stress (Free et al., 2013; Heron & Smyth, 2010; Marzano et al., 2015).

While the influence of real and mediated nature in the form of images and videos on health and well-being has been investigated in depth (Beute & de Kort, 2014; Berto, 2014; Bowler et al., 2010; Bratman et al., 2012; Haluza et al., 2014; Mantler & Logan, 2015; Velarde et al., 2007), studies about nature interventions provided by the means of mHealth applications are scarce (Beute et al., 2016). The aim of this research was therefore to investigate whether watching nature slideshows on a mobile device over a period of six days would have beneficial effects on psychological and physiological indices of stress. The effectiveness of nature slideshows in mitigating stress was compared to watching urban slideshows or no slideshows at all. Before delving into the details of the experimental setup, a review of the literature from the fields of stress and nature restoration is provided. More specifically, the physiological and psychological consequences of stress are described and an introduction to assessing stress by measuring heart rate variability (HRV) is provided. Furthermore, the pathways through which nature may exert its beneficial effects on health are illustrated and studies investigating the psychological and physiological effects of both real and mediated nature exposure are reviewed. This introduction concludes by introducing the main research questions that were investigated in the present work.

1.1 Stress

While the term 'stress' is frequently used in everyday language, it is a concept which remains difficult to define (Monroe, 2008). One of the most commonly used definitions is that of Cohen and colleagues (1997) who define stress as "*a process in which environmental demands tax or exceed the adaptive capacity of an organism, resulting in psychological and biological changes that may place persons at risk for disease*" (Cohen, Kessler, & Gordon, 1997, p. 1). This definition highlights that, in order to adequately deal with internal and external challenges or stressors, the human body is continuously required to adjust to current circumstances, a process which is referred to as 'allostasis' (McEwen, 1998; McEwen & Seeman, 1999; McEwen & Wingfield, 2003; Sterling & Eyer, 1988). For example, in order to maintain blood flow to the brain and prevent fainting when getting out of bed after a good night's sleep, the body is required to increase blood pressure (McEwen & Wingfield, 2003).

1.1.1 The physiological stress system

The two main physiological pathways that are activated in response to stressors are the sympathetic-adrenal-medullary (SAM) axis and the hypothalamic-pituitary-adrenocortical (HPA) axis (Cohen et al., 1997; Gunnar & Quevedo, 2007; Tsigos & Chrousos, 2002). The SAM axis is responsible for what is commonly called the 'fight-or-flight' response and is activated within seconds after the central nervous system has identified a stressor (Carrasco & Van de Kar, 2003; Kemeny, 2003; King & Hegadoren, 2002). The main driver of this process is the sympathetic nervous system (SNS), which, when activated in response to acute stressors, triggers the release of the catecholamines epinephrine and norepinephrine from the adrenal glands into the bloodstream (Gunnar & Quevedo, 2007; Kemeny, 2003; Tsigos & Chrousos, 2002). Epinephrine and norepinephrine then bind to receptors at various target organs to cause the typical fight-or-flight reactions such as elevated heart rate and blood pressure as well as increased blood flow to the brain, heart and skeletal muscles and restricted blood flow to less relevant organs such as the skin and the digestive system (Cohen et al., 1997; Gunnar & Quevedo, 2007; Kemeny, 2003; Piazza, Almeida, Dmitrieva, & Klein, 2010). In addition, norepinephrine released in the central nervous system is responsible for an increase in vigilance, arousal and focused attention (Gunnar & Quevedo, 2007). While the sympathetic nervous system is in charge of the fight-or-flight response in the face of imminent threats, there is a second system, called the parasympathetic nervous system (PNS), which is primarily active during relaxed states and responsible for regenerative and restorative functions such as growth, digestion, respiration and slowing of the heart (Kemeny, 2003; Porges, 1995; Tsigos & Chrousos, 2002). Together, the SNS and the PNS form a larger network called the autonomic nervous system (ANS; Kemeny, 2003; Porges, 1995; Tsigos & Chrousos, 2002). The SNS and the PNS are of particular interest for stress research, as they play an important role in regulating heart rate. Under resting conditions, the heart is predominantly under control of the parasympathetic nervous system, which has inhibitory effects on heart rate (Porges, 1995; Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012). In the face of stressors, parasympathetic activity is suppressed and the sympathetic nervous system is activated (Porges, 1995; Thayer et al., 2012). As a consequence of this process, heart rate is increased. Thus, while parasympathetic dominance indicates a state of relaxation, decreased parasympathetic and heightened sympathetic activity may signal that the body is occupied with handling external challenges.

Besides the SAM axis and the ANS, another important system that is triggered in response to stressors is the HPA axis. While the activation of the SAM axis is fast and short, it takes several minutes for the HPA axis response to reach its peak (Gunnar & Quevedo, 2007; Kemeny, 2003; King & Hegadoren, 2002; Piazza et al., 2010). The HPA axis is triggered by the hypothalamus, which secretes hormones that, through a complex series of steps, cause the release of glucocorticoids, in particular cortisol, from the adrenal glands (Charmandari, Tsigos, & Chrusos, 2005; Gunnar & Quevedo, 2007; Tsigos & Chrousos, 2002). Cortisol plays an important role in maintaining and increasing blood glucose levels, which ensures that the body has enough energy during the encounter with stressors (Chrousos, 2009; Miller & O'Callaghan, 2002). Furthermore, cortisol is involved in the regulation of various other processes such as the immune system and the formation of memories (Chrousos, 2009; McEwen & Seeman, 1999; Carrasco & Van de Kar, 2003). Together, the glucocorticoid cortisol and the catecholamines epinephrine and norepinephrine form the primary hormonal effectors of the physiological stress system (Chrousos, 2009; McEwen & Seeman, 1999; McEwen & Wingfield, 2003).

Importantly, as long as the activation of the SAM system and the HPA axis is of relatively short duration and limited frequency, this adaptive process is vital for survival and allows the human body to effectively deal with internal and external stressors (Berntson & Cacioppo, 2007; Kemeny, 2003; McEwen, 1998). However, repeated or chronic exposure to stressors may cause a disruption of the physiological systems involved in the stress response, consequently leading to an over- or underexposure of the body to stress hormones and eventually contributing to the development of disease (McEwen, 1998; McEwen & Seeman, 1999; McEwen & Wingfield, 2003). The accumulation of the damaging effects of repeated exposure to stressors over time is termed 'allostatic load' (McEwen, 1998; McEwen & Seeman, 1999; McEwen & Wingfield, 2003). Besides the repeated or too intense exposure to stressors, there are several other situations that may contribute to allostatic load. For instance, the stress system may fail to adapt or habituate to similar types of stressors, the body might be unable to shut off the stress response after exposure to a stressor has long been terminated, or the magnitude of the response to a stressor might be inadequate (e.g., too strong or too weak; McEwen, 1998; McEwen & Seeman, 1999). Allostatic load may manifest itself in a variety of ways. For example, since the activation of the sympathetic nervous system leads to increases in heart rate and blood pressure, chronic stress plays an important role in promoting the development of cardiovascular diseases such as hypertension or atherosclerosis (Brotman et al., 2007; McEwen & Seeman, 1999; Miller & O'Callaghan, 2002; Thayer et al., 2010). Furthermore, heightened cortisol concentrations as a consequence of HPA axis activation were found to be associated with increased food intake (Adam & Epel, 2007; Dallman, 2010; Peckett et al., 2011). In combination with the metabolic changes induced by cortisol, this may lead to the accumulation of body fat and in the long term obesity and diabetes (Adam & Epel, 2007; Björntorp, 2001; Joseph & Golden, 2016; Kyrou &

Tsigos, 2009; Peckett et al., 2011; Tsigos & Chrousos, 2002; Vegiopoulos & Herzig, 2007; Wardle et al., 2011). In addition, stress can also influence the immune system. While acute or short-term stress was found to mobilize immune cells, thereby enhancing the immune system, long-term, chronic stress can suppress or dysregulate the immune response and contribute to the development of inflammatory, allergic or autoimmune diseases (Dhabhar, 2014; Morey et al., 2015; Segerstrom & Miller, 2004; Sternberg, 2001; Steptoe, Hamer, & Chida, 2007; Stojanovich, 2010). Finally, stress also has profound effects on the brain (McEwen, 2012). Glucocorticoids released in response to stress were for example found to be able to structurally change or even damage the hippocampus, potentially leading to the impairment of memory and cognitive function (Het, Ramlow, & Wolf, 2005; Lupien, Maheu, Tu, Fiocco, & Schramek, 2007; McEwen & Sapolsky, 1995; McEwen, 2012; Sauro et al., 2003). Similar structural changes of the hippocampus accompanied by a dysregulation of the HPA axis were also found in anxiety and depression, indicating that chronic stress plays an important role in the development of psychiatric disorders as well (Gold, Machado-Vieira, & Pavlatou, 2015; Hammen, 2005; Lee, Ogle, & Sapolsky, 2002; McEwen, 2005; Pariante & Lightman, 2008). In sum, previous research demonstrates that chronic activation of the stress system may promote the development of a variety of diseases including diseases of cardiovascular, metabolic, immunologic and cognitive nature.

1.1.2 Psychological aspects of stress

It is important to understand that the presence of a stressor alone is not enough to predict the outcome of the stress response. There exist a great variety of psychological and environmental factors that influence how individuals react to stressors and whether a physiological stress response is triggered at all. Modern psychological models of stress recognize that cognitive appraisal, the process according to which it is decided whether a stressor represents a relevant threat to one's personal well-being and if so, what can be done in order to mitigate the stressor, plays a particularly important role in determining the magnitude and duration of the stress response (Folkman, 1984; Ganzel, Morris, & Wethington, 2010; Kemeny, 2003; Moksnes & Espnes, 2016). The meaning and personal relevance of a stressor may thus greatly influence how individuals react to stressors. For example, stressors which are interpreted as opportunities for growth may lead to different outcomes than stressors which are evaluated as harmful to one's well-being (Folkman, 1984; Kemeny, 2003). Similarly, stressors which are perceived as uncontrollable were found to cause more pronounced stress reactions than stressors which are interpreted as controllable or predictable (Dickerson & Kemeny, 2004; Folkman, 1984). In addition, aspects such as ambiguity, novelty or duration of the stressor may all have an influence on the outcomes of the stress response as well (Kemeny, 2003; Folkman, 1984).

The outcome of an encounter with a stressor can further be influenced by the type of coping strategy used. Coping can be defined as the type of approach that is chosen to manage, reduce or prevent a stressor (Carver & Connor-Smith, 2010; Connor-Smith & Flachsbart, 2007; Folkman, 1984). Typical coping strategies for example include efforts to directly reduce or remove stressors, called problem-focused coping, or strategies to manage negative emotions in response to stressors, for example by expressing negative emotion or seeking emotional support, termed emotion-focused coping (Carver & Connor-Smith, 2010; Connor-Smith & Flachsbart, 2007; Folkman, 1984). Another way of categorizing coping strategies is by looking at how stressors are approached: engagement coping includes attempts at actively dealing with the stressor whereas disengagement coping describes withdrawal-strategies such as avoidance, denial or wishful thinking (Carver & Connor-Smith, 2010; Connor-Smith & Flachsbart, 2007). Importantly, previous research shows that the process of cognitive appraisal and the choice of coping strategy can be influenced by aspects of personality. Optimists for example show the ability to choose coping strategies in an effective and flexible manner, by engaging in problem-focused coping if the stressor is manageable and by relying on emotion-focused coping in case of more uncontrollable stressors (Carver & Connor-Smith, 2010; Carver et al., 2010). Being more optimistic was furthermore found to be linked to better physiological and psychological well-being, particularly during stressful times (Carver & Connor-Smith, 2010; Carver, Scheier & Segerstrom, 2010; Rasmussen, Scheier, & Greenhouse, 2009). A higher level of neuroticism, on the other hand, was found to be associated with a tendency to more easily categorize stressors as threatening, a greater reliance on disengagement coping strategies, as well as lower levels of mental health (Carver & Connor-Smith, 2010; Malouff, Thorsteinsson, & Schutte, 2005; Vollrath, 2001). Compared to neurotics, extroverted, conscientious or agreeable individuals appear to have a higher tendency to appraise a stressor as a challenge instead of as a threat (Carver & Connor-Smith, 2010).

Another cognitive process which is of particular importance with regard to the development of chronic stress is perseverative thinking. Perseverative thinking is a term that describes repeated or chronic, intrusive thought processes about psychological stressors (Brosschot, Gerin, & Thayer, 2006). Concrete examples of perseverative thinking include worry, characterized by negatively charged thoughts about uncertain aspects of the future, as well as rumination, meaning repetitive, negative thoughts primarily about stressful incidents in the past (Brosschot, 2010; Brosschot et al., 2006). Importantly, the prolonged or repetitive cognitive representation of stressors was found to have physiological consequences similar to those experienced during actual exposure to stressors, thereby prolonging the negative effects of stressors beyond their occurrence (Brosschot, 2010; Brosschot et al., 2006; Brosschot, Van Dijk, & Thayer, 2007; Pieper & Brosschot, 2005; Pieper, Brosschot, van der Leeden, & Thayer, 2007; Verkuil, Brosschot, Borkovec, & Thayer, 2009a). For example, in a laboratory study, Verkuil and colleagues (2009a) compared the cardiac effects of worry to the effects of cognitive load as well as a relaxation control condition. Worry was induced by asking participants to write down three personal worry topics, whereas cognitive load was manipulated with a cognitive problem solving task consisting of moral dilemmas. Results showed that, compared to the control condition, participants in the worry condition as well as participants in the cognitive load condition both experienced comparable increases in heart rate and decreases in parasympathetic activity. In line with the known effects of chronic stress on health and well-being, there is increasing evidence that perseverative cognition may promote the development of stress-related diseases as well, particularly cardiac diseases and psychiatric disorders such as anxiety and depression (Brosschot et al., 2006; Nolen-Hoeksema, 2000; Pieper & Brosschot, 2005). Summing up, results from previous studies support that cognitive processes and aspects of personality are important predictors of the stress response.

1.1.3 Measuring stress

Given the implications of stress for health and well-being, being able to adequately measure stress is of great importance. There exists a wide variety of both psychological and physiological methods for the assessment of stress. Psychological instruments commonly assess stress by either focusing on the situational aspects of the stress process, by for example evaluating stressful life events or daily hassles (e.g., the Life Experiences Survey by Sarason, Johnson and Siegel, 1978; or the Survey of Recent Life Experiences by Kohn and Macdonald, 1992), or by assessing individual appraisals of stress via self-report measures (e.g., the Perceived Stress Scale by Cohen, Kamarck and Mermelstein, 1983; Kopp et al., 2010; Monroe, 2008).

While there is no doubt that well established psychological instruments such as the perceived stress scale have good psychometric properties (Lee, 2012; Monroe, 2008; Roberti, Harrington, & Storch, 2006), a general drawback of self-report measures is that they are greatly dependent on an individual's ability to adequately recognize and report personal levels of stress. A promising approach is thus to combine psychological scales with physiological measures of stress, as physiological reactions to stress are to a great degree beyond conscious influence. A widely used physiological stress measure is heart rate variability (HRV). As the name suggests, measurement of HRV relies on the fact that the rhythm of the heart is subject to constant fluctuations due to continuous influences of both the sympathetic and parasympathetic branches of the autonomic nervous system (Sztajzel, 2004; Task Force of ESC, 1996). Heart rate variability is thus a measure that quantifies the degree of variation in the length of the time intervals between consecutive heart beats (Acharya, Joseph, Kannathal, Lim, & Suri, 2006; Peltola, 2012; Task Force of ESC, 1996). The time interval between two heart beats, commonly referred to as R-R interval, interbeat interval (IBI), or sometimes N-N interval, can be obtained from the electrocardiogram by measuring the duration between two consecutive R-peaks of the QRS complex, as depicted in Figure 1.1 (Kamath, Watanabe, & Upton, 2012).

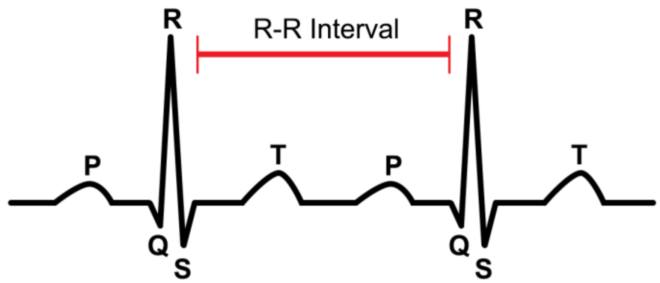

Figure 1.1 Schematic depiction of the R-R interval.

There exist a number of different physiological HRV indices. The most popular types of HRV indices can be divided into two broad categories: time-domain measures and frequency-domain measures. Time-domain measures are relatively easy to calculate and are either directly applied to the R-R intervals or derived from the differences between consecutive R-R intervals (Task Force of ESC, 1996). Among the most common time-domain measures are the SDNN (standard deviation of the N-N interval), the RMSSD (square root of the mean squared differences of successive N-N intervals) and the NN50 / pNN50 (number of interval differences of successive N-N intervals greater than 50 milliseconds; Task Force of ESC, 1996). While the SDNN is interpreted as a measure of total variance, the RMSSD and NN50 / pNN50 are markers of parasympathetic activity (Ernst, 2014; Task Force of ESC, 1996; Xhyheri, Manfrini, Mazzolini, Pizzi, Bugiardini, 2012). In order to be able to analyze HRV in the frequency domain, a further transformative step is required. Since the sympathetic and the parasympathetic contributions of the autonomic nervous system modulate the heart rate in a periodic fashion (Acharya et al., 2006), it is possible to decompose the heart rate variability signal into its respective frequency components, thereby describing the individual intensities (termed variance or power) at which the sympathetic and parasympathetic branches as well as other processes influence heart rate (Ernst, 2014; Sztajzel, 2004). In short-term (≈ five minute) recordings of heart rate variability, total power is typically divided into three frequency bands: high frequency (HF; 0.15–0.4 Hz), low frequency (LF; 0.04–0.15 Hz) and very low frequency (VLF; 0–0.04 Hz or 0.003– 0.04 Hz in case of long-term recordings). HF power is of particular interest in stress research, as it is considered to be modulated primarily by the activity of the parasympathetic system (Kamath et al., 2012; Task Force of ESC, 1996). The interpretation of the low frequency band, on the other hand, is controversial. Some sources say that LF power provides information about the sympathetic system only, while others state that it is modulated by both the sympathetic and the parasympathetic system (Task Force of ESC, 1996). In addition, the ratio of the LF and the HF band (LF/HF ratio) is interpreted by many as an index of sympathovagal balance, although its meaning is controversial as well (Ernst, 2014; Task Force of ESC, 1996; Xhyheri et al., 2012).

With regard to the interpretation of HRV indices, higher heart rate variability, particularly higher total variance and higher parasympathetic activity, is generally considered to be a signal of a healthy interplay between the sympathetic and parasympathetic system, whereas a reduction in HRV may be indicative of disease (Acharya et al., 2006; Sztajzel, 2004; Thayer et al., 2010). Specifically, low HRV was found to be associated with an increased risk of both cardiovascular and all-cause mortality in patients with a history of chronic heart failure (Bilchick et al., 2002; Nolan et al., 1998; Ponikowski et al., 1997) and myocardial infarction (Bigger et al., 1992; Lombardi et al., 1987; Kleiger, Miller, Bigger, & Moss, 1987). Low HRV was furthermore found to be associated with diseases such as hypertension (Huikuri et al., 1996; Schroeder et al., 2003; Singh et al., 1998), diabetes (Liao et al., 1995; Schroeder et al., 2005; Singh et al., 2000), depression (Agelink, Boz, & Ullrich, 2002; Carney, Freedland, & Veith, 2005; Kemp et al., 2007; Rottenberg, 2007; Udupa et al., 2007) and anxiety (Chalmers, Quintana, Abbott, & Kemp, 2014; Friedman, 2007). In addition, several studies have linked higher HRV to better health in the general population as well (Dekker et al., 2000; Gerritsen et al., 2001; Tsuji et al., 1994; Tsuji et al., 1996). Heart rate variability can therefore be a valuable method for the assessment of autonomic nervous system function, not only in patients but also in healthy individuals.

The employment of heart rate variability as a measure of stress and autonomic nervous system function has several other advantages. It provides insight about changes in both the sympathetic and parasympathetic branches of the autonomic nervous system and can be monitored continuously over a prolonged period of time. Furthermore, modern heart rate variability monitors are low cost, noninvasive, lightweight, wearable devices that allow for the measurement of heart rate variability both in- and outside of the laboratory environment. All of these aspects contribute to heart rate variability being a convenient and noninvasive method for the assessment of the autonomic nervous system (Dekker et al., 2000; Kleiger et al., 1987; Liao et al., 1997). Importantly, when studying heart rate variability, it is crucial to be aware of the various factors known to confound HRV measurements. Specifically, it was found that HRV generally decreases with age and is lower in women compared to men (Bonnemeier et al., 2003; Jensen-Urstad et al., 1997; Stein, Kleiger, & Rottman, 1997; Umetani, Singer, McCraty, & Atkinson, 1998). HRV is further influenced by a circadian rhythm, which manifests itself through a decrease of HRV during the day and an increase of HRV during the night (Furlan et al., 1990; Guo & Stein, 2003; Huikuri et al., 1994). Lifestyle-related factors such as smoking (Barutcu et al., 2005; Dinas, Koutedakis, & Flouris, 2013; Hayano et al., 1990; Niedermaier et al., 1993), alcohol (Ingjaldsson, Laberg, & Thayer, 2003; Koskinen, Virolainen, & Kupari, 1994; Murata et al., 1994; Rossinen et al., 1997; Thayer, Hall, Sollers, & Fischer, 2006) and caffeine consumption (Bonnet, Tancer, Uhde, & Yeragani, 2005; Sondermeijer, van Marle, Kamen, &

Krum, 2002) were found to have a negative influence on heart rate variability as well. Furthermore, several studies support that regular exercise is associated with increases in HRV, particularly increases in parasympathetic activity (Carter, Banister, & Blaber, 2003; Goldsmith, Bloomfield, & Rosenwinkel, 2000; Sandercock, Bromley, & Brodie, 2005). Certain types of cardiovascular drugs may also influence HRV (Ernst, 2014; Kamath et al., 2012; Task Force of ESC, 1996). In addition, subtle aspects such as posture, breathing or speech may introduce further ambiguities (Berntson et al., 1997; Garde, Laursen, Jørgensen, & Jensen, 2002), making it difficult to determine the precise amounts of sympathetic and parasympathetic modulation in the HRV signal. It can be concluded that, while heart rate variability can be used for assessing the state of the autonomic nervous system and for quantifying stress, it is recommended to control for factors that could potentially interfere with HRV outcomes.

1.1.4 Stress and heart rate variability

A wide variety of studies have employed measures of heart rate variability as a means to quantify the human stress response. HRV was for example used in the context of laboratory induced mental stress, work stress, various sources of real life stress as well as stress in relation to worry and rumination. This section provides a short overview of the most relevant studies conducted in this field. It is important to note that studies investigating HRV often differ greatly in terms of methodology and HRV indices employed, which makes the identification of common patterns a challenge.

In the laboratory, stress is typically induced with tasks that are specifically designed to increase cognitive load or social evaluative threat such as for example the Stroop task, memory tests, arithmetic tests or the Trier Social Stress Test. The majority of results showed that mental and social stress can lead to autonomic changes characterized by a withdrawal of parasympathetic activity and a shift toward sympathetic dominance. Particularly, stress was found to be associated with decreases in SDNN (Lackschewitz, Hüther, Kröner-Herwig, 2008; Visnovcova et al., 2014), RMSSD (Lackschewitz et al., 2008; Weber et al., 2010), pNN50 (Taelman, Vandeput, Spaepen, & Van Huffel, 2009) and HF power (Hall et al., 2004; Hjortskov et al., 2004; Lackschewitz et al., 2008; Visnovcova et al., 2014) as well as increases in heart rate (Lackschewitz et al., 2008; Taelman et al., 2009; Visnovcova et al., 2014) and LF/HF ratio (Hall et al., 2004; Hjortskov et al., 2004; Lackschewitz et al., 2008). It is important to note that despite the evidence for an association between laboratory stress and decreased HRV, a number of studies were unable to find significant results (Garde et al., 2002; Hoshikawa & Yamamoto, 1997; Wahlström, Hagberg, Johnson, Svensson & Rempel, 2002).

Importantly, stress was not only investigated in the laboratory but also under a variety of real life conditions. A wide range of studies found stress at the workplace to be associated with decreases in HRV (Chandola, Heraclides, & Kumari, 2010). Collins, Karasek and Costas (2005) for example studied the influence of job strain on autonomic indices. HRV was continuously monitored during one work day and one non-workday. Furthermore, participants completed diary entries eight times a day, answering questions relating to aspects such as their current activities, psychological demands or social interactions. Results showed that HF power was significantly lower for participants experiencing high job strain during the entire monitoring period, compared to participants experiencing low job strain. Furthermore, the LF/HF ratio was significantly higher for participants under high stress on the workday as well. Together, these results indicate a decrease of parasympathetic activity and autonomic balance in response to stress at the workplace. In a different study, Hintsanen and colleagues (2007) investigated the relationship between work stress, measured by assessing the degree of imbalance between the amount of effort required and the size of the reward received at work, and cardiovascular activity. They found that high effort-reward imbalance was significantly associated with higher heart rate and lower parasympathetic activity (RMSSD and pNN50) among women, but not among men. Vrijkotte, van Doornen and de Geus (2000) similarly operationalized work stress in terms of effort-reward imbalance and investigated its effects on blood pressure, heart rate and heart rate variability monitored during two workdays and one non-workday. Results showed that participants experiencing high effort-reward imbalance had significantly higher heart rate and lower RMSSD during work and leisure days, compared to participants with low effort-reward imbalance. Although the majority of studies found stress at the workplace to be associated with decreases in HRV, not all studies were able to find such a relationship. For example, Riese, Van Doornen, Houtman and De Geus (2004) investigated the effects of job strain on cardiovascular measures among healthy female nurses but failed to find a significant relationship.

In addition to work-related studies, real-life stress was assessed under various other conditions. Sloan and colleagues (1994) for example measured HRV over a period of one day and asked participants to keep a daytime diary by answering questions about their current activities and emotions approximately once per hour. Results showed that perceived stress was associated with a significant increase in heart rate and LF/HF ratio, indicating a shift toward sympathetic dominance. Myrtek, Weber, Brügner and Müller (1996) investigated stress among female students by continuously tracking HRV for the duration of one day. During this recording period, participants were further asked to answer a set of questions about current activities and feelings of arousal and enjoyment every 10-20 minutes. Chronic stress was assessed once at the beginning of the study. Results showed that MSSD and feelings of enjoyment were significantly lower, while arousal was significantly higher during study time, compared to leisure time. Furthermore, students with high chronic stress had significantly higher heart rate as well as significantly lower MSSD values, compared to students with low chronic stress. Together, these results indicate that both acute and chronic forms of stress may be associated with a decrease in parasympathetic activity. A study conducted by Lucini, Norbiato, Clerici and Pagani (2002) was aimed at investigating the influence of mild real-life stress on HRV among university students. Short-term HRV recordings were collected right before an exam as well as three months later during holidays. Results showed that normalized HF power was significantly lower, whereas heart rate, normalized LF power and LF/HF ratio were significantly higher before the exam, compared to the HRV measurements taken during the holidays. In line with findings by Myrtek and colleagues (1996), these results suggest a decrease in parasympathetic activity and a shift toward sympathetic dominance in response to stress in a student population. In sum, the results of several studies about real-life stress indicate that stress is primarily associated with a decrease in parasympathetic activity as well as a shift toward sympathetic dominance. Specifically, real-life stress was found to be associated with decreases in RMSSD and HF power as well as increases in heart rate, LF power and LF/HF ratio. With the exception of the controversial HRV index of LF power, these results are in line with findings about work stress and stress in the laboratory.

As discussed earlier, forms of perseverative cognition such as worrisome or ruminative thinking may substantially prolong stressful experiences (Brosschot et al., 2006). As a result, a number of studies have investigated the influence of perseverative cognition on indices of HRV. In this context, an important distinction has to be made between state worry and rumination, meaning the frequency and amount of worrisome and ruminative thoughts at a given point in time, and trait worry and rumination, meaning an individual's disposition to be a worrier or ruminator. The majority of studies investigating trait worry were unable to find any significant relationships with HRV indices (Brosschot et al., 2007; Davis, Montgomery and Wilson, 2002; Knepp & Friedman, 2008). With regard to state worry, however, there exists evidence that worrisome thinking is associated with decreases in HRV. For example, Brosschot and colleagues (2007) investigated the influence of daily worry, trait anxiety and trait worry on heart rate and heart rate variability by monitoring participants for one day including night-time. Trait anxiety and trait worry were assessed at the beginning of the study, whereas heart rate and heart rate variability were measured throughout the whole experiment. Furthermore, participants kept a diary reporting on worry periods and stressors approximately once per hour. Results showed that daily worry and stressors were associated with significantly higher heart rate and lower RMSSD, both during waking and sleeping, indicating that state worry may decrease parasympathetic activity. In a similar study, Pieper and colleagues (2007) investigated the cardiac effects of worry episodes and stressful events. For the duration of four days, HR and HRV were continuously monitored. Furthermore, an electronic diary prompted participants to report on worry episodes and stressful events approximately once per hour. In line with the findings by Brosschot and colleagues (2007), results showed that both stressful events and worry episodes were associated with significant increases in heart rate and significant decreases in

RMSSD. In sum, while daily worry episodes are associated with increases in heart rate and decreases in parasympathetic activity, trait worry appears to be poorly reflected by HRV indices. With regard to trait and state rumination, results are inconclusive. While there are several studies which found state or trait rumination to be associated with decreases in HRV (Gerteis & Schwerdtfeger, 2016; Key, Campbell, Bacon and Gerin, 2008; Verkuil, Brosschot, de Beurs, & Thayer, 2009b; Woody, McGeary, & Gibb, 2014), others were unable to find evidence for such a relationship (Ottaviani, Shapiro, Davydov, Goldstein, & Mills, 2009; Vahle-Hinz, Bamberg, Dettmers, Friedrich, & Keller, 2014). Overall, rumination appears to be less effective at predicting heart rate variability than worry (Verkuil et al., 2009b). Concluding this section, accumulating research shows that stress as measured by heart rate variability in the laboratory as well as in real life may negatively affect cardiovascular heath by increasing heart rate and lowering parasympathetic activity. In the light of these negative implications of stress for health and well-being, the development of appropriate stress-reducing interventions becomes of great importance. The next section reviews how exposure to nature could serve as a potential remedy to these detrimental effects of stress.

1.2 Nature

As indicated by several recent literature reviews, accumulating research suggests that nature is beneficial for health (Beute & de Kort, 2014; Berto, 2014; Bowler et al., 2010; Bratman et al., 2012; Haluza et al., 2014; Mantler & Logan, 2015; Velarde et al., 2007). Support for the positive link between nature and well-being comes from several cross-sectional studies. For example, in a study conducted among a large Dutch sample it was found that living in proximity of green space was positively related to perceived general health (Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006). A later study conducted by the same authors further revealed that the prevalence of depression, anxiety and several other diseases was lower for individuals living close to green space as well (Maas et al., 2009). Similar results were obtained by Nutsford, Pearson and Kingham (2013), who found that lower distance to and larger proportions of close-by green space were associated with lower frequencies of mood disorder treatments among urban residents. In addition, an fMRI study conducted by Lederbogen and colleagues (2011) discovered that living in urban versus more rural environments negatively influenced activity in brain regions associated with stress processing. More specifically, brain regions related to the processing of stress and negative affect showed higher activity during arithmetic and mental stress tasks for participants who were raised in urban environments, compared to participants with nature upbringing (Lederbogen et al., 2011). Given this evidence that living in greener areas is associated with better health outcomes, what are the mechanisms that could explain how natural environments promote health and well-being? There exist two major theories that provide explanations for the theoretical pathways underlying the relationship between nature and health: the Stress Reduction Theory (SRT; Ulrich, 1983) and the Attention Restoration Theory (ART; Kaplan, 1995).

The Stress Reduction Theory, also known as psycho-evolutionary theory, was developed by Ulrich (1983) and is based on the proposition that humans have evolved to react favorably to environments which are beneficial for survival and well-being. According to the theory, environments are capable of evoking affective reactions even before extensive cognitive processing of the features of the environment has taken place. The initial emotions elicited by an environment partially determine whether an environment is evaluated positively and whether it will encourage approach or avoidance behavior. Ulrich (1983) identified various properties that influence whether an environment may elicit initial preference or not. The proposed properties include complexity, the number of independent elements in a scene, depth, meaning the spaciousness of an environment, and structure, describing the grouping of elements in the environment as well as the presence of a focal point. Further properties described by Ulrich (1983) are ground surface texture, meaning the evenness or roughness of the ground, threat, referring to the presence of tension or danger, and deflected vistas, describing the ability of an environment to suggest that there is more to be explored. In addition, the presence of water may also lead to positive outcomes. Importantly, the theory suggests that nature environments are rich in properties that promote favorable evaluation. Consequently, spending time in nature is thought to promote a reduction in arousal and an elicitation of positive emotions, thereby counteracting negative affective states and stress (Ulrich, 1983).

The Attention Restoration Theory by Kaplan (1995) posits that nature exerts its beneficial effects on well-being by promoting recovery from directed attention fatigue. According to the theory, cognitively demanding tasks require substantial amounts of mental effort as well as voluntary control to inhibit distraction from intrusive stimuli competing for attention. Importantly, sustaining directed attention for a prolonged time may eventually lead to directed attention fatigue, a state which is characterized by irritability, ineffectiveness and inability to focus (Beute & de Kort, 2014; Kaplan, 1995). The theory posits that, in order to restore directed attention, it is necessary to engage in a different, involuntary and effortless type of attention which can be found in environments which are inherently fascinating (Kaplan, 1995). In order for an environment to be able to promote restoration, it must furthermore provide the feeling of being away, offer a rich and extensive experience, and be compatible with one's personal needs (Kaplan, 199). According to Kaplan (1995), nature environments are particularly well suited for restoring directed attention, as they provide access to an abundance of so called "soft" fascinations such as clouds, sunsets or natural patterns. In addition, nature environments such as parks, forests and other recreative places are rich in information, highly compatible and provide an excellent opportunity for "getting away". Overall, while different in terms of their proposed underlying mechanisms, both the Stress Reduction Theory by Ulrich (1983) and the

Attention Restoration Theory by Kaplan (1995) provide plausible explanations for the restorative effects of nature.

1.2.1 Nature and stress reduction

In the light of the positive effects of green neighborhoods on well-being and the theoretical frameworks provided by Ulrich (1983) and Kaplan (1995), it is reasonable to think that nature is capable of mitigating the negative effects of stress as well. A sizable body of literature provides support for this proposition. For instance, a frequently cited study which demonstrates the health promoting effects of nature is Ulrich's (1984) seminal research on surgical patients. In this study, the influence of viewing real nature on parameters such as length of hospital stay, strength of analgesics required and number of complications experienced was investigated in patients following surgery. It was found that patients facing a window with a nature view had significantly shorter hospital stays and consumed lower doses of painkillers, in comparison to patients facing a window with view on a brick wall (Ulrich, 1984). Lee, Park, Tsunetsugu, Kagawa and Miyazaki (2009) conducted a study in which they compared the effects of viewing real forest landscapes with viewing urban environments among healthy individuals over a period of three days. Results showed that participants had significantly lower salivary cortisol concentrations, diastolic blood pressure and pulse rate after viewing forest landscapes compared to urban landscapes. Furthermore, participants felt significantly more comfortable, soothed and refreshed when viewing the forest environments. In another interesting study conducted by Tyrväinen et al., (2014), the psychological and physiological effects of visiting three different types of environments with varying degrees of nature (city center, park and forest) were investigated. While there were no significant differences with regard to the physiological measurements, it was found that restorative experience was overall significantly higher for the park and the forest environment, in comparison to the city center. In addition, ratings for subjective vitality and positive mood were significantly higher for the park and the forest environment as well. Several studies furthermore investigated the effects of walking in nature versus urban environments. Hartig, Evans, Jamner, Davis and Gärling (2003) investigated the effects of viewing real nature through a window and subsequently walking in nature versus not viewing nature followed by walking in an urban area on measures of positive affect, attentiveness, fear arousal, happiness, sadness, anger and blood pressure. Subjects experienced significantly steeper declines in diastolic blood pressure while viewing nature and had significantly stronger decreases in systolic blood pressure 30 minutes into the walk in nature, in comparison to the participants in the urban condition. In addition, walking in the nature environment was associated with improvements in positive affect and anger, compared to participants in the urban condition in which measures deteriorated. Performance on an attentional task furthermore improved slightly during the nature walk but not the walk in the urban area. Several other studies have found support for the notion that nature is beneficial in terms of mood and cognitive restoration (e.g., Berman, Jonides, & Kaplan, 2008; van den Berg, Koole, & van der Wulp, 2003; Bratman, Daily, Levy, & Gross, 2015a; Geniole et al., 2016; Roe & Aspinall, 2011; Teas, Hurley, Ghumare, & Ogoussan, 2007). Moreover, there is evidence that exposure to nature can reduce rumination as well. Bratman, Hamilton, Hahn, Daily and Gross (2015b) investigated the influence of nature walks versus urban walks on rumination as measured using self-reports and neuroimaging techniques. Results showed that self-reported rumination was significantly lower after walking in nature for 90 minutes, compared to measures taken before the walk. In addition, there was a significant decrease in blood flow to brain regions associated with rumination after walking, compared to before. No such differences were observed for participants walking in an urban environment. Overall, results from previous research suggest that exposure to real nature is beneficial in terms of a variety of outcome variables, including stress, mood, rumination and several physiological measures.

In addition, numerous studies have shown that images or videos of nature are capable of reducing psychological and physiological stress as well. For example, in a study conducted by Ulrich and colleagues (1991), it was found that recovery after exposure to a stressful movie was faster for individuals who viewed nature videotapes following the stressor, in comparison to watching urban videotapes (Ulrich et al., 1991). More specifically, participants in the nature condition experienced significantly lower anger and fear as well as higher positive affect, compared to participants in the urban condition. A particularly interesting finding furthermore was that heart rate remained low throughout the entire videotape for participants in the nature condition, whereas heart rate continued to accelerate for participants watching the urban video. According to the authors, this pattern indicates that participants in the nature condition were more focused and experienced higher parasympathetic activity than participants exposed to the urban video (Ulrich et al., 1991). Laumann, Gärling and Stormark (2003) conducted a study in which participants were asked to either watch a nature or an urban video after a series of proofreading tasks. As in the study by Ulrich and colleagues (1991), heart rate during the video was significantly lower compared to baseline measurements for participants in the nature condition, but not for participants in the urban group (Laumann et al., 2003). In line with these results, van den Berg and colleagues (2015) furthermore found that watching nature slides following a stress induction task was associated with significantly stronger increases in parasympathetic activity as measured by respiratory sinus arrhythmia and pre-ejection period, compared to watching slides of built scenes. The results further revealed that participants perceived the nature slides as more restorative than the urban slides (van den Berg et al., 2015). In a different study, Berto (2005) investigated the restorative potential of slides either depicting nature environments, urban areas or geometrical patterns. Participants first performed an attention task and then watched one of the three aforementioned slideshow types, followed by a second attention task. Results showed that attention significantly improved after watching the slideshows compared to baselines measures for participants in the nature condition but not for participants in any of the other two conditions (Berto, 2005). De Kort and colleagues (2006) investigated the importance of immersion in a digital nature environment with regard to restoration from stress. In their study, participants were first exposed to a stressful mental arithmetic task and then asked to watch a restorative nature movie presented either on a large screen (high immersion) or a small screen (low immersion). Results showed that while immersion had no influence on self-reported affect measures, participants in the high immersion condition demonstrated faster recovery from stress with regard to heart rate and skin conductance level than participants in the low immersion condition (de Kort et al., 2006). For the majority of the studies reviewed, the manipulation consisted of either picture or video material. However, Valtchanov and colleagues (2010) conducted a study in which they investigated the influence of a virtual nature environment on outcome measures including heart rate, skin-conductance, cognitive fatigue and affect, in comparison to a virtual control environment consisting of abstract paintings. Results showed that exposure to the nature virtual environment led to significant decreases in skin-conductance level as well as increases in positive affect – outcomes which were not observed for the control condition (Valtchanov et al., 2010). In sum, a wide range of studies provide support for the restorative properties of both real and mediated nature. An important question to be answered is then whether the positive effects of nature are reflected in heart rate variability indices as well. As discussed in the next section, several studies show that this may indeed be the case.

1.2.2 Nature and heart rate variability

Several studies about the influence of both real and mediated nature on HRV indices have been conducted. Studies investigating the effect of real nature typically involve walking or sitting in natural environments for a predefined amount of time. For example, Song and colleagues (2014) investigated both the psychological and physiological effects of walks in urban parks versus walks in city areas. They found that HF power was significantly higher, whereas heart rate and LF/HF ratio were significantly lower during walks in the urban park, compared to walks in the city. In support of these results, psychological assessments showed that participants felt more comfortable, natural, relaxed and vigorous after walking in the urban park, while fatigue and anxiety were lower after a walk in the urban park as well, compared to walks in the city area. In a similar study, Qin, Zhou, Sun, Leng and Lian (2013) investigated the influence of green spaces on environmental satisfaction and physiological indices. Participants were asked to spend half an hour in one of the following five randomly assigned types of green spaces located in a botanical garden: lawn, arbor forest, bamboo grove, cherry blossom tree show or tulip show. In addition, there was a control condition with no vegetation. Results showed that, compared to the environment without vegetation, green spaces were associated with significantly higher environmental satisfaction as well as significantly lower LF/HF ratio. Furthermore, there was a significant negative correlation between LF/HF ratio and environmental satisfaction, indicating that low values of environmental satisfaction were associated with high LF/HF ratio values. Gladwell, Kuoppa, Tarvainen and Rogerson (2016) investigated the influence of lunchtime walks in nature on night-time heart rate variability. After lunchtime walks of approximately 17 minutes in green or built environments, participants were asked to track their heart rate variability the following night. They found that SDNN and RMSSD during sleep were significantly higher following walks in green environments, compared to walks in built environments, indicating greater parasympathetic activity in response to green exercise. However, not all studies were able to find positive influences of natural environments on heart rate variability. Brown, Barton, Pretty and Gladwell (2014) for example investigated the influence of lunchtime walks in nature versus built environments in an eight-week-long randomized control trial. Results showed that neither HR nor HRV were significantly different between groups. Similarly, Gidlow and colleagues (2016) compared the effects of walking in natural versus urban environments on psychological and physiological measures. While restorative experience and cognitive function significantly improved in natural compared to urban environments, no significant differences were found for self-reported mood and heart rate variability.

In addition to the investigations about physiological effects of real nature environments and green spaces, several studies have explored the influence of mediated nature in the form of photos, videos or artificial environments. For example, Gladwell and colleagues (2012) compared the effects of viewing nature slideshows with the effect of watching urban slideshows on autonomic activity. It was found that SDNN, RMSSD and HF power were significantly higher while watching nature slideshows, compared to viewing urban slideshows. This result indicates that, in comparison to viewing built environments, viewing nature is associated with higher parasympathetic modulation. No significant differences were observed for heart rate or blood pressure. In a similar study, Brown, Barton and Gladwell (2013) researched whether viewing nature slideshows would positively affect physiological recovery from a mental stressor. It was found that viewing a nature slideshow prior to the exposure of a mental stressor was associated with a significant increase in RMSSD relative to baseline measurements during recovery from the stressor. Watching built environment slides, however, was associated with a decrease in RMSSD below baseline during recovery from the mental stressor. From a psychological perspective, self-esteem significantly improved from baseline to post-stress in the nature condition, while there was a decrease of self-esteem in the built condition. Beute and de Kort (2014) conducted two laboratory studies in which they investigated the influence of nature exposure on self-regulation, mood and physiological measures including heart rate and heart rate variability. Participants were first asked to complete one (study one) or two (study two) tasks which were designed to require either high (depleting condition) or low (non-depleting condition) amounts of self-control. Following this ego-depletion manipulation, participants were exposed to slideshows of either nature or urban photos. Finally, participants were asked to complete one (study two) or two (study one) performance tasks. Mood was assessed at discrete moments whereas physiological measures were monitored continuously. Results showed that heart rate variability as measured by the LF/HF ratio was improved during one of the performance tasks of study one as well as while watching the slideshows in study two. In addition, their second study found that mood improved more after viewing nature slideshows, compared to viewing urban slideshows, irrespective of whether participants were in the depleting or non-depleting condition. These outcomes provide further support that exposure to mediated nature may be beneficial in terms of heart rate variability and mood. In addition, the fact that the beneficial effects of nature were present irrespective of the depletion condition indicates that nature might have buffering effects with regard to stress (Beute & de Kort, 2014). In a study conducted by Annerstedt and colleagues (2013), participants first participated in a stress task and were then exposed to either a virtual forest environment with sound, a virtual forest environment without sound or a control environment without vegetation during recovery from the stressor. Heat rate, LF power, normalized LF power and LF/HF ratio significantly increased, whereas normalized HF power significantly decreased during the stress task, compared to baseline measures. Surprisingly, all of these measures remained stable, or in case of LF power increased even further, during recovery from the stressor, independent of the type of virtual environment participants were exposed to. However, throughout all stages of the experiment and particularly during recovery, HF power was significantly higher in the group exposed to the forest environment with sound, as compared to the other two groups. Overall, the results of the study conducted by Annerstedt and colleagues (2013) indicate that virtual nature environments have the potential to improve parasympathetic activity following a stressor and that the presence of sound might have an important influence on whether stress recovery in nature environments is successful. Concluding this section, previous studies provide convergent evidence for the restorative properties of both real and mediated nature with regard to a variety of psychological and physiological indices, including stress, worry, rumination, heart rate and heart rate variability. However, it is important to note that studies vary greatly in terms of protocols, measures and manipulations employed. Consequently, there is a considerable degree of variability between studies with regard to the success of manipulations and the robustness of results.

1.3 Current research

As discussed in the beginning of this review, technological advancements have paved the way for novel approaches to provide healthcare services and interventions. Importantly, technology has not only benefited the area of healthcare, it also has made valuable contributions to the discipline of psychology. Topics such as stress, mood or perseverative cognition describe complex phenomena that exert their influence on well-being on a day-to-day basis. While laboratory studies provide the advantage of full experimental control, studying stress and its concomitants exclusively in the laboratory may lead to conclusions of uncertain ecological and external validity (Beute et al., 2016; Cacioppo & Gardner, 1999). Employing modern technology such as mobile devices or sensors for the purpose of studying psychophysiological processes in everyday life may thus provide valuable insights about the effectiveness of nature-centered mHealth interventions (Beute et al., 2016). In psychology, Ecological Momentary Assessment (EMA), also referred to as Experience Sampling Method (ESM; Csikszentmihalyi, Larson, & Prescott, 1977), describes a data collection technique in which individuals repetitively rate their current state over time in the context of their own personal environment (Beute et al., 2016; Shiffman, Stone, & Hufford, 2008). EMA has several advantages over laboratory studies. First, due to the fact that EMA takes place outside of the laboratory in participants' personal environments, results have better ecological and external validity (Beute et al., 2016; Scollon, Prieto, & Diener, 2009; Shiffman et al., 2008). Second, retrospective bias is expected to be lower, as participants are rating their feelings at the present moment as opposed to in the past (Beute et al., 2016; Scollon et al., 2009; Shiffman et al., 2008). Furthermore, given that the repeated assessment of momentary states is at the core of this technique, EMA facilitates the assessment of not only between- but also within-participant changes in feelings over time (Beute et al., 2016; Scollon et al., 2009; Shiffman et al., 2008). Naturally, the very advantages of EMA also constitute its major limitations. Particularly, since the assessment takes place in participants' own environments, it is impossible to control for environmental factors to the same degree as in the case of laboratory studies (Beute et al., 2016; Shiffman et al., 2008). Furthermore, reactivity may be an issue, as continuously measuring specific phenomena may alter participants' perspective on the variables of interest (Beute et al., 2016; Scollon et al., 2009; Shiffman et al., 2008). For example, by measuring participants' momentary levels of stress over a prolonged period of time, participants may become more aware of stressful encounters. Finally, another challenge of EMA is lack of compliance. Asking participants to answer questionnaires repeatedly over the course of one or multiple days places a substantive burden on participants' lives (Beute et al., 2016; Scollon et al., 2009; Shiffman et al., 2008). As a result, participants may be inclined to skip questionnaires or drop out entirely, thereby affecting data quality (Beute et al., 2016; Shiffman et al., 2008). However, despite these drawbacks, EMA is a valuable technique for studying processes in everyday life. Moreover, it is possible to combine EMA with experimental treatments with the aim to for example evaluate healthcare interventions, a technique which is described as Ecological Momentary Interventions (EMI; Beute et al., 2016; Heron & Smyth, 2010).

The purpose of the current study was to investigate the influence of a health-promoting nature intervention on a variety of stress-related psychological and physiological outcome variables through the means of an ecological momentary intervention study. More specifically, participants were asked to rate their momentary affective state as well as their current level of stress, worry and rumination multiple times a day over a period of six days. In addition, participants were asked to watch nature slideshows depicting natural scenes up to three times a day, depending on their current level of stress. Importantly, the restorative potential of nature slideshows was compared to watching slideshows of urban scenes or not watching any slideshows at all. Thus, participants were either assigned to a nature slideshow, an urban slideshow or a control condition. Moreover, heart rate and heart rate variability were assessed continuously over the entire experiment. Based on previous research (e.g., van den Berg et al., 2015; Berman et al., 2008; Berto, 2005; Beute & de Kort, 2014; Bowler et al., 2010; Bratman et al., 2012; Mantler & Logan, 2015; Ulrich et al., 1991; Velarde et al., 2007), it was hypothesized that participants in the nature slideshow condition would experience lower levels of stress in general, compared to participants in the urban slideshow and the control condition:

***Hypothesis 1**:* Participants in the nature slideshow condition will experience lower levels of stress than participants in the urban slideshow or the control condition.

Given the favorable effects of nature exposure on mood (e.g., van den Berg et al., 2003; Berman et al., 2008; Beute & de Kort, 2014; Bratman et al., 2015a; Geniole et al., 2016; Hartig et al., 2003; Roe & Aspinall, 2011; Teas et al., 2007; Tyrväinen et al., 2014; Ulrich et al., 1991; Valtchanov et al., 2010), it was further expected that participants in the nature slideshow condition would generally experience more positive mood states, compared to participants in the other two conditions.

***Hypothesis 2**:* Participants in the nature slideshow condition will experience better mood than participants in the urban slideshow or the control condition.

In addition, as previous research has shown that contact with nature is capable of decreasing rumination and anxiety (e.g., Bratman et al., 2015a; Bratman et al., 2015b; Teas et al., 2007; Ulrich et al., 1991), it was hypothesized that worry and ruminative thoughts would be lower for participants in the nature slideshow condition as well, compared to participants in either of the other two conditions.

Hypothesis 3: Participants in the nature slideshow condition will experience less worry and rumination than participants in the urban slideshow or the control condition.

With regard to the physiological measures collected, it was expected that participants in the nature condition would display lower heart rate and higher parasympathetic activity as measured by RMSSD during and right after watching the nature slideshow as compared to before watching the slideshow, an effect which was observed by several studies investigating the influence of nature exposure on heart rate and heart rate variability (e.g., Brown et al., 2013; Gladwell et al., 2012; Gladwell et al., 2016; Laumann et al., 2003; Ulrich et al., 1991; van den Berg et al., 2015). No such differences were expected for participants in the urban slideshow condition.

> ***Hypothesis 4a**:* Participants in the nature slideshow condition will demonstrate lower heart rate during and after watching the slideshow, compared to before watching the slideshow.

> ***Hypothesis 4b**:* Participants in the nature slideshow condition will demonstrate higher RMSSD during and after watching the slideshow, compared to before watching the slideshow.

For participants in the nature slideshow condition, it was further expected that total variability as measured by SDNN would be higher during and after watching the nature slideshow, compared to before-slideshow measures (e.g., Gladwell et al., 2012; Gladwell et al., 2016). For participants in the urban slideshow condition, no such differences were expected.

> ***Hypothesis 4c**:* Participants in the nature slideshow condition will demonstrate higher SDNN during and after watching the slideshow, compared to before watching the slideshow.

In addition, several studies have found stress to be related to higher heart rate (e.g., Lackschewitz et al., 2008; Lucini et al., 2002; Myrtek et al., 1996; Sloan et al., 1994; Taelman et al., 2009; Visnovcova et al., 2014) and lower heart rate variability, particularly parasympathetic activity (e.g., Hintsanen et al., 2007; Lackschewitz et al., 2008; Myrtek et al., 1996; Visnovcova et al., 2014; Vrijkotte et al., 2000; Weber et al., 2010). It was thus hypothesized that the momentary levels of stress would be a positive predictor of heart rate and a negative predictor of heart rate variability as measured by both SDNN and RMSSD at any given point in time, for all participants of this study.

> ***Hypothesis 5a**:* Higher levels of stress will be associated with higher heart rate for all participants at any point in time.

> ***Hypothesis 5b**:* Higher levels of stress will be associated with lower levels of heart rate variability as measured by SDNN and RMSSD for all participants at any point in time.

2 Method

2.1 Design

The experiment was designed as an ecological momentary intervention (EMI) study with one between-subject factor called ‘intervention type’, representing the independent variable. Participants were randomly assigned to one of the following three intervention types: control, nature slideshows or urban slideshows. The duration of the actual experiment was six days. In the course of these six days, daily psychological and physiological measurements were obtained with the help of a tablet computer and a heart rate monitor. Participants who were part of either the nature or the urban slideshow treatment condition were furthermore asked to watch between one and three slideshows per day. Prior to the start to the experiment, all participants were invited to a 45-minute-long introduction meeting during which participants gave their written consent, filled in a pre-experiment questionnaire, and received all instructions necessary for their participation. After the completion of the experiment, participants were invited to a 30-minutes-long conclusion meeting during which they filled in a post-experiment questionnaire, participated in a short interview, and were thoroughly debriefed. Importantly, participants did not all participate in parallel and starting dates therefore varied. Thus, while one participant might have started on a Tuesday, another participant might have chosen to start on a Friday. Since participants were invited to an introduction meeting the day before the start of the main EMI experiment, the earliest day of the week on which participants were able to start with the main experiment was a Tuesday. Common to all participants was thus that the experiment took place over a timespan of six days, of which two days were part of the weekend. Figure A.1 in Appendix A provides a schematic overview of the structure of the experiment.

2.1.1 Dependent variables

The main dependent variables which were assessed using the heart rate monitor and the EMA questionnaires on the tablet included stress, mood, worry, rumination, mind-wandering, self-control, well-being and the physiological measures of heart rate and heart rate variability. The EMA questionnaires were distributed randomly between 9:00 and 21:00 hours with a minimum time distance of one and a maximum distance of two hours between questionnaire notifications (Figure 2.2). In addition to these daytime questionnaires, participants were further instructed to answer one daily morning questionnaire before 12:00 hours assessing sleep quality and one daily evening questionnaire after 21:00 hours assessing satisfaction with the current day (Figure 2.2). Besides the questionnaires answered on the tablet, participants were asked twice to fill in questionnaires measuring overall stress, depression, and health – once during the introduction meeting and once during the conclusion meeting. In comparison to the EMA measures which were analyzed using the multilevel modelling (MLM) technique, these pre-post measures were treated as traditional within-subject dependent variables and therefore analyzed using a mixed factorial analysis of variance (ANOVA).

2.1.2 Experimental manipulation

Participants were randomly assigned to either a control condition or one of two treatment conditions (nature slideshows versus urban slideshows). Participants in the control condition did not receive any intervention and were simply instructed to complete the questionnaires on the tablet and wear the heart rate monitor during the six days of the actual experiment. Participants in the treatment conditions, on the other hand, were also instructed to watch slideshow interventions on the tablet, in addition to filling in the questionnaires and wearing the heart rate monitor. The interventions consisted of three-minute slideshows of photos of either nature or urban environments, depending on the condition assigned. In total, there were 12 different slideshows for each condition. The slideshows were shown in a rotating fashion, meaning that if a participant was instructed to watch more than 12 slideshows during the entire experiment, the tablet would start anew with the first slideshow in the pool. Each individual slideshow was composed of 18 photos, each of which was shown for the duration of 10 seconds. In total, there were 108 different photos for each condition. Since there were 12 different slideshows per condition and 18 photos per slideshow, each photo was used twice. Examples of photos used for the slideshows are shown in Figure 2.1. The photos were selected such that there was always semi-overcast or sunny weather and there were no close-ups of people. The photos were matched on composition by eye and lightness was controlled for by calculating lightness in ImageJ (http://imagej.net), an open source software for scientific image analysis (Abràmoff, Magalhães, & Ram, 2004). To give the impression of slow movement, a motion effect zooming in or out of the photos was applied to the slideshows. At the beginning of each slideshow, participants were furthermore asked to imagine being at the location currently displayed.

Nature environments — Urban environments

Figure 2.1 Examples of photos used for the slideshow manipulations.

Participants in the treatment conditions were instructed to watch one slideshow each evening after nine o'clock, prior to filling in the evening questionnaire. This fixed slideshow intervention was introduced to ensure that all participants in the treatment conditions had a stable baseline of at least one slideshow per day. In addition to these fixed interventions, participants received tailored slideshow recommendations, depending on their current level of stress. Specifically, participants had two additional opportunities to be recommended a slideshow intervention: once within the first four and a second time during the second four of the totally eight daily questionnaires. In both cases, the algorithm was implemented such that participants were recommended watching a slideshow the first time their stress rating was four or higher on a seven-point Likert scale. The threshold of four was determined based on a previous study conducted at the department for Human-Technology Interaction at Eindhoven University of Technology, which has shown that the average stress rating given on a seven-point Likert scale was around three. Once participants were given a slideshow recommendation, no additional recommendations were given within the current batch of four questionnaires, even if subsequent stress ratings of the current batch were above four. In total, participants in the treatment conditions therefore watched between a minimum of one and a maximum of three slideshows per day, depending on their stress levels. Figure 2.2 shows a schematic overview of the daily tasks.

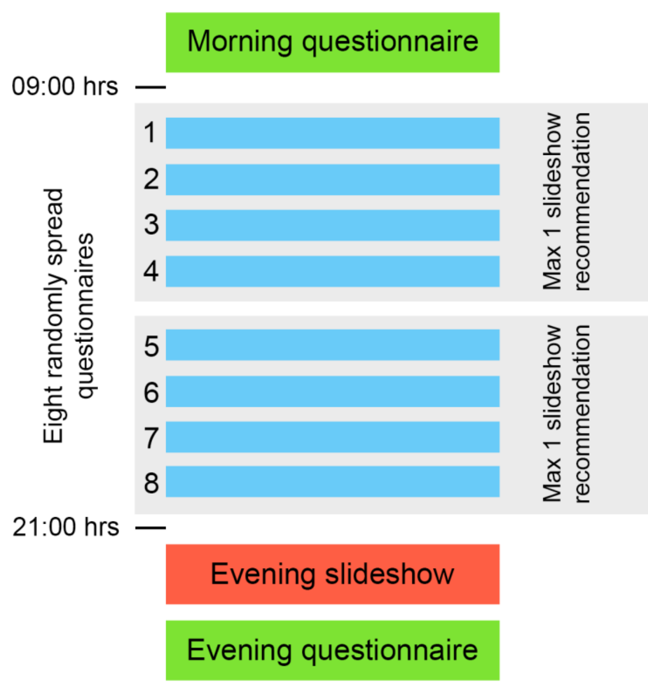

Figure 2.2 Schematic overview of the daily tasks of the experiment.

2.2 Participants

A total of 46 Dutch-speaking individuals agreed to participate in this study. Participants were recruited via the participant database maintained by the J.F. Schouten School for User System Interaction Research (http://ppdb.tm.tue.nl) as well as through distributing flyers on the Eindhoven University of Technology campus. The experiment was advertised as a study on the application of modern technology for measuring health and well-being. Participants were therefore naïve to the true purpose of the experiment. Interested individuals were asked to complete a screening questionnaire prior to being invited to the actual experiment, in order to ensure that only individuals with above average stress or depression levels would participate. The reasoning behind this selection criterion was that individuals with high stress or depression levels would benefit the most from a stress-reducing intervention. Furthermore, individuals with heart diseases or heavy smoking or drinking behavior were excluded as well, in order to prevent unexpected interactions with the heart rate measurements. As shown in Figure A.1 in Appendix A, a total of 159 individuals completed the screening questionnaire. Of these, 68 individuals were eligible for the experiment, whereas 91 individuals either did not satisfy the stress or depression thresholds required for the experiment or had to be excluded due to medical conditions or their above average alcohol or nicotine consumption. Of the eligible individuals, 46 eventually decided to participate, while the remaining 22 of the suitable candidates declined or did not react to the invitation. Participants were compensated €30 upon completion of the experiment. The proposal for the experiment was approved by the Human-Technology Interaction Daily Management Board and the Ethical Review Board of the Eindhoven University of Technology.

Of the 46 individuals who agreed to participate, four had to be excluded due to non-compliance (Figure A.1 in Appendix A). Excluding these participants, the final sample had an age range of 18 to 48 years (M = 24.024, SD = 7.093) and was assigned to the three intervention groups as follows: control (N = 14, 8 women), nature slideshows (N = 14, 8 women) and urban slideshows (N = 14, 13 women; Figure A.1 in Appendix A). As discussed in more detail under Section 2.4, a variety of variables regarding stress, depression and personality were assessed in the course of the experiment. Table 2.1 provides an overview of the demographic properties of the final sample in comparison to reference values from previous studies. As expected, both the stress (M = 19.524, SD = 5.662) and depression (M = 12.634, SD = 9.818) variables obtained during the screening stage of the experiment were substantially higher than reference values for depression by Roelofs et al. (2013) and stress norms for academics with an advanced degree by Cohen and Janicki-Deverts (2012). Furthermore, dispositional worry (M = 55.214, SD = 12.900) was considerably higher, whereas trait optimism was lower (M = 12.500, SD = 4.008) in the current sample, compared to reference values for worry by van der Heiden, Muris, Bos, van der Molen and Oostra (2009) and normative values for optimism by Scheier, Carver and Bridges (1994). The results for the remaining personality variables were comparable the reference data for individuals aged 24 by Srivastava, John, Gosling and Potter (2003).

Table 2.1 Demographic properties of the final sample of the experiment.

	Current sample				Reference sample		
	N	*M*	*SD*		*N*	*M*	*SD*
BDI-II Screening	41	12.63	9.82	Roelofs et al. (2013)	7500	10.60	10.90
PSS-10 Screening	42	19.52	5.66	Cohen et al. (2012), academics	231	14.65	7.14
PSS-10 Pre	42	16.74	7.44	Cohen et al. (2012), academics	231	14.65	7.14
SCL-90-R DEP Pre	42	30.69	10.39	Arrindell & Ettema (1986)	2367	21.58	7.56
SCL-90-R SOM Pre	42	19.74	4.73	Arrindell & Ettema (1986)	2367	16.68	5.34
PSWQ	42	55.21	12.90	van der Heiden et al. (2009)	842	42.40	11.80
LOT-R	42	12.50	4.01	Scheier et al. (1994)	2055	14.33	4.28
BFI Extraversion	42	3.22	0.81	Srivastava et al. (2003), age=24	4494	3.28	0.89
BFI Neuroticism	42	3.31	0.81	Srivastava et al. (2003), age=24	4494	3.29	0.82
BFI Openness	42	3.63	0.66	Srivastava et al. (2003), age=24	4494	3.95	0.65
BFI Conscientious	42	3.35	0.53	Srivastava et al. (2003), age=24	4494	3.55	0.71
BFI Agreeableness	42	3.67	0.53	Srivastava et al. (2003), age=24	4494	3.67	0.70

Note. BDI-II = Beck Depression Inventory II, PSS-10 = Perceived Stress Scale (10-item version), SCL-90-R DEP = Symptom Checklist 90 Revised – Depression, SCL-90-R SOM = Symptom Checklist 90 Revised – Somatic Complaints, PSWQ = Penn State Worry Questionnaire, LOT-R = Life Orientation Test Revised, BFI = Big Five Inventory

2.3 Apparatus and materials

In the course of the six-day-long experiment, the following devices and applications were used:

Samsung Galaxy Tab 4: The tablet used for this experiment was the 7" version of the Samsung Galaxy Tab 4. This tablet has a screen resolution of 1280 x 800 pixels and runs Android 4.4 (KitKat). The tablet was chosen due to its compact and lightweight size and because of its support of Bluetooth LE, which was required in order to be able to connect to the heart rate monitor. Prior to giving the tablets to the participants, the brightness of the screens was set to medium and the volume to maximum.

Polar H7: The heart rate monitor used for this experiment was the Polar H7, a Bluetooth heart rate sensor chest strap manufactured by Polar Electric. The Polar H7 is a heart rate monitor which is worn around the chest and marketed as an easy-to-use fitness device. Participants were responsible for putting on the device each morning as instructed during the introduction meeting. The Polar H7 was chosen because it measures heart rate both in form of beats per minute (BPM) and R-R intervals and because it was found to be a reliable device during testing. Furthermore, the device has a relatively long battery life and is frequently used in research (e.g., Costigan et al., 2015; Lukach et al., 2016; Sonne & Jensen, 2014). Via Bluetooth, the Polar H7 chest strap sends approximately one data package to its connected devices per second. This package contains one value representing the beats per minute since the previous package and, depending on the current heart rate, one or several values representing R-R intervals measured in the unit of 1/1024 seconds. Figure 2.3 shows an example of a data package sent by the Polar H7.

BPM	R-R int.	R-R int.
89	697	685

Figure 2.3 Example of a Polar H7 data package consisting of one value representing the beats per minute (BPM) and two values representing R-R intervals. R-R intervals are provided in the unit of 1/1024 seconds.

Applications: Two separate Android applications were developed, one application for answering the questionnaires and watching the slideshows and another application for establishing a connection with the Polar H7 heart rate monitor. The Polar H7 was connected to the tablet via Bluetooth LE, transmitting all heart rate measurements immediately to the tablet where the data was stored. The questionnaire application was designed such that participants could easily access the different questionnaires by clicking on the respective buttons located on the main screen (see Figure B.1). Furthermore, participants in the treatment conditions also had a button leading to the slideshow, which was hidden for participants in the control condition (Figure B.1). In Section B.3 of Appendix B, screenshots of all screens of the questionnaire application are provided. The heart rate tracking application consisted of a simple button for starting or stopping the tracking of data (see Figure B.2). The application was purposely designed such that participants were unable to see their own heart rate, to prevent any influence on behavior or heart rate from simply watching heart rate measurements.

2.4 Questionnaires

A wide range of questionnaires was administered, before and after as well as during the actual EMI experiment. The questionnaires administered before and after the experiment were conducted on regular computers whereas the questionnaires during the experiment were filled in on a tablet. Table 2.2 provides an overview of all questionnaires administered in the course of the experiment.

Table 2.2 Overview of all questionnaires administered during the course of the experiment.

Screening	Pre-experiment	Experiment	Post-experiment
PSS-10	PSS-10	KSD	PSS-10
BDI-II	SCL-90-R DEP	EMA, measuring:	SCL-90-R DEP
FSQ	SCL-90-R SOM	• Stress	SCL-90-R SOM
Smoking	BFI	• Mood	ACS-90
Demographics	PSWQ	• Worry	
	LOT-R	• Rumination	
	MCTQ	• Mind-wandering	
	Demographics	• Self-control	
		• Well-being	
		• Satisfaction	

2.4.1 Screening measures

Participants were required to fill in a screening questionnaire prior to being invited to the experiment, in order to ensure that only individuals with above average stress or depression levels would participate. Furthermore, individuals were excluded if they had a heart disease or if their answers indicated extreme smoking or drinking behaviors. The following questionnaires were administered in order to ensure these requirements:

Perceived Stress Scale (PSS-10): The Perceived Stress Scale (PSS-10; Cohen et al., 1983) is a popular measure designed to assess the degree to which aspects in one's life are regarded as stressful. The PSS-10 consists of ten statements, each of which is rated on a five-point Likert scale ranging from 0 (never encountered these stressful experiences) to 4 (very often encountered these stressful experiences). Total scores range from 0 to 40, with higher scores reflecting higher levels of perceived stress. The PSS-10 was found to have acceptable psychometric properties (Lee, 2012; Roberti et al., 2006). In the current study, Cronbach's alpha during the screening was 0.842, indicating good internal consistency. To qualify for this study, individuals were required to have a score of 14 or higher on the PSS-10, unless they satisfied the selection criterion for the Beck Depression Inventory (BDI-II) described below. The threshold for the PSS-10 was determined based on the results of a study conducted on a large sample in the United States which found that mean scores on the PSS-10 among individuals with an advanced degree were roughly around 14 (N = 231, M = 14.65, SD = 7.14 in Cohen & Janicki-Deverts, 2012).

Beck Depression Inventory (BDI-II): The Beck Depression Inventory (BDI-II; Beck, Steer, Ball, & Ranieri, 1996; Dutch version: van der Does, 2002) is a widely used instrument for measuring the severity of depressive symptoms. The scale consists of 21 items with each item being dedicated to a particular symptom and rated on a scale ranging from 0 (least) to 3 (most). Participants were asked to rate their depressive symptoms based on their feelings during the past two weeks. Total scores can range from 0 to 63, with higher scores indicating more severe depressive symptoms. The BDI-II was found to be a psychometrically sound instrument (Osman et al., 1997; Segal, Coolidge, Cahill, & O'Riley; 2008). In the current study, Cronbach's alpha was 0.923, indicating excellent internal consistency. To be selected for this study, individuals were required to have a score of 14 or higher on the Beck Depression Inventory (BDI-II), unless they satisfied the Perceived Stress Scale requirements described above. The threshold for the BDI-II was selected based on the official guideline which states that scores below 14 are considered minimal (Beck et al., 1996).

Five-Shot Questionnaire (FSQ): The Five-Shot Questionnaire (FSQ; Seppä, Lepistö, & Sillanaukee, 1998) is a frequently used screening instrument for detecting alcohol abuse. The questionnaire consists of five items and was recommended for screening of alcohol problems in general practice or emergency departments by several studies (Aertgeerts, Buntinx, Ansoms, & Fevery, 2001; Rick & Vanheule, 2007). Total scores range from 0 to 7, with higher scores indicting higher severity of alcohol abuse. For this study, an individual's drinking behavior was considered heavy if they reached a score of 4.5 or higher on the Five-Shot Questionnaire. Seppä and colleagues (1998) suggest a cut-off score of ≥ 2.5 or ≥ 3 to determine heavy drinking. However, due to the sample of this study consisting of comparably frequent consumers of alcohol (N = 41, M = 2.073, SD = 1.186), the cut-off score had to be increased.

Smoking: There is no set definition of what constitutes a heavy smoker. A short literature search revealed that a frequent threshold used for determining a heavy smoker is 20 or more cigarettes per day (e.g., Gruica, Wang, Lang, & Buser, 2004; Hippisley-Cox & Coupland, 2012; Wakabayashi, 2008). This threshold was confirmed by Statistics Netherlands (CBS), which defines a heavy smoker as someone who smokes 20 or more cigarettes daily (Centraal Bureau voor de Statistiek [CBS], 2014). For this study, individuals were therefore excluded if they were smoking 20 or more cigarettes per day.

2.4.2 Global outcome measures

A number of measures were used to assess global stress, depression and health right before and after the actual experiment. The following questionnaires were administered during the introduction as well as the conclusion meeting:

Perceived Stress Scale (PSS-10): While the Perceived Stress Scale (PSS-10; Cohen et al., 1983) was already used as a screening instrument, it was used again as an outcome measure to be able to perform a pre-post comparison of overall stress. Since the PSS-10 is designed to assess perceived stress during the past month, the timespan was reduced to one week, to be able to take into account the timespan of the experiment. Thus, participants were asked to report how often they have found themselves confronted with stressful thoughts or experiences within the *past week*, as compared to the *past month* as stated in the original questionnaire. While there is no data on the suitability of the PSS-10 for shorter time periods, Cohen's Frequently Asked Questions (FAQ) section mentions that the PSS-10 is applicable for shorter timespans as well (Cohen, 2014). Specifically, asking participants about their perceived stress over a period longer than a month might introduce problems, as it is very hard for participants to remember what happened over a month ago. Asking participants about their perceived stress during the past week, on the other hand, does not introduce such drawbacks. Cronbach's alpha for the PSS-10 administered before and after the actual experiment was 0.912 (pre) and 0.884 (post) respectively, indicating good to excellent internal consistency.

Symptom Checklist 90 Revised – Depression (SCL-90-R DEP): For a pre-post comparison of depression levels, participants were asked to fill in the depression subscale of the Dutch version of the Symptom Checklist 90 Revised scale (SCL-90-R; Derogatis & Unger, 2010; Dutch version: Arrindell & Ettema, 1986). The SCL-90-R is a frequently used instrument designed for assessing psychological symptoms and distress. The SCL-90-R was found to be instrument of high reliability and validity and is described as a useful tool for measuring psychological distress and symptom severity by a variety of studies (e.g., Hafkenscheid, 1993; Schmitz et al., 2000). In the current study, Cronbach's alpha was 0.924 before and 0.922 after the actual experiment, indicating excellent internal consistency. The depression subscale consists of 16 items, with each item describing a certain depression symptom. The items are rated on five-point Likert scales ranging from 1 (not at all) to 5 (very much). Total scores range from 0 to 80, with higher values representing higher severity of depressive symptoms. The SCL-90-R was chosen in place of the BDI-II due to its timeframe: while the BDI-II asks participants to rate depressive symptoms over the *past two weeks*, the SCL-90-R depression subscale is rated over the *past week*.

Symptom Checklist 90 Revised – Somatic Complaints (SCL-90-R SOM): To assess overall health before and after the experiment, participants were asked to fill in the somatic complaints subscale of the Dutch version of the SCL-90-R scale. This subscale contains 12 items describing a wide range of psychosomatic complaints such as headache, muscle pain, or breathing difficulties. Each item is rated on a five-point Likert scale ranging from 1 (not at all) to 5 (very much). Total scores range from 0 to 60, with higher values representing higher severity of somatic problems. Cronbach's alpha was 0.683 before and 0.653 after the actual experiment, indicating questionable but still acceptable internal consistency.

2.4.3 EMA outcome measures

With the help of the questionnaire application on the tablet, participants furthermore answered up to eight short ecological momentary assessment (EMA) questionnaires daily, thereby providing information about current stress, mood, worry, rumination and mind-wandering, self-control and well-being. In addition, participants' sleep quality was assessed once per day after waking. The evening questionnaire further assessed participants' satisfaction with the current day. The EMA questionnaire consisted of the following parts (for screenshots, see Section B.3 in Appendix B):

Stress: The current perceived stress level was assessed with two questions: "How much stress are you experiencing at the moment?" and "How much time pressure are you experiencing at the moment?" Both questions were rated on a seven-point Likert scale ranging from 1 (not at all) to 7 (very much).

Mood: The current mood was assessed with three seven-point semantic differential rating scales which were based on the UWIST Mood Adjective Checklist (UMACL; Matthews, Jones, & Chamberlain, 1990). Specifically, participants were asked to rate their mood in terms of the three factors obtained by Matthews and colleagues (1990): hedonic tone (happy vs. sad), tense arousal (relaxed vs. tense) and energetic arousal (energetic vs. tired). In addition, two items for measuring anger were added. Specifically, participants were asked how much they agree with the following two statements: "I am feeling angry" and "I am feeling irritable". These two questions were rated on regular seven-point Likert scales ranging from 1 (not at all) to 7 (very much).

Worry: The current perceived level of worry was measured with two seven-point Likert scales ranging from 1 (not at all) to 7 (very much). Specifically, participants were asked how much they agree with the following two statements: "I am worrying" and "I am pondering".

Rumination and mind-wandering: To assess rumination and mind-wandering, participants were furthermore asked whether they have experienced an event since the previous questionnaire which made them feel negative and whether their mind was wandering right before the current questionnaire. Specifically, participants were asked "Since the previous notification, have you experienced something that caused negative emotions?" This question was taken from a study by Moberly and Watkins (2008) which investigated the influence of ruminative self-focus on negative affect. Furthermore, mind-wandering was assessed with the two questions "Was your mind wandering right before the current notification?" and "Did you experience difficulties with controlling unwanted thoughts right before the current notification?" These questions were inspired by a study conducted by Kane and colleagues about mind-wandering (Kane et al., 2007). The questions were all rated on a binary yes versus no answering scheme.

Self-control: Current self-control was assessed with three questions: "How well can you concentrate at the moment?", "How patient are you at the moment?", and "How well can you make decisions at the moment?" The questions were all rated on seven-point Likert scales ranging from 1 (not at all) to 7 (very much).

Well-being: Current well-being was measured with one simple question rated on a seven-point Likert scale ranging from 1 (not at all) to 7 (very much). Specifically, participants were asked to rate how much they agree with the statement "I am feeling good".

Sleep quality: Sleep quality was assessed once per day in the morning with a Dutch translation of the Karolinska Sleep Diary (KSD; Akerstedt, Hume, Minors, & Waterhouse, 1994). The KSD is an instrument for subjective assessment of sleep quality which consists of questions about bedtime, time of awakening, sleep duration as well as a range of questions about sleep quality rated on five-point Likert scales.

Satisfaction with the current day: Satisfaction with the current day was assessed once per day in the evening questionnaire. More specifically, on a seven-point Likert scale ranging from 1 (not at all) to 7 (very much), participants were asked: "How satisfied are you with how your day has progressed?" The evening questionnaire assessed several other aspects, including how much time participant spent sporting and how long participants were outside. Furthermore, the evening questionnaire asked whether participants had an exam, presentation or any other type of test situation.

Heart rate and heart rate variability: For the duration of the experiment, participants were wearing the heart rate monitor throughout each day up until after the evening questionnaire. Heart rate was measured in beats per minute whereas R-R intervals were measured in 1/1024 seconds. Data was transferred from the heart rate monitor to the tablet roughly once per second, with each message including one heart rate reading and one or more R-R intervals, depending on the current heart rate.

2.4.4 Ancillary measures

Besides the core dependent variables, several questionnaires were administered to control for effects of personality.

Big Five Inventory (BFI): During the introduction meeting, personality was assessed in order to control for effects of personality on the dependent variables, as it was found that personality traits play an important role with regard to the appraisal of and coping with stressful situations (Carver & Connor-Smith, 2010; Vollrath, 2001). The Big Five Inventory (BFI; John, Naumann, & Soto, 2008; Dutch version: Denissen, Geenen, van Aken, Gosling, & Potter, 2008) is a popular measure designed for assessing the big five personality traits, which include extraversion, agreeableness, conscientiousness, neuroticism and openness. The scale consists of 44 items, with each item being a statement about a specific personality characteristic. Participants were asked to rate on five-point Likert scales ranging from 1 (strongly disagree) to 5 (strongly agree) how much they agree with each statement. The English as well as the Dutch version of the BFI were both found to have good psychometric properties (Denissen et al., 2008; John et al., 2008). In the current study, Cronbach's alpha coefficients were 0.902 (extraversion), 0.886 (neuroticism), 0.832 (openness), 0.737 (conscientiousness) and 0.740 (agreeableness), overall indicating acceptable to excellent internal consistency for the scale.

Penn State Worry Questionnaire (PSWQ): During the introduction meeting, trait worry was assessed with the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990; Dutch version: van der Heiden, 2009; van Rijsoort, Emmelkamp, & Vervaeke, 1999). The PSWQ consists of 16 statements, each describing different aspects of pathological worry. Participants were asked to rate on five-point Likert scales ranging from 1 (not at all typical of me) to 5 (very typical of me) the degree to which they identify with each statement. Total scores range from 16 to 80, with higher scores indicating stronger tendencies toward pathological worry. The PSWQ is a widely used instrument, with good psychometric properties with regard to both the English and Dutch version of the scale (Brown, Antony, & Barlow, 1992; Meyer et al., 1990; van Rijsoort et al., 1999; Startup & Erickson, 2006; Verkuil & Brosschot, 2012; Zlomke, 2009). In the current study, the internal consistency of the scale was excellent, as indicated by a Cronbach's alpha of 0.931.

Life Orientation Test Revised (LOT-R): There is growing evidence for the beneficial influence of dispositional optimism on coping as well as physical and psychological well-being (Carver et al., 2010; Smith & MacKenzie, 2006). In order to control for individual differences in optimism, the Life Orientation Test Revised (LOT-R; Scheier et al., 1994; Dutch version: ten Klooster et al., 2010) was administered during the introduction meeting. The LOT-R consists of ten statements: three positively formulated items, three negatively formulated items, as well as four items which are used as fillers. Participants were asked to rate how much they agreed with each statement on a five-point Likert scale ranging from 0 (strongly disagree) to 4 (strongly agree). Total scores range from 0 to 24, with higher numbers indicating stronger tendencies toward optimism. Psychometric properties of the LOT-R were found to be good (Glaesmer et al., 2012; Scheier et al., 1994). Internal consistency in the current study was acceptable, as indicated by a Cronbach's alpha of 0.755.

Munich ChronoType Questionnaire (MCTQ): During the introduction meeting, participants were furthermore asked to fill in the Munich ChronoType Questionnaire (MCTQ; Roenneberg, Wirz-Justice, & Merrow, 2003; Dutch version by the same authors), in order to account for individual differences with regard to chronotype. The MCTQ asks a range of simple questions about the time at which the respondent usually goes to bed, how long it takes for the respondent to fall asleep, what time the respondent wakes up and how many minutes it takes for the respondent to get out of bed (Roenneberg et al., 2007). All questions have to be answered twice, once for work days and once for free days. Based on studies conducted by Roenneberg and colleagues, the MCTQ represents a sound measure for assessing chronotype (Roenneberg et al., 2003; Roenneberg et al., 2007).

Action Control Scale (ACS-90): An important aspect with regard to an individual's motivation to put goals and intentions into practice is the individual's mode of action control. According to Kuhl's theory of action-state orientation (Diefendorff, Hall, Lord, & Strean, 2000; Kuhl, 1981), people differ with regard to their tendencies of being action versus state oriented. Action oriented individuals have the ability to easily initiate work on tasks, are better at ignoring thoughts about competing goals during task completion, and efficiently manage to maintain their focus on the task until its completion (Diefendorff et al., 2000). State oriented individuals, on the other hand, have the tendency to be more hesitant with task initiation, are more preoccupied with thoughts unrelated to the task at hand and experience more difficulties with staying focused on a given task (Diefendorff et al., 2000). With regard to the current study, this distinction is important, as action oriented individuals might be more committed to filling in the daily questionnaires than state oriented individuals. Furthermore, due to their ability of reacting to stressful situations with a change- and goal-oriented attitude, action oriented individuals might experience the slideshow manipulations as more disruptive and therefore less helpful as compared to state oriented individuals. To account for individual differences with regard to action orientation, the 24-item revised version of the Action Control Scale (ACS; Diefendorff et al., 2000; Dutch version: Koole & Jostmann, 2004; Koole & van den Berg, 2005) was administered during the conclusion meeting. Each of the 24 items of the ACS describes a specific everyday life situation and is accompanied by two answer-options: one option describing a reaction characteristic for state-oriented individuals and another option describing an approach typical for action-oriented individuals. The 24-item version of the ACS consists of two subscales, measuring the two subdomains of action control called preoccupation versus disengagement (AOF) and hesitation versus initiative (AOD). Total scores for each subscale range from 0 to 12. Diefendorff and colleagues (2000) found that the revised version of the ACS had good psychometric properties and concluded that the scale is suitable for assessing the construct of action-state orientation.

2.5 Heart rate variability

Heart rate variability was measured for both the questionnaires and the slideshows according to the recommendations by the Task Force of the European Society of Cardiology (1996). Specifically, before the start of a questionnaire response, short-term three minute segments were selected for HRV analysis. With regard to the slideshows, HRV analysis was conducted on short-term three minute segments before, during and after watching a slideshow. Three minute windows were chosen due to the length of the slideshow, which was three minutes as well. For each of the short-term recordings collected, the time-domain measures SDNN and RMSSD were obtained. Figure 2.4 provides an overview of all the segments that were analyzed. HRV recordings were analyzed using the software Kubios HRV (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014; http://www.kubios.com).

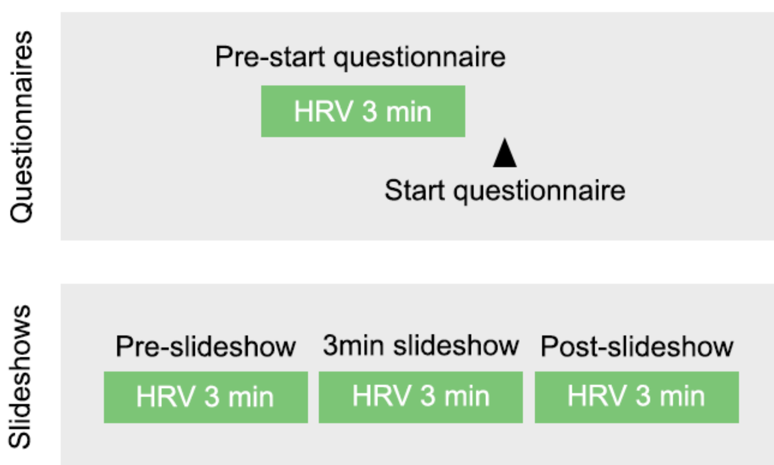

Figure 2.4 Schematic overview of all recordings selected for HRV analysis.

2.5.1 Time domain analysis

In the time domain, the standard deviation of the R-R intervals (SDNN) and the root mean square of successive R-R interval differences (RMSSD) were calculated. The SDNN can be calculated directly on the R-R intervals and is interpreted as a global index of HRV, representing the total variance within a series of R-R intervals. It is important to note that SDNN is dependent on the length of a recording (Kamath et al., 2012; Task Force of ESC, 1996). For this reason, it was made sure that the HRV recordings taken before and after the slideshow had the same length as the recordings taken during the slideshow (three minutes). Since the SDNN is very sensitive to artifacts such as ectopic or missed beats, it requires careful preprocessing (Kleiger, Stein, & Bigger, 2005). The calculation of the RMSSD is based on the differences between successive R-R intervals. Thus, to calculate the RMSSD, first the difference between each R-R interval and its successor is calculated and then squared. Following this calculation, the average of all of these squared differences is calculated and the square root is taken. The RMSSD is of particular interest for this study since it is interpreted as a marker for parasympathetic activity (Ernst, 2014; Task Force of ESC, 1996). Specifically, higher RMSSD values indicate increased parasympathetic modulation and may signal a relaxed state, whereas lower values represent decreased parasympathetic activity and may indicate stress (Xhyheri et al., 2012).

2.5.2 Preprocessing and noise reduction

As mentioned earlier, the SDNN is very sensitive to artifacts such as ectopic or missed beats and therefore requires careful preprocessing (Kleiger et al., 2005). HRV segments were inspected visually as well as analyzed using the software Kubios HRV in order to identify artifacts such as outliers or missing values. Segments with more than 3% of aberrant R-R intervals were dropped from the analysis. Cubic spline interpolation was used to replace artifacts in segments that were suitable for further analysis (Tarvainen et al., 2014). For the data analysis, a HRV value was considered an outlier if it deviated more than two standard deviations from the mean.

2.6 Procedure

Prior to being invited for participation, individuals interested in participating in the experiment were asked to fill in an online screening questionnaire. With the help of this screening questionnaire, it was determined which individuals were suitable for the experiment and which had to be excluded. As part of the screening questionnaire, participants were asked to provide information about their smoking and drinking behavior, assessed with the Five-Shot Questionnaire (FSQ), as well as answer questions about potential heart diseases and consumption of heartbeat-regulating medication. Furthermore, stress and depression were assessed with the Perceived Stress Scale (PSS) and Beck Depression Inventory II (BDI-II), respectively. Participants smoking more than 20 cigarettes daily, reaching a score of 4.5 or higher on the FSQ, or suffering from a heart disease were excluded from the experiment. Furthermore, participants who did not reach a score of at least 14 or higher on either the PSS or BDI-II were excluded as well. Participants satisfying the screening requirements were invited via email for participation and were sent a link to a website for registration for the introduction meeting. Participants who decided to register for the experiment were randomly assigned prior to the introduction meeting to one of the following three conditions: control condition, nature slideshow condition or urban slideshow condition.

Participants were individually welcomed to the introduction meeting at the Human-Technology Interaction laboratories at Eindhoven University of Technology. The introduction meeting was approximately 45 minutes in duration and included a detailed explanation of the goals and requirements of the experiment, a questionnaire administered on a computer, as well as a thorough introduction to the devices and applications. After arrival at the laboratory, the goals of the experiment and the procedures following the introduction were explained. All participants were asked to sign an informed consent form detailing the requirements, payment, and participant rights. Once participants signed the informed consent form, they were asked to fill in a range of questionnaires administered on a computer. The questionnaires included the Perceived Stress Scale (PSS), the Symptom Checklist 90 Revised (SCL-90-R), the Big Five Inventory (BFI), the Penn State Worry Questionnaire (PSWQ), the Life Orientation Test Revised (LOT-R), as well was the Munich ChronoType Questionnaire (MCTQ). Furthermore, participants were asked questions about their age, gender, work habits and coffee-drinking behavior.

After filling in the questionnaires, participants were introduced to the devices. First, the tablet was shown and the questionnaire application was explained. Participants were instructed to fill in the morning questionnaire consisting of the Karolinska Sleep Diary (KSD) each day right after awakening or, in case this was impossible, no later than at twelve noon. Participants were further explained that they would receive a total of eight randomly spread notifications daily between nine o'clock in the morning and nine o'clock in the evening for filling in a short questionnaire. The questionnaire to be filled-in included questions about stress, mood, worry, rumination and mind-wandering, self-control and general well-being. Upon receipt of a notification, participants were instructed to fill in the questionnaire as soon as possible or, if this was impossible, within 15 minutes of the onset of the alarm. Finally, participants were instructed to fill in the evening questionnaire after nine o'clock in the evening or before going to bed. The evening questionnaire consisted of questions about the time participants spent outside or sporting, about whether participants encountered an exam or test situation during the day and about how satisfied participants were with the progression of their day in general. Furthermore, in case participants were unable to respond to all questionnaires during the day, the evening questionnaire gave participants the opportunity to explain why. Following this general instruction, participants in the treatment groups (nature slideshows or urban slideshows) were given further instructions about the slideshows. Specifically, participants in the treatment groups were instructed to watch the slideshow once per day after nine o'clock in the evening, right before filling in the evening questionnaire. Furthermore, it was explained that participants might get a recommendation for watching a slideshow during the day as well, after filling in a questionnaire. In case there was a slideshow recommendation following the questionnaire, participants were instructed to watch the slideshow within one hour following the recommendation.

Following the explanations about the questionnaire application, the participants were then explained how to use the heart rate monitor and how to establish a Bluetooth connection with the tablet. Participants were instructed to put the heart rate monitor on in the morning, after getting ready for their day, and to take it off in the evening, after filling in the evening questionnaire. Furthermore, participants were explained that they had to stay within close distance of the tablet, in order to be able to record data on the tablet. Participants were allowed to take off the heart rate monitor for specific occasion (e.g., swimming or showering), but were otherwise asked to wear the heart rate monitor as long and often as possible. With help of the heart rate monitor, both heart rate in beats per minute (BPM) and R-R intervals in 1/1024 seconds were recorded throughout each day of the experiment. Participants received detailed instructions about how to handle the heart rate monitor and had the opportunity to practice establishing a connection between the tablet and the heart rate monitor with the help of the heart rate application on the tablet. At the end of the instruction session, participants were given a small instruction booklet containing a summary of all the important points and contact details in case problems would occur during the experiment. Finally, an appointment was made for the conclusion meeting. The six days following the introduction meeting, participants were following the instructions of the experiment.

For the conclusion meeting, participants were again welcomed at the Human-Technology Interaction laboratories at Eindhoven University of Technology. The conclusion meeting was approximately 30 minutes in duration and included a questionnaire administered on a computer, a short interview as well as a thorough debriefing. Participants were first asked to fill in a range of questionnaires on a computer. These questionnaires included again the Perceived Stress Scale (PSS) and the Symptom Checklist 90 Revised (SCL-90-R), as well as the Action Control Scale (ACS-90). Furthermore, participants were asked to provide information about the amount of nature present in their living environment and were given the opportunity to give written feedback about the experiment. After the questionnaires, a short interview was conducted (for an overview of the interview questions, see Appendix D). During the interview, participants were asked about their overall experience with the experiment, their opinion about the applications and devices as well as their impression of the questionnaire and slideshows, in case a participant was in one of the treatment conditions. Throughout the interview, audio recordings were made with the help a smartphone. Finally, after the completion of the interview, participants were explained the true goal of the experiment and were given the opportunity to ask questions. After the debriefing, participants were paid and thanked for their participation.

2.7 Statistical analyses

Three main types of quantitative data were analyzed in the course of this study: the repeated measures data, which was collected before and after the main ecological momentary intervention (EMI) experiment, the ecological momentary assessment data, which was gathered at various moments throughout the six-day-long main experiment, as well as the heart rate and R-R interval data, which was collected continuously throughout the entire six days of the main experiment.

2.7.1 Repeated measures data

The stress and depression measures that were administered before and after the main EMI experiment were analyzed using a mixed design analysis of variance (ANOVA) with a within-subject factor for time (pre-experiment versus post-experiment) and a between-subject factor for treatment group (control, nature slideshows and urban slideshows). With regard to the outlier analysis, scores were considered outliers if they were more than three standard deviations away from the mean value.

2.7.2 Ecological momentary assessment data

The ecological momentary assessment data, which was collected via questionnaires triggered eight times a day by an application on a tablet, was analyzed using multilevel models (MLM). Each time a questionnaire was answered, the questionnaire data was stored in a text file on the tablet together with a timestamp. Multilevel models were chosen due to the hierarchical nature of the data: The individual measures collected throughout the six-day-long main experiment were nested within people. As such, the multilevel models tested in this analysis had two levels: a 'measurement level' (level one) representing the individual measurements taken (e.g., momentary stress or worry) and a 'person level' (level two) representing the individual participants. The main predictor variables used were time and treatment condition. Time was entered at level one (measurement level) in order to account for changes in the dependent variable over time, whereas treatment condition was entered at level two (person level) to test for differences between groups. The dependent variables included stress, mood, worry, rumination and mind-wandering, self-control, well-being, sleep quality and satisfaction. Again, scores deviating for more than three standard deviations from the mean were considered outliers.

2.7.3 Heart rate variability data

R-R intervals were collected throughout the entire time of the six-day-long main experiment and stored in a text file on the tablet together with a timestamp representing the time at which each R-R interval was received by the tablet from the Polar H7 heart rate monitor. While R-R intervals were collected continuously, HRV was calculated for specific segments at the following moments only: for a period of three minutes before answering an ecological momentary assessment questionnaire as well was for three-minute intervals before, during and after watching a slideshow. Matching R-R intervals for questionnaires and slideshows were extracted with the help of tailored Python scripts (http://www.python.org). More specifically, the scripts were programmed to collect all R-R intervals within a timespan of three minutes before each respective valid questionnaire as well as within three minutes before, during and after corresponding valid slideshows, by comparing timestamps of the R-R intervals with the timestamps collected for the questionnaires and slideshows. The extracted R-R interval segments were then inspected for noise with Kubios HRV (Tarvainen et al., 2014; http://www.kubios.com) and heart rate variability was calculated. Finally, heart rate variability was used as a dependent variable in a multilevel model analysis. For the questionnaire-related HRV measures, the multilevel model had two levels: a 'measurement level' (level one) representing the individual HRV measures collected and a 'person level' (level two) representing the individual participants. Two different multilevel models with this nesting-structure were tested. In the first model, the level-one predictor time and the level-two predictor treatment condition were entered in order to test for the influence of group membership on change in HRV over time. In the second model, it was tested whether there was any correlation between HRV measures (physiological index of stress) and psychological stress as measured by the ecological momentary assessment questionnaires. This was achieved by entering momentary level of stress as a level-one predictor. Finally, the slideshow-related HRV measures required a three-level multilevel model with the following nesting: a 'measurement level' (level one) representing the individual HRV measures collected, a 'pre-during-post level' (level two) representing the grouping of HRV measures collected before, during and after watching a specific slideshow, as well as 'person level' (level three) representing the individual participants. In case of HRV, a value was considered an outlier if it deviated more than two standard deviations from the mean.

2.7.4 Qualitative analysis of the interview data

As described earlier, short interviews were conducted during the conclusion meeting after the main EMI experiment. The main goal of the interviews was to gather more information about the devices, the questionnaires and the slideshow manipulations, as well as to gain insight about what could be improved for similar experiments in the future. The interview data was therefore supplementary in nature. Given the explorative nature of the interviews, only one researcher was involved in the transcription and interpretation of the interview data. The interviews were semi-structured, meaning that there was a list with predefined questions that was followed but it was allowed to divert from this list in order to explore additional topics that were not covered by the questions. The questions were developed such that the main aspects of the experiment were included: the overall experience, the devices, the questionnaires and the slideshows, in case participants were assigned to one of the two treatment groups. Questions were ordered from more general to more concrete, in order to not influence participants' answers. Furthermore, it was made sure that no leading or judgmental questions were asked, that each question was focused on one single thought and that questions were open-ended, in order to give participants room for elaboration. Throughout the interviews, audio recordings were made with the help of a smartphone. Following the experiment, these audio recordings were transcribed word for word and then translated from Dutch to English such that both a Dutch and an English transcription was available. During the transcription process, all personal information that potentially could identify participants (e.g., workplace information or names) was anonymized. In addition, the content was annotated with facial and verbal expressions, to facilitate interpretation. Following the transcription process, the transcriptions were read and the main themes and issues discussed were identified. Subsequently, for each theme identified, all sentences matching the theme were extracted and gathered in one place. To ensure traceability, each sentence was labelled with the respective participant id, the experimental condition and the participant's gender and age. Based on this structured information, the most important and interesting aspects were identified and summarized.

3 Results

The results are organized into four main sections. The first section summarizes the overall mental health scores. This includes results for the global stress and depression questionnaires administered before as well as after the main ecological momentary intervention (EMI) experiment. In the second section, the results of the ecological momentary intervention analysis are presented. This includes a descriptive analysis of the number of questionnaires answered and slideshows watched as well as the multilevel model analysis of the ecological momentary assessment questionnaire data. The third section is devoted to the topic of heart rate variability and presents descriptive statistics as well as the multilevel model analysis for HRV. Finally, the last section describes the results of the qualitative analysis from the interviews conducted at the end of the experiment. For the multilevel model analyses reported in Sections 3.2 and 3.3, outliers were handled as follows: Analyses were first run and reported including outliers. In a second step, outliers were excluded and it was examined whether removing outliers had any influence on the results. This strategy for handling outliers was chosen due to the fact that removing outliers led to the introduction of new outliers in almost all analyses. The outliers were thus likely the result of the non-normal distribution of the data, as opposed to being exceptional or extreme cases. As reported earlier, data points were generally considered outliers if they were more than ±3 standard deviations away from the mean. For heart rate variability, however, measurements were categorized as outliers if they were ±2 standard deviations away from the mean. It is important to note that for the multilevel model analyses run on the EMI and HRV data, the model assumptions were violated consistently and data transformations were unsuccessful in most cases. For this reason, a similar strategy was chosen for the data transformations as in case of the outliers: Analyses were first run and reported without transforming the data. In a second step, data transformations were carried out and it was reported to what extent the transformations were successful and whether the results changed. Finally, due to the large number of statistical test that were run, it is important to keep in mind that there is a possibility that significant results may have surfaced by chance.

3.1 Repeated measures analysis

3.1.1 Descriptive statistics

Both before and after the actual EMI experiment, participants completed a battery of questionnaires assessing momentary stress and depression levels as well as a wide range of personality traits. Table C.1 in Appendix C provides descriptive statistics for each of these variables with respect to the three experimental conditions (control, nature slideshows and urban slideshows). In the majority of cases, no significant differences between groups were found at baseline. However, as can be seen from the group counts in Figure 3.1, there was a considerable gender imbalance in the urban slideshow treatment group, with only one participant being male and all other participants being female. For the remaining two groups, gender was more balanced, with eight female and six male participants each.

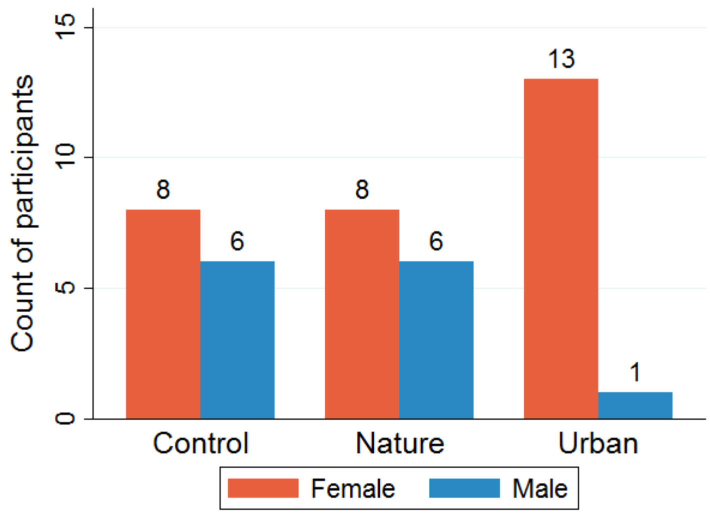

Figure 3.1 Differences between groups with regard to gender.

3.1.2 Quantitative analysis

Three different questionnaires were administered both before and after the main EMI experiment. The first questionnaire assessed stress (PSS-10), the second depression (SCL-90-R DEP) and the third somatic complaints (SCL-90-R SOM). In the following sections, the repeated measures analysis results for each of these questionnaires are summarized.

3.1.2.1 *Perceived stress (PSS-10)*

In order to investigate the effect of the main EMI experiment on perceived stress scores, a mixed design analysis of variance (ANOVA) with a within-subject factor for time (pre-experiment and post-experiment) and a between-subject factor for the treatment group (control, nature slideshows and urban slideshows) was conducted. Table 3.1 provides an overview of the means and standard deviations for each of the treatment groups before and after the main experiment.

Table 3.1 Means and standard deviations of perceived stress scores for each treatment group before and after the main experiment.

		Pre-experiment		**Post-experiment**	
	N	*M*	*SD*	*M*	*SD*
Control	14	15.643	8.509	14.286	7.426
Nature slideshow	14	18.857	7.645	16.429	6.936
Urban slideshow	14	15.714	6.044	14.857	6.916
Total	42	16.738	7.441	15.190	6.982

The standardized residuals of the post-experiment scores were significantly different from the normal distribution, $W(42) = 0.946$, $p = 0.048$, indicating a violation of the normality assumption. For this reason, both the pre- and the post-experiment perceived stress scores were transformed using a square root transformation. Results from the mixed design ANOVA revealed a significant main effect for time (pre- versus post-experiment), $F(1, 39) = 5.253$, $p = 0.027$, $\omega_p^2 = 0.094$. More specifically, perceived stress was significantly lower after the main ecological momentary intervention experiment compared to scores obtained before the main experiment for all participants, independently of the participants' treatment condition. Thus, there was no significant main effect for the treatment condition, $F(2, 39) = 0.702$, $p = 0.502$, $\omega_p^2 = -0.014$. Furthermore, there was no interaction between time (pre- versus post-experiment) and treatment condition, $F(2, 39) = 0.291$, $p = 0.749$, $\omega_p^2 = -0.035$, indicating that the type of treatment condition (control, nature slideshows or urban slideshows) did not influence the degree of stress reduction between pre-experiment and post-experiment scores. Figure 3.2 illustrates the difference in perceived stress before and after the main experiment

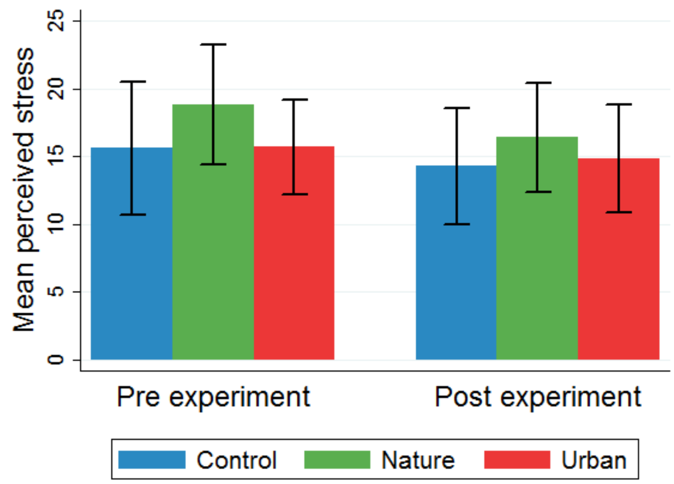

Figure 3.2 Mean perceived stress scores for all three experimental conditions both before and after the main experiment. The range of the Perceived Stress Scale is 0 to 40. Error bars represent 95% confidence intervals.

3.1.2.2 Depressive symptoms (SCL-90-R DEP)

As with perceived stress, a mixed design ANOVA was conducted in order to investigate the effect of the main EMI experiment on depression scores (SCL-90-R Depression). Table 3.2 provides an overview of the means and standard deviations for each of the treatment groups before and after the main experiment. The standardized residuals of both the pre-experiment scores, $W(42) = 0.918$, $p = 0.005$, and the post-experiment scores, $W(42) = 0.894$, $p = 0.001$, were significantly different from the normal distribution. The pre- and the post-experiment depression scores were therefore transformed using a square root transformation. Results from the mixed design ANOVA revealed no significant effects. Thus, there was no significant main effect for time, $F(1, 39) = 2.226$, $p = 0.144$, $\omega_p^2 = 0.029$, as well as no significant main effect for the treatment condition, $F(2, 39) = 1.309$, $p = 0.282$, $\omega_p^2 = 0.015$. Furthermore, the interaction effect between time and treatment condition was non-significant as well, $F(2, 39) = 0.334$, $p = 0.718$, $\omega_p^2 = -0.033$.

Table 3.2 Means and standard deviations of depression scores for each treatment group before and after the main experiment.

		Pre-experiment		**Post-experiment**	
	N	*M*	*SD*	*M*	*SD*
Control	14	0.790	0.606	0.665	0.680
Nature slideshow	14	1.085	0.753	1.098	0.803
Urban slideshow	14	0.879	0.589	0.701	0.413
Total	42	0.918	0.649	0.821	0.667

3.1.2.3 *Somatic complaints (SCL-90-R SOM)*

As in case of the previous two analyses, the effect of the main ecological momentary intervention experiment on somatic complaints (SCL-90-R Somatic Complaints) was analyzed using a mixed design ANOVA. Table 3.3 provides an overview of the means and standard deviations for each of the treatment groups before and after the main experiment. Results from the mixed design ANOVA revealed no significant effects. However, there was a trend toward significance for time, $F(1, 39) = 2.998$, $p = 0.091$, $\omega_p^2 = 0.046$, indicating a tendency toward a decrease in somatic complaints over time for all participants, irrespective of their experimental condition. No significant main effect was found for treatment condition, $F(2, 39) = 1.505$, $p = 0.235$, $\omega_p^2 = 0.023$. The interaction effect between time and treatment condition was non-significant as well, $F(2, 39) = 0.092$, $p = 0.912$, $\omega_p^2 = -0.045$.

Table 3.3 Means and standard deviations of somatic complaints scores for each treatment group before and after the main experiment.

		Pre-experiment		**Post-experiment**	
	N	*M*	*SD*	*M*	*SD*
Control	14	0.518	0.358	0.435	0.282
Nature slideshow	14	0.720	0.438	0.667	0.399
Urban slideshow	14	0.696	0.378	0.595	0.399
Total	42	0.645	0.394	0.565	0.368

3.2 Ecological momentary intervention analysis

The core of this section consists of the multilevel model analysis of the questionnaire data gathered from the EMI experiment. However, before delving into the details of these results, a descriptive overview is provided about the overall number of questionnaires answered and slideshows watched.

3.2.1 Compliance and descriptive statistics

3.2.1.1 Questionnaires

Participants ($N = 42$) received a total of eight daytime questionnaire notifications per day over a period of six days, adding up to a total of 48 notifications over the entire experiment. On average, participants completed 36.357 ($SD = 5.834$) questionnaires in total, as shown in Table 3.4.

Table 3.4 Means and standard deviations for the number of questionnaires answered.

	Overall ($N = 42$) *M (SD)*	**Control ($N = 14$)** *M (SD)*	**Nature slides ($N = 14$)** *M (SD)*	**Urban slides ($N = 14$)** *M (SD)*
Number of valid daytime questionnaires	36.357 (5.834)	36.571 (6.047)	39.643 (4.534)	32.857 (5.036)
Number of valid morning questionnaires	5.976 (0.154)	6.000 (0)	6.000 (0)	5.929 (0.267)
Number of valid evening questionnaires	5.690 (0.643)	5.786 (0.426)	5.714 (0.469)	5.571 (0.938)

Note. These statistics represent per person averages.

Figure 3.3 provides an overview of the frequencies of participants for the total number of daytime responses provided. The majority of participants (16 or 38.10%) gave between 35 and 39 daytime responses in total. A one-way between subjects ANOVA revealed a significant effect of experimental condition on the total number of daytime questionnaires answered, $F(2, 39) = 5.879$, $p = 0.006$, $\omega_p^2 = 0.189$. Post hoc comparisons using the Tukey test indicated that participants in the nature slideshow condition ($M = 39.643$, $SD = 4.534$) completed significantly ($p < 0.01$) more questionnaires than participants in the urban slideshow condition ($M = 32.857$, $SD = 5.036$). There were no significant differences between the control group ($M = 36.571$, $SD = 7.676$) and either of the treatment conditions. A comparison of the mean number of responses between conditions is illustrated in Figure 3.4.

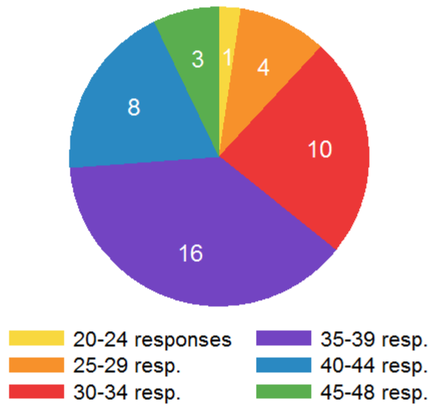

Figure 3.3 Total number of daytime responses provided over the entire experiment and the respective frequencies of participants.

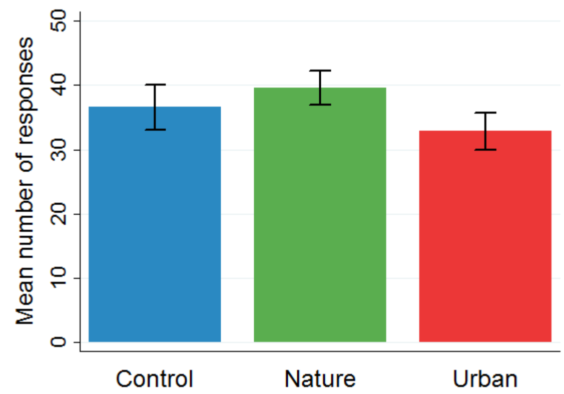

Figure 3.4 Mean number of daytime responses with respect to the experimental conditions. Error bars represent 95% confidence intervals.

In addition to the daytime questionnaires, participants were asked to answer one morning and one evening questionnaire per day, adding up to a total of six morning and six evening questionnaires over the entire experiment. Participants (N = 42) answered an average of 5.976 (SD = 0.154) morning questionnaires as well as an average of 5.690 (SD = 0.643) evening questionnaires in total.

3.2.1.2 Slideshows

Total number of slideshows: Participants (N = 28, excluding the control condition) were asked to watch at least one slideshow every evening. In addition, depending on their momentary stress levels, participants received up to two slideshow recommendations throughout the day, adding up to a maximum of three slideshows per day (including the evening slideshow). On average, participants watched a total of 10.750 (SD = 3.362) slideshows, as summarized in Table 3.5.

While participants in the nature condition (M = 11.571, SD = 3.155) watched slightly more slideshows on average than participants in the urban condition (M = 9.929, SD = 3.474), an independent samples t-test revealed no significant difference between the two groups, $t(26)$ = 1.310, p = 0.202, Hedges's g_s = 0.480. Figure 3.5 provides an overview of the frequencies of participants for the total number of slideshows watched over the entire period of the six-day-long experiment, whereas Figure 3.6 shows how the slideshows were spread over the six-day-long period of the experiment. A large majority of participants (20 or 71.43%) watched at least one slideshow per day (Figure 3.6).

Table 3.5 Means and standard deviations for the number of slideshows watched.

	Overall (N = 28) *M (SD)*	Nature slides (N = 14) *M (SD)*	Urban slides (N = 14) *M (SD)*	t (26)	p
Number of slideshows watched	10.750 (3.362)	11.571 (3.155)	9.929 (3.474)	1.310	0.202
Number of slideshows recommended	5.857 (3.363)	6.500 (3.611)	5.214 (3.093)	1.012	0.321
Number of recommended slideshows watched	5.214 (3.348)	5.929 (3.407)	4.500 (3.252)	1.135	0.267
Percentage of recommended slideshows watched	0.893 (0.168)	0.926 (0.096)	0.860 (0.218)	1.046	0.309
Number of evening slideshows watched	4.893 (1.315)	4.929 (1.492)	4.857 (1.167)	0.141	0.889
Number of extra daytime slideshows watched	0.643 (0.989)	0.714 (0.914)	0.571 (1.089)	0.376	0.710

Note. These statistics represent per person averages.

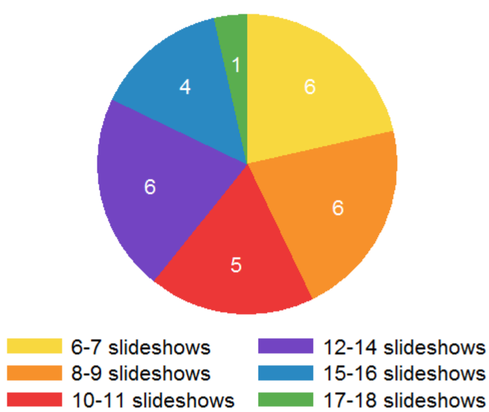

Figure 3.5 Total number of slideshows watched over the entire experiment and the respective frequencies of participants.

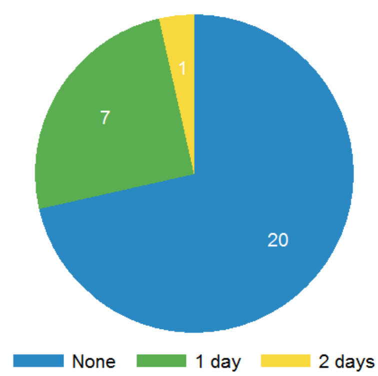

Figure 3.6 Number of consecutive days on which slideshows were skipped and the respective frequencies of participants.

Recommended daytime slideshows: On average, participants were recommended a total of about six (*M* = 5.857, *SD* = 3.363) extra slideshows in addition to the six mandatory evening slideshows (Table 3.5). Only two of the total 28 participants (7%) were recommended no additional slideshows throughout the day, indicating that the majority of participants (93%) was stressed enough to qualify for extra slideshows. While participants in the nature condition (*M* = 6.500, *SD* = 3.611) were recommended slightly more extra slideshows than participants in the urban condition (*M* = 5.214, *SD* = 3.093), an independent samples t-test revealed no significant difference between the two groups, $t(26) = 1.012$, $p = 0.321$, Hedges's $g_s = 0.371$. Importantly, although most of the participants were recommended extra slideshows, not all of these recommended slideshows were watched. As shown in Table 3.5, participants watched on average 5.214 (*SD* = 3.348) recommended slideshows. While participants in the nature condition (*M* = 5.929, *SD* = 3.407) watched slightly more of the recommended slideshows than participants in the urban condition (*M* = 4.500, *SD* = 3.252), an independent samples t-test did not find a significant difference between the two groups, $t(26) = 1.135$, $p = 0.267$, Hedges's $g_s = 0.417$. Looking at the percentage of recommended slideshows watched provided similar results: Participants in the nature condition had a slightly higher percentage of recommended slideshows watched (*M* = 0.926, *SD* = 0.096) than participants in the urban condition (*M* = 0.860, *SD* = 0.218), however, the difference was not significant, $t(26) = 0.897$, $p = 0.378$, Hedges's g_s = 0.380.

Evening slideshows: On average, participants watched a total of 4.893 (*SD* = 1.315) evening slideshows, as shown in Table 3.5. Participants in the nature condition (*M* = 4.929, *SD* = 1.492) watched slightly more evening slideshows than participants in the urban condition (*M* = 4.857, *SD* = 1.167). However, an independent samples t-test revealed no significant differences between groups, $t(26) = 0.141$, $p = 0.889$, Hedges's $g_s = 0.052$. Figure 3.7 provides an overview of the total number of evening slideshows watched and the respective frequencies of participants per category. While a total of 12 participants (42.86%) watched six or seven slideshows in total, a total of 16 participants (57.14%) watched less than six evening slideshows in total and therefore must have skipped certain evenings. Figure 3.8 shows that the majority of participants (13 or 46.43%) never skipped more than one evening slideshow in a row. It is important to note that overall, none of the participants included in this analysis watched less than six slideshows over the entire experiment. Thus, in case participants skipped evening slideshows, they made up for these lost slideshows by either watching recommended daytime slideshows or extra daytime slideshows.

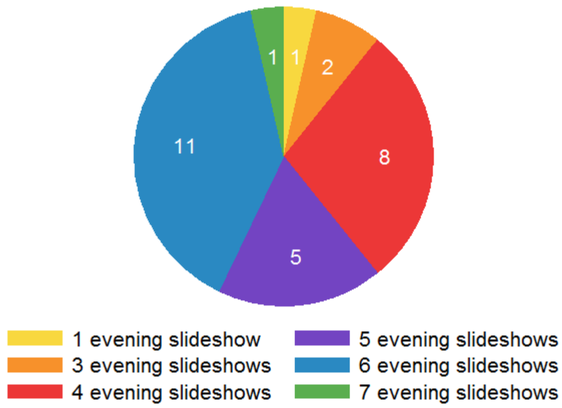

Figure 3.7 Total number of evening slideshows watched and the respective frequencies of participants.

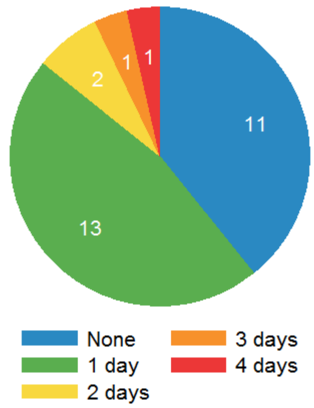

Figure 3.8 Number of consecutive days on which the evening slideshow was skipped and the respective frequencies of participants.

Extra daytime slideshows: On average, participants watched 0.643 (*SD* = 0.989) extra daytime slideshows which were neither required nor recommended. Although participants in the nature condition (*M* = 0.714, *SD* = 0.914) watched slightly more extra slideshows than participants in the urban condition (*M* = 0.571, *SD* = 1.089), an independent samples t-test found no significant difference between the two groups, $t(26) = 0.376$, $p = 0.710$, Hedges's $g_s = 0.138$.

Number of slideshows watched in relation to the amount of stress: The EMI application on the tablet was programmed such that participants with high stress scores were recommended more slideshows throughout the day than participants with low stress scores. In order to investigate whether highly stressed or depressed individuals watched more slideshows compared to participants with low stress or depression, a correlation analysis was conducted. As shown in Table 3.6, the total number of slideshows watched, the total number of slideshows recommended and the total number of recommended slideshows watched all had a significant positive correlation with the main stress and depression scales administered before and after the six-day-long experiment. This is in line with expectations and confirms that the manipulation was executed as intended.

Table 3.6 Correlations between slideshows watched and the stress and depression scales administered before and after the experiment.

	Number of slide-shows watched	Number of slide-shows recommended	Number of recommended slideshows watched
BDI Screening	0.306	0.448*	0.429*
PSS Screening	0.394*	0.517**	0.518**
SCL-90 Depression Pre	0.553**	0.635**	0.626**
SCL-90 Depression Post	0.486**	0.601**	0.525**
SCL-90 Somatic Pre	0.579**	0.610**	0.530**
SCL-90 Somatic Post	0.521**	0.622**	0.520**
PSS Pre	0.480**	0.667**	0.639**
PSS Post	0.577**	0.690**	0.635**

Note. *significant at the 0.05 level, **significant at the 0.01 level

3.2.2 Multilevel model analysis

In the current section, the results of the multilevel model analyses for each of the dependent variables from the ecological momentary assessment (EMA) questionnaire will be presented. For each of the multilevel model analyses, a similar stepwise approach was chosen. First, the empty model was calculated by simply including the dependent variable under investigation, omitting any predictors, random intercepts or random slopes. Next, to model nesting of responses within participants, a random intercept for participants was added. Subsequently, the measurement level (level one) predictor time, as measured by the questionnaire index (between 1 and 48), was added, in order to test the presence of a linear effect of time. Finally, the person level (level two) variable for treatment condition was added as a predictor, in order to test whether there were significant differences between groups with respect to the dependent variable in general. Since there were three conditions (control, nature slideshows and urban slideshows), the predictor was added in form of dummy variables. Two different models were estimated. In the first model, dummy variables for the nature and urban condition were included, contrasting the difference of treatment versus control. In the second model, dummy variables for the urban and the control condition were added, to test the presence of significant differences between watching nature versus urban slideshows. Importantly, no random slopes were added, as it was hypothesized that the treatment condition would affect all participants in the same manner. Furthermore, this section only reports the results for the final models including both treatment condition and time as predictors.

3.2.2.1 Perceived stress

Participants were prompted to rate their momentary level of stress on a seven-point Likert scale eight times a day. Adding a random intercept to the empty model revealed that there was a considerable amount of within-subject ($\sigma_\varepsilon^2 = 1.415$) as well as between-subject ($\sigma_0^2 = 0.603$) variance with regard to momentary stress. The intra-class correlation coefficient was found to be $\varrho = 0.299$, indicating that roughly 30% of the total variance in perceived stress was due to differences on the participant level, whereas the remaining 70% was due to variance on the level of the individual measurements. Given this considerable amount of variance at both levels, conducting a multilevel model analysis was considered justified. Adding time (measurement level) and the treatment condition (person level) as predictors to the model revealed no significant results, as shown in Table 3.7. However, the linear effect of time was close to reaching significance with $p = 0.064$, indicating a trend toward increases in perceived stress over time for all participants, irrespective of their experimental condition – a result which was not expected. Overall, these results are not in line with hypothesis 1, which predicted that participants in the nature slideshow condition would experience lower levels of stress than participants in the urban slideshow or control condition. Importantly, the residuals on the measurement level, $W(1527) = 0.971$, $p < 0.000$, as well as on the person level, $W(1527) = 0.973$, $p < 0.000$, were significantly different from the normal distribution. Data transformations were not successful at restoring normality. Furthermore, a Levene's test on the person level indicated a significant difference of variances between treatment groups, $F(2, 1524) = 6.250$, $p = 0.002$. In addition, 6 observations on the measurement level were identified with a standard deviation of more than ±3 from the mean. While removing these outliers did not drastically change the outcomes reported in Table 3.7, it further increased the *p*-value for time to $p = 0.128$. Due to the violations of the assumptions, the results have to be interpreted carefully.

Table 3.7 Results for the multilevel model analysis with perceived stress as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	2.469	0.218	0.000	[2.042, 2.896]
Time	0.004	0.002	0.064	[-0.000, 0.008]
Nature condition	0.275	0.299	0.358	[-0.311, 0.860]
Urban condition	0.235	0.300	0.433	[-0.353, 0.823]
	Treatment condition relative to nature condition			
Intercept	2.744	0.217	0.000	[2.317, 3.170]
Time	0.004	0.002	0.064	[-0.000, 0.008]
Control condition	-0.275	0.299	0.358	[-0.860, 0.311]
Urban condition	-0.040	0.299	0.895	[-0.626, 0.547]

3.2.2.2 Time pressure

In addition to stress, participant rated their momentary experience of time pressure on a seven-point Likert scale eight times a day. Adding a random intercept to the empty model revealed that there was a considerable amount of within-subject (σ_{ε}^2 = 1.627) as well as between-subject (σ_0^2 = 0.534) variance with regard to momentary time pressure. The intra-class correlation coefficient was ϱ = 0.247, indicating that roughly 25% of the total variance in time pressure was due to differences on the participant level, whereas the remaining 75% was due to variance on the level of the individual measurements. The final model including time and treatment condition as predictors revealed a significant positive effect of the urban condition in relation to the control condition – a result which indicates that that participants in the urban slideshow condition provided significantly higher ratings for time pressure, compared to participants in the control condition (Table 3.8). In addition, the nature condition was close to reaching significance with a $p = 0.069$. Interestingly, the relationship between the nature condition and the control condition was positive as well, indicating that participants in the nature condition similarly had the tendency to experience more time pressure, compared to participants in the control condition. These results overall contradict hypothesis 1, which predicted that participants in the nature slideshow condition would experience lower levels of stress than participants in the urban slideshow or control condition, and indicates that watching slideshows was associated with increased stress instead. As with the dependent variable stress, the residuals on the measurement level, $W(1527) = 0.978$, $p < 0.000$, as well as on the person level, $W(1527) = 0.976$, $p < 0.000$, were significantly different from the normal distribution. Transforming the dependent variable did not restore normality. Furthermore, the equal variance assumption was violated for predictor treatment condition, as indicated by a significant Levene's test, $F(2, 1524) = 8.814$, $p < 0.000$. In addition, 3 outliers on the measurement level were identified with a standard deviation from the mean larger than 3. Removing these outliers did not considerably change the output presented in Table 3.8.

Table 3.8 Results for the multilevel model analysis with time pressure as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	2.474	0.200	0.000	[2.082, 2.867]
Time	0.001	0.002	0.607	[-0.003, 0.006]
Nature condition	0.494	0.272	0.069	[-0.039, 1.027]
Urban condition	0.540	0.273	**0.048**	[0.005, 1.075]
	Treatment condition relative to nature condition			
Intercept	2.969	0.200	0.000	[2.577, 3.360]
Time	0.001	0.002	0.607	[-0.003, 0.006]
Control condition	-0.494	0.272	0.069	[-1.027, 0.039]
Urban condition	0.046	0.272	0.866	[-0.488, 0.580]

Combining the two treatment groups and comparing the effect of treatment to the control group resulted in an even stronger positive main effect for treatment, as shown in Table 3.9. As in case of the previous analysis with separated treatment groups, the direction of the effect was such that participants in the treatment groups (nature slideshows and urban slideshows) experienced significantly more time pressure than participants in the control condition. Again, the residuals at the measurement level, $W(1527) = 0.978$, $p < 0.000$, as well as at the person level, $W(1527) = 0.976$, $p < 0.000$, were significantly different from the normal distribution. Data transformations were not successful at restoring normality. Furthermore, as indicated by a significant Levene's test, the equal variance assumption was violated for the predictor treatment condition, $F(2, 1524) = 8.802$, $p < 0.000$. In addition, there were 3 outliers on the measurement level with a standard deviation from the mean larger than 3. Removing these outliers did not considerably change the results reported in Table 3.9.

Table 3.9 Results for the multilevel model analysis with time pressure as a dependent variable and time (level one) and the pooled treatment conditions (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment conditions relative to control condition			
Intercept	2.474	0.201	0.000	[2.081, 2.867]
Time	0.001	0.002	0.606	[-0.003, 0.006]
Treatment condition	0.517	0.236	**0.028**	[0.054, 0.979]

3.2.2.3 Worry

Worry was measured with two seven-point Likert scale items eight times a day. The results for these two items were averaged. Adding a random intercept to the empty model split the total variance into a considerable amount of within-subject ($\sigma_\varepsilon^2 = 1.019$) as well as between-subject ($\sigma_0^2 = 0.743$) variance. The intra-class correlation coefficient was $\varrho = 0.422$, indicating that roughly 42% of the total variance in worry was due to differences on the participant level, whereas the remaining 58% was due to variance on the level of the individual measurements. For the final model, no significant effects were found, as shown in Table 3.10. This result is not in line with hypothesis 3, which predicted that participants in the nature slideshow condition would experience less worry than participants in the urban slideshow or control condition. The residuals on the measurement level, $W(1527) = 0.972$, $p < 0.000$, as well as on the person level, $W(1527) = 0.968$, $p < 0.000$, were again significantly different from the normal distribution. Data transformations were not successful at restoring normality. Additionally, a Levene's test indicated significant differences of variances between treatment groups, $F(2, 1524) = 68.655$, $p < 0.000$. While a total of 11 outliers were identified on the measurement level, removing these outliers did not considerably change the outcomes shown in Table 3.10.

Table 3.10 Results for the multilevel model analysis with worry as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	2.166	0.234	0.000	[1.707, 2.624]
Time	0.000	0.002	0.836	[-0.003, 0.004]
Nature condition	0.439	0.325	0.177	[-0.198, 1.075]
Urban condition	0.211	0.325	0.517	[-0.427, 0.848]
	Treatment condition relative to nature condition			
Intercept	2.604	0.234	0.000	[2.147, 3.062]
Time	0.000	0.002	0.836	[-0.003, 0.004]
Control condition	-0.439	0.325	0.177	[-1.075, 0.198]
Urban condition	-0.228	0.325	0.483	[-0.865, 0.409]

3.2.2.4 Mind-wandering

Mind-wandering was assessed with three binary yes versus no questions. First, participants were asked whether they had experienced any events since the previous questionnaire that caused negative emotions. Second, they were asked whether they had difficulties with controlling unwanted thoughts right before the notification for the current questionnaire. Third, they were asked whether their mind was wandering right before the notification. In order to analyze this binary data, three mixed-effects logit regression model analyses for binary outcomes were conducted. As with the multilevel analyses, a stepwise approach was chosen. First, a random intercept for participants was added, in order to model nesting of responses within participants. Subsequently, to test for a linear effect of time, the measurement level (level one) predictor time was added. Finally, the person level (level two) variable for treatment condition was added as a predictor, to test whether there were significant differences between groups. As in the previous analyses, two final models were estimated, one with the control condition as a reference category, and a second one with nature as a reference category. No random slopes were used, as it was hypothesized that the treatment condition would affect all participants in the same manner.

Negative emotions: Table 3.11 shows the results for the analysis with negative emotions as a dependent variable. The final model revealed that none of the predictors were able to explain a significant portion of the variance in the dependent variable.

Table 3.11 Results for the mixed-effects logit regression model analysis with negative emotions (0 = no, 1 = yes) as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Odds ratio	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	0.112	0.038	0.000	[0.057, 0.219]
Time	1.000	0.006	0.941	[0.988, 1.011]
Nature condition	0.984	0.435	0.970	[0.414, 2.339]
Urban condition	0.851	0.384	0.721	[0.351, 2.061]
	Treatment condition relative to nature condition			
Intercept	0.110	0.038	0.000	[0.056, 0.216]
Time	1.000	0.006	0.941	[0.988, 1.011]
Control condition	1.017	0.449	0.970	[0.428, 2.417]
Urban condition	0.865	0.390	0.748	[0.358, 2.092]

Unwanted thoughts: Similarly to the model for negative emotions, the final model with unwanted thoughts as a dependent variable did not find any significant results (Table 3.12).

Table 3.12 Results for the mixed-effects logit regression model analysis with unwanted thoughts (0 = no, 1 = yes) as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Odds ratio	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	0.070	0.031	0.000	[0.029, 0.167]
Time	0.999	0.007	0.910	[0.986, 1.013]
Nature condition	0.982	0.554	0.975	[0.325, 2.970]
Urban condition	0.415	0.250	0.144	[0.128, 1.349]
	Treatment condition relative to nature condition			
Intercept	0.069	0.030	0.000	[0.029, 0.160]
Time	0.999	0.007	0.910	[0.986, 1.013]
Control condition	1.018	0.575	0.975	[0.337, 3.078]
Urban condition	0.423	0.253	0.150	[0.131, 1.367]

Mind-wandering: For mind-wandering, a significant main effect for time was found, as shown in Table 3.13. More specifically, the results suggest that each one-step increase in time was associated with a 2% decrease in the odds of the occurrence of mind-wandering. Thus, there was a general decrease in mind-wandering over time for all participants. None of the other effects reached significance.

Table 3.13 Results for the mixed-effects logit regression model analysis with mind-wandering (0 = no, 1 = yes) as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Odds ratio	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	0.249	0.084	0.000	[0.129, 0.481]
Time	0.982	0.005	**0.000**	[0.973, 0.992]
Nature condition	1.617	0.707	0.272	[0.686, 3.811]
Urban condition	1.036	0.461	0.937	[0.433, 2.478]
	Treatment condition relative to nature condition			
Intercept	0.403	0.130	0.005	[0.214, 0.760]
Time	0.982	0.005	**0.000**	[0.973, 0.992]
Control condition	0.619	0.271	0.272	[0.262, 1.458]
Urban condition	0.641	0.280	0.309	[0.272, 1.509]

3.2.2.5 Happiness versus sadness

Participants rated their momentary happiness eight times a day on a seven-point semantic differential rating scale ranging from happy (1) to sad (7). Adding a random intercept to the empty model revealed that there was a considerable amount of within-subject (σ_ε^2 = 0.912) as well as between-subject (σ_0^2 = 0.416) variance with regard to momentary happiness. The intra-class correlation coefficient was found to be ϱ = 0.313, indicating that roughly 31% of the total variance in happiness was due to differences on the participant level, whereas the remaining 69% was due to variance on the level of the individual measurements. No significant results were found for the final model, as shown in Table 3.14. However, the coefficient for the urban condition was close to being significantly different from zero with p = 0.059. Interestingly, the relationship between the urban and the nature condition was negative, meaning that being part of the urban condition was associated with a lower score on the happiness versus sadness scale. Since happiness was on the lower side of the scale, this indicates that participants in the urban condition had the tendency to feel happier, compared to participants in the nature condition, a result which is contradictory to hypothesis 2, which predicted that participants in the nature slideshow condition would experience better mood than participants in the urban slideshow or the control condition. Importantly, the residual distributions on the measurement level, $W(1527) = 0. 980$, $p < 0.000$, as well as on the person level, $W(1527) = 0.953$, $p < 0.000$, were significantly different from the normal distribution. Transforming the dependent variable was not successful at restoring normality. Furthermore, a Levene's test on the person level indicated a violation of the equal variance assumption for the treatment groups, $F(2, 1524) = 9.416$, $p < 0.000$. In addition, 13 observations were identified on the measurement level with a standard deviation from the mean of more than 3. Removing these outliers from the analysis did not considerably change the results reported in Table 3.14.

Table 3.14 Results for the multilevel model analysis with happiness as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	2.881	0.176	0.000	[2.537, 3.225]
Time	0.002	0.002	0.323	[-0.002, 0.005]
Nature condition	0.233	0.241	0.332	[-0.239, 0.705]
Urban condition	-0.222	0.242	0.358	[-0.696, 0.252]
	Treatment condition relative to nature condition			
Intercept	3.114	0.175	0.000	[2.771, 3.458]
Time	0.002	0.002	0.323	[-0.002, 0.005]
Control condition	-0.233	0.241	0.332	[-0.705, 0.239]
Urban condition	-0.455	0.241	0.059	[-0.928, 0.017]

3.2.2.6 Relaxation versus tension

As with happiness, participants rated their momentary level of relaxation eight times a day on a seven-point semantic differential rating scale ranging from relaxed (1) to tense (7). Adding a random intercept to the empty model split the total variance into a considerable amount of within-subject ($\sigma_\varepsilon^2 = 1.319$) as well as between-subject ($\sigma_0^2 = 0.472$) variance. The intra-class correlation coefficient was found to be $\varrho = 0.263$, indicating that roughly 26% of the total variance in level of relaxation was due to differences on the participant level, whereas the remaining 74% was due to variance on the level of the individual measurements. As shown in Table 3.15, the final model including time and treatment condition as predictors did not reveal any significant results. Consequently, hypothesis 2, which predicted that participants in the nature slideshow condition would experience better mood than participants in the urban slideshow or the control condition, was not supported by the data. As in the previous analyses, there was a significant deviation from the normal distribution for both the residuals on the measurement level, $W(1527) = 0.982$, $p < 0.000$, as well as the person level, $W(1527) = 0.977$, $p < 0.000$. Data transformations were not successful at restoring normality. Furthermore, the equal variance assumption was violated for the treatment conditions, as indicated by a significant Levene's test, $F(2, 1524) = 9.001$, $p < 0.000$. In addition, there were 6 outliers with a standard deviation from the mean larger than 3. Running the analysis excluding the outliers did not reveal drastic changes in the outcomes presented in Table 3.15.

Table 3.15 Results for the multilevel model analysis with relaxation as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	2.914	0.196	0.000	[2.529, 3.299]
Time	0.000	0.002	0.999	[-0.004, 0.004]
Nature condition	0.126	0.268	0.639	[-0.399, 0.651]
Urban condition	-0.026	0.269	0.924	[-0.553, 0.501]
	Treatment condition relative to nature condition			
Intercept	3.040	0.196	0.000	[2.656, 3.423]
Time	0.000	0.002	0.999	[-0.004, 0.004]
Control condition	-0.126	0.268	0.639	[-0.651, 0.399]
Urban condition	-0.151	0.268	0.573	[-0.678, 0.375]

3.2.2.7 *Energy versus tiredness*

Participants also rated their momentary level of energy eight times a day on a seven-point semantic differential rating scale ranging from energetic (1) to tired (7). Adding a random intercept to the empty model revealed that there was a considerable amount of within-subject ($\sigma_\varepsilon^2 = 1.468$) as well as between-subject ($\sigma_0^2 = 0.377$) variance with regard to momentary level of energy. The intra-class correlation coefficient was found to be $\varrho = 0.204$, indicating that roughly 20% of the total variance in level of energy was due to differences on the participant level, whereas the remaining 80% was due to variance on the level of the individual measurements. In the final model, a significant positive main effect for time was found, indicating that over time, there was a general increase in tiredness for all participants (Table 3.16). In addition, the effect for urban condition was close to being significant with $p = 0.077$. Interestingly, this effect was negatively related to the nature condition. Since a high level of energy was on the lower side of the scale, this result indicates that participants in the urban condition had a tendency to feel more energetic than participants in the nature condition. Hypothesis 2, which predicted that participants in the nature slideshow condition would experience better mood than participants in the urban slideshow or the control condition, was thus again not supported by the data. Importantly, the normality assumption was violated for both the residuals on the measurement level, $W(1527) = 0.990$, $p < 0.000$, as well as for the residuals on the person level, $W(1527) = 0.876$, $p < 0.000$. Data transformations were not successful at restoring normality. A Levene's test further indicated significant differences of variances between treatment groups, $F(2, 1524) = 28.950$, $p < 0.000$. Furthermore, there were 3 outliers with a standard deviation from the mean of more than 3 on the measurement level as well as 79 outliers with a standard deviation larger than ±3 on the person level. Removing the outliers from the analysis on the measurement level did not considerably influence the results reported in Table 3.16. However, removing the outliers on the person level rendered the main effect for time non-significant at $p = 0.053$, further increased the p-value for the urban condition in relation to the nature condition to $p = 0.115$ and additionally revealed a significant main effect for the urban condition with regard to the control condition at $p = 0.035$.

Table 3.16 Results for the multilevel model analysis with energy level as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	3.328	0.175	0.000	[2.985, 3.671]
Time	0.006	0.002	**0.005**	[0.002, 0.011]
Nature condition	0.248	0.235	0.291	[-0.213, 0.710]
Urban condition	-0.168	0.237	0.477	[-0.632, 0.296]
	Treatment condition relative to nature condition			
Intercept	3.576	0.174	0.000	[3.235, 3.918]
Time	0.006	0.002	**0.005**	[0.002, 0.011]
Control condition	-0.248	0.235	0.291	[-0.710, 0.213]
Urban condition	-0.417	0.236	0.077	[-0.880, 0.046]

3.2.2.8 Anger and irritability

Anger and irritability were measured eight times a day with two seven-point Likert scale items. The results for these two items were averaged into a combined anger score. Adding a random intercept to the empty model split the total variance into a moderate amount of within-subject ($\sigma_\varepsilon^2 = 0.680$) and between-subject ($\sigma_0^2 = 0.341$) variance. The intra-class correlation coefficient was $\varrho = 0.334$, indicating that roughly 33% of the total variance in anger was due to differences on the participant level, whereas the remaining 67% was due to variance on the level of the individual measurements. Adding time (measurement level) and the treatment condition (person level) as predictors to the final model revealed no significant results, as shown in Table 3.17. Again, these outcomes are not in line with hypothesis 2, which predicted that participants in the nature slideshow condition would experience better mood than participants in the urban slideshow or the control condition. However, the normality assumption was violated for both the residuals on the measurement level, $W(1527) = 0.876$, $p < 0.000$, as well as for the residuals on the person level, $W(1527) = 0.959$, $p < 0.000$. Transforming the dependent variable was not successful at restoring normality. Furthermore, the equal variance assumption was violated for the treatment groups as well, as indicated by a significant Levene's test, $F(2, 1524) = 34.898$, $p < 0.000$. In addition, a total of 24 outliers on the measurement level with a standard deviation from the mean of more than 3 were identified. Removing the outliers did not considerably change the results presented in Table 3.17.

Table 3.17 Results for the multilevel model analysis with anger and irritability as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	1.838	0.163	0.000	[1.519, 2.158]
Time	0.001	0.002	0.520	[-0.002, 0.004]
Nature condition	0.037	0.225	0.868	[-0.403, 0.477]
Urban condition	-0.143	0.225	0.525	[-0.584, 0.298]
	Treatment condition relative to nature condition			
Intercept	1.876	0.163	0.000	[1.557, 2.194]
Time	0.001	0.002	0.520	[-0.002, 0.004]
Control condition	-0.037	0.225	0.868	[-0.477, 0.403]
Urban condition	-0.180	0.225	0.422	[-0.621, 0.260]

3.2.2.9 Well-being

In addition to the other questions, participants were prompted to rate their momentary well-being on a seven-point Likert scale eight times a day. Adding a random intercept to the empty model revealed that there was a considerable amount of within-subject ($\sigma_\varepsilon^2 = 1.052$) as well as between-subject ($\sigma_0^2 = 0.545$) variance with regard to momentary well-being. The intra-class correlation coefficient was $\varrho = 0.342$, indicating that roughly 34% of the total variance in well-being was due to differences on the participant level, whereas the remaining 66% was due to variance on the level of the individual measurements. The final model including time (measurement level) and treatment condition (person level) as predictors revealed a significant negative main effect for time and urban condition, as shown in Table 3.18. More specifically, participants experienced a decrease in well-being over time in general. Furthermore, in comparison to participants in the nature condition, participants in the urban condition gave higher ratings of well-being, a result which is contradictory to the hypotheses of this study. Importantly, the residuals on the measurement level, $W(1527) = 0.981$, $p < 0.000$, as well as on the person level, $W(1527) = 0.938$, $p < 0.000$, were both significantly different from the normal distribution. Data transformations on the dependent variable were not successful at restoring normality. Furthermore, there was a significant Levene's test for the treatment conditions, indicting a violation of the equal variances assumption, $F(2, 1524) = 11.333$, $p < 0.000$. In addition, there were 13 observations on the measurement level and 34 data points on the person level with a standard deviation from the mean larger than 3. Removing these outliers rendered the significant effects for time and urban condition non-significant at $p = 0.115$ and $p = 0.250$ respectively.

Table 3.18 Results for the multilevel model analysis with well-being as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	4.904	0.198	0.000	[4.515, 5.292]
Time	-0.004	0.002	**0.050**	[-0.007, -0.000]
Nature condition	-0.343	0.273	0.209	[-0.878, 0.192]
Urban condition	0.210	0.274	0.442	[-0.326, 0.747]
	Treatment condition relative to nature condition			
Intercept	4.561	0.198	0.000	[4.173, 4.949]
Time	-0.004	0.002	**0.050**	[-0.007, -0.000]
Control condition	0.343	0.273	0.209	[-0.192, 0.878]
Urban condition	0.553	0.273	**0.043**	[0.018, 1.089]

3.2.2.10 Self-control

Self-control was measured eight times a day with three seven-point Likert scale items. The items were averaged in order to obtain one value representing self-control. Adding a random intercept to the empty model split the total variance into a moderate amount of within-subject ($\sigma_\varepsilon^2 = 0.749$) as well as between-subject ($\sigma_0^2 = 0.430$) variance. The intra-class correlation coefficient was found to be $\varrho = 0.365$, indicating that roughly 37% of the total variance in self-control was due to differences on the participant level, whereas the remaining 63% was due to variance on the level of the individual measurements. As can be seen from Table 3.19, the final model did not find any significant results. However, the main effect for time was close to being significant with p = 0.055, indicating that there was a trend for all participants to experience a decrease in self-control over time. Importantly, the normality assumption was violated for both the residuals on the measurement level, $W(1527) = 0.993$, $p < 0.000$, as well as the residuals on the person level, $W(1527) = 0.924$, $p < 0.000$. Furthermore, the variances for the treatment groups were significantly different, as indicated by a Levene's test, $F(2, 1524) = 118.854$, $p < 0.000$. In addition, there were 8 outliers with a standard deviation from the mean below 3 for the measurement level as well as 48 observations with a standard deviation from the mean above 3 for the person level. While removing the outliers on the measurement level did not considerably change the outcomes presented in Table 3.19, deleting outliers on the person level led to a significant main effect for time at $p = 0.031$.

Table 3.19 Results for the multilevel model analysis with self-control as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	4.603	0.181	0.000	[4.247, 4.958]
Time	-0.003	0.002	0.055	[-0.006, 0.000]
Nature condition	-0.229	0.251	0.360	[-0.720, 0.262]
Urban condition	-0.199	0.251	0.427	[-0.691, 0.293]
	Treatment condition relative to nature condition			
Intercept	4.373	0.181	0.000	[4.019, 4.728]
Time	-0.003	0.002	0.055	[-0.006, 0.000]
Control condition	0.229	0.251	0.360	[-0.262, 0.720]
Urban condition	0.030	0.251	0.905	[-0.462, 0.521]

3.2.2.11 Morning questionnaire

Participants filled in the Karolinska Sleep Diary once per day during the morning. Sleep quality was measured with five items from the Karolinska Sleep Diary, each of which was represented as a five-point Likert scale ranging from 1 (very poor) to 5 (very good). Responses to the five items were averaged into a global index for sleep quality in which a rating of 1 represents lowest and a rating of 5 equals best possible sleep quality. As in case of the previous scales, a multilevel model analysis was conducted. Adding a random intercept to the empty model found rather small amounts of within-subject ($\sigma_\varepsilon^2 = 0.287$) as well as between-subject ($\sigma_0^2 = 0.087$) variance with regard to sleep quality. The intra-class correlation coefficient was $\varrho = 0.232$, indicating that roughly 23% of the total variance in well-being was due to differences on the participant level, whereas the remaining 77% was due to variance on the level of the individual measurements. As shown in Table 3.20, the final model with time (level one) and treatment condition (level two) as predictors revealed a significant negative main effect for time, indicating that sleep quality decreased from the beginning toward the end of the six-day-long experiment for all participants – a result which was unexpected. There was no effect for treatment condition. Importantly, the normality assumption was violated for both the residuals on the measurement level, $W(251) = 0.982$, $p = 0.003$, as well as the residuals on the person level, $W(251) = 0.964$, $p < 0.000$. A square root transformation was able to restore normality on the measurement level but not the person level. Results for the transformed dependent variable were comparable to the outcomes reported in Table 3.20. Furthermore, a significant Levene's test indicated that variances between treatment groups were significantly different, $F(2, 248) = 3.188$, $p = 0.043$. In addition, 3 outliers with a standard deviation from the mean larger than ±3 were found on the measurement level. Dropping these outliers from the analysis rendered the previously significant main effect for time non-significant at $p = 0.080$.

Table 3.20 Results for the multilevel model analysis with sleep quality as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	3.498	0.109	0.000	[3.284, 3.713]
Time	-0.040	0.020	**0.040**	[-0.079, -0.002]
Nature condition	-0.074	0.138	0.593	[-0.344, 0.197]
Urban condition	-0.006	0.138	0.968	[-0.276, 0.265]
	Treatment condition relative to nature condition			
Intercept	3.425	0.109	0.000	[3.210, 3.639]
Time	-0.040	0.020	**0.040**	[-0.079, -0.002]
Control condition	0.074	0.138	0.593	[-0.197, 0.344]
Urban condition	0.068	0.138	0.621	[-0.203, 0.339]

3.2.2.12 Evening questionnaire

In addition to the morning questionnaire in which participants rated the sleep quality of the previous night, participants further completed a short evening questionnaire at the end of each day. As part of this questionnaire, participants provided information about the number of hours they went sporting on the current day as well as the number of hours they spent outside. Furthermore, they indicated whether they had any exams. This data was analyzed traditionally with one-way between subjects ANOVAs. With regard to the total number of hours spent sporting, a one-way between subjects ANOVA revealed no significant differences between groups, $F(2, 39) = 0.382$, $p = 0.685$, $\omega_p^2 = -0.030$. Similarly, a one-way between subjects ANOVA with number of hours spent outside as a dependent variable did not find any significant results either, $F(2, 39) = 0.378$, $p = 0.687$, $\omega_p^2 = -0.031$. Furthermore, no significant differences between experimental groups were found for the total number of days on which participants had exams, as shown by the results of a one-way between subjects ANOVA, $F(2, 39) = 0.028$, $p = 0.972$, $\omega_p^2 = -0.049$.

As part of the evening questionnaire, participants further rated their satisfaction with the current day on a seven-point Likert scale ranging from 1 (not at all satisfied) to 7 (very satisfied). As with the previous EMA questionnaires, this data was analyzed using a two-level multilevel model. Adding a random intercept to the empty model revealed that there was a moderate amount of within-subject ($\sigma_\varepsilon^2 = 1.111$) as well as between-subject ($\sigma_0^2 = 0.409$) variance with regard to satisfaction with the current day. The intra-class correlation coefficient was $\varrho = 0.269$, indicating that roughly 27% of the total variance in satisfaction was due to differences on the participant level, whereas the remaining 73% was due to variance on the level of the individual measurements. According to the final model with time (level one) and treatment condition (level two) as predictors, no significant effects were found. The residuals on both the measurement level, $W(239) = 0.972$, $p < 0.000$, as well as the participant level, $W(239) = 0.971$, $p < 0.000$, had a distribution significantly different from normal. A square root transformation was successful at restoring normality at the measurement level but not the residual level. Importantly, the results for the analysis with the transformed variable as a dependent variable did not differ markedly from the results reported in Table 3.21. In addition, the equal variance assumption was violated for the treatment groups (person level), as indicated by a significant Levene's test, $F(2, 236) = 4.522$, $p = 0.012$.

Table 3.21 Results for the multilevel model analysis with satisfaction with the current day as a dependent variable and time (level one) and treatment condition (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	4.745	0.228	0.000	[4.299, 5.191]
Time	-0.019	0.040	0.629	[-0.097, 0.059]
Nature condition	0.067	0.289	0.818	[-0.501, 0.634]
Urban condition	0.312	0.291	0.283	[-0.258, 0.881]
	Treatment condition relative to nature condition			
Intercept	4.811	0.226	0.000	[4.368, 5.255]
Time	-0.019	0.040	0.629	[-0.097, 0.059]
Control condition	-0.067	0.289	0.818	[-0.634, 0.501]
Urban condition	0.245	0.291	0.399	[-0.325, 0.815]

3.2.2.13 Influence of gender imbalance on psychological variables

Given the substantial gender imbalance in the urban condition, which consisted of only 1 male and 13 female participants, all multilevel model analyses for the EMA questionnaires were repeated with gender as a predictor. In the majority of cases, no significant main effect for gender was found and adding gender as a predictor did not considerably influence the results reported in earlier sections. However, there were two exceptions with regard to mood. More specifically, there was a significant negative gender effect with regard to happiness versus sadness, indicating that male participants in comparison to female participants had lower scores on the happiness to sadness scale (Table 3.22). Since happiness was on the lower side of the scale, this result indicates that male participants were significantly happier than female participants. In addition, adding gender as a predictor rendered the previously marginally significant main effect for the urban condition in comparison to the nature condition strongly significant. The direction of the effect was such that participants in the urban slideshow condition felt significantly happier than participants in the nature slideshow condition. In addition, the main effect for urban condition in comparison to the control condition was close to significant with a p = 0.088, indicating a trend that participants in the urban condition felt happier than participants in the control condition. These results clearly contradict hypothesis 2, which predicted that participants in the nature slideshow condition would experience better mood than participants in the urban slideshow or the control condition. Importantly, both the residual distributions on the measurement level, $W(1527)$ = 0. 980, $p < 0.000$, as well as on the person level, $W(1527)$ = 0. 960, $p < 0.000$, were significantly different from the normal distribution. Data transformations were not successful at restoring normality. Furthermore, a significant Levene's test on the person level indicated a violation of the equal variance assumption for the treatment groups, $F(2, 1524) = 11.608$, $p < 0.000$. In addition, there were 14 observations at the measurement level with a standard deviation from the mean of more than ±3. Removing these outliers further increased the *p*-value for the urban condition in relation to the control condition to $p = 0.110$. The remaining results did not change considerably in comparison to the outcomes reported in Table 3.22.

Table 3.22 Results for the multilevel model analysis with happiness as a dependent variable and time (level one), treatment condition (level two) and gender (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
		Treatment condition relative to control condition		
Intercept	3.103	0.189	0.000	[2.733, 3.473]
Time	0.002	0.002	0.327	[-0.002, 0.005]
Nature condition	0.234	0.225	0.298	[-0.207, 0.676]
Urban condition	-0.406	0.239	0.088	[-0.874, 0.061]
Gender (male)	-0.520	0.214	**0.015**	[-0.939, -0.101]
		Treatment condition relative to nature condition		
Intercept	3.337	0.188	0.000	[2.968, 3.706]
Time	0.002	0.002	0.327	[-0.002, 0.005]
Control condition	-0.234	0.225	0.298	[-0.676, 0.207]
Urban condition	-0.641	0.238	**0.007**	[-1.108, -0.174]
Gender (male)	-0.520	0.214	**0.015**	[-0.939, -0.101]

In addition to the gender effect found for happiness versus sadness, there was also a significant negative main effect for gender for energy versus tiredness, as shown in Table 3.23. The direction of the effect was such that male participants had significantly lower scores on the energy versus tiredness scale, compared to female participants. Since high levels of energy were on the lower side of the scale, this result indicates that male participants felt significantly more energetic than female participants. Adding gender as a predictor furthermore rendered the previously marginally significant negative main effect for the urban condition in relation to the nature condition highly significant, indicating that participants watching urban slideshows felt more energetic than participants watching nature slideshows (Table 3.23). The positive main effect for time remained significant after adding gender as a predictor. Overall, these results contradict hypothesis 2, which predicted that participants in the nature slideshow condition would experience better mood than participants in the urban slideshow condition. As in case of the previous analyses, the normality assumption was violated for both the residuals at the measurement level, $W(1527) = 0.990$, $p < 0.000$, and the person level, $W(1527) = 0.884$, $p < 0.000$. Transforming the data was not successful at restoring normality. Furthermore, a significant Levene's test on the person level indicated a violation of the equal variance assumption for the treatment groups, $F(2, 1524) = 22.370$, $p < 0.000$. In addition, there were 3 observations at the measurement level as well as 34 observations on the person level with a standard deviation from the mean of more than ±3. Removing these outliers rendered all previously significant main effects non-significant: time at $p = 0.060$, gender at $p = 0.084$ and the urban condition in relation to the nature condition at $p = 0.089$.

Table 3.23 Results for the multilevel model analysis with energy level as a dependent variable and time (level one), treatment condition (level two) and gender (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	3.511	0.191	0.000	[3.137, 3.886]
Time	0.006	0.002	**0.005**	[0.002, 0.011]
Nature condition	0.250	0.225	0.267	[-0.191, 0.690]
Urban condition	-0.320	0.238	0.179	[-0.787, 0.147]
Gender (male)	-0.431	0.213	**0.044**	[-0.848, -0.013]
	Treatment condition relative to nature condition			
Intercept	3.761	0.190	0.000	[3.388, 4.134]
Time	0.006	0.002	**0.005**	[0.002, 0.011]
Control condition	-0.250	0.225	0.267	[-0.690, 0.191]
Urban condition	-0.569	0.238	**0.017**	[-1.036, -0.103]
Gender (male)	-0.431	0.213	**0.044**	[-0.848, -0.013]

In addition to the significant influence of gender on mood, there were two other variables where a gender effect was close to being significant: well-being and rumination. In case of well-being, as shown in Table 3.24, there was a marginally significant positive main effect for gender at $p = 0.052$, indicating a trend that male participants experienced significantly better well-being than female participants.

Table 3.24 Results for the multilevel model analysis with well-being as a dependent variable and time (level one), treatment condition (level two) and gender (level two) as predictors.

	Coefficient	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	4.698	0.218	0.000	[4.271, 5.125]
Time	-0.004	0.002	**0.050**	[-0.007, 0.000]
Nature condition	-0.344	0.261	0.188	[-0.856, 0.168]
Urban condition	0.381	0.276	0.168	[-0.161, 0.923]
Gender (male)	0.481	0.248	0.052	[-0.004, 0.967]
	Treatment condition relative to nature condition			
Intercept	5.079	0.192	0.000	[4.703, 5.456]
Time	-0.004	0.002	**0.050**	[-0.007, 0.000]
Control condition	-0.381	0.276	0.168	[-0.923, 0.161]
Urban condition	-0.725	0.276	**0.009**	[-1.266, -0.184
Gender (male)	0.481	0.248	0.052	[-0.004, 0.967]

With regard to rumination, there was a marginally significant positive main effect at p = 0.083 for gender in terms of the experience of negative emotions (Table 3.25). The direction of the effect was such that the odds for experiencing events that caused negative emotions for male participants were almost twice the odds for female participants. Thus, there was a trend for male participants to experience more events that triggered negative emotions than for female participants. In sum, gender had a significant effect on the results in two cases: happiness and level of energy. In addition, a trend toward a significant main effect of gender was found for well-being and rumination. Given that gender did not influence results in most cases, it can be concluded that there is little concern that the gender imbalance in the urban condition strongly influenced the outcomes with regard to the EMA questionnaires.

Table 3.25 Results for the mixed-effects logit regression model analysis with negative emotions (0 = no, 1 = yes) as a dependent variable and time (level one), treatment condition (level two) and gender (level two) as predictors.

	Odds ratio	***SE***	**p**	**95% *CI***
	Treatment condition relative to control condition			
Intercept	0.081	0.032	0.000	[0.038, 0.174]
Time	1.000	0.006	0.948	[0.988, 1.011]
Nature condition	0.998	0.429	0.995	[0.429, 2.319]
Urban condition	1.127	0.526	0.798	[0.451, 2.815]
Gender (male)	2.026	0.825	0.083	[0.912, 4.500]
	Treatment condition relative to nature condition			
Intercept	0.081	0.031	0.000	[0.038, 0.173]
Time	1.000	0.006	0.948	[0.988, 1.011]
Control condition	1.003	0.431	0.995	[0.431, 2.330]
Urban condition	1.130	0.524	0.793	[0.455, 2.803]
Gender (male)	2.026	0.825	0.083	[0.912, 4.500]

3.3 Heart rate variability analysis

The main goal of this section is to discuss the results of the multilevel model analysis for heart rate variability. Before describing the results in detail, a short descriptive overview is provided about the total number of valid R-R interval segments that were isolated from the data collected by the Polar H7 heart rate monitor.

3.3.1 Descriptive statistics

As described in the method section, three-minute-long R-R interval segments were selected for heart rate variability analysis before participants answered ecological momentary assessment questionnaires as well as before, during and after participants watched slideshows. Since the connection between the Polar H7 heart rate monitor and the tablet on which the R-R interval data was stored was at times disrupted, R-R interval segments could be isolated for a subset of the questionnaires answered and slideshows watched only. Furthermore, segments with more than 3% of artifacts had to be discarded. With regard to the R-R interval segments collected before answering a questionnaire, on average a total of 19.857 (*SD* = 9.792) valid R-R interval segments were isolated per participant, as shown in Table 3.26. For three participants, there were two or less R-R interval segments available. For all remaining participants, between 7 and 38 valid R-R interval segments were collected.

Table 3.26 Counts as well as means and standard deviations for the number of valid R-R interval segments collected before answering questionnaires.

	Overall (*N* = 42) *M (SD)*	**Control (*N* = 14)** *M (SD)*	**Nature slides (*N* = 14)** *M (SD)*	**Urban slides (*N* = 14)** *M (SD)*
Number of questionnaires answered	1527	512	555	460
Number of valid R-R interval segments	834	274	317	243
Average number of valid R-R interval segments	19.857 (9.792)	19.571 (10.675)	22.643 (10.285)	17.357 (8.215)

With regard to the R-R interval segments collected before, during and after watching a slideshow, valid R-R interval segments were isolated for 6.071 (*SD* = 3.610) slideshows per person, on average (Table 3.27). However, in order to be able compare heart rate variability before, during and after watching slideshows, at least two valid segments per slideshow were required. Slideshows with only one valid R-R interval segment were thus discarded from the analysis, leading to an average of 4.429 (*SD* = 2.999) slideshows per person with at least two valid R-R interval segments. For three participants, there were no slideshows with at least two valid segments. Of these, two were in the urban slideshow condition and one was in the nature slideshow condition. For all of the remaining participants, there were between 1 and 10 slideshows with at least two valid R-R interval segments available.

Table 3.27 Counts as well as means and standard deviations for the slideshows for which valid R-R interval segments could be extracted.

	Overall (*N* = 28) *M (SD)*	**Nature slides (*N* = 14)** *M (SD)*	**Urban slides (*N* = 14)** *M (SD)*
Number of slideshows watched	301	162	139
Number of slideshows with valid R-R interval segments	170	91	79
Average number of slideshows with valid R-R interval segments per person	6.071 (3.610)	6.500 (4.128)	5.643 (3.104)
Number of slideshows with more than one valid R-R interval segment	124	67	57
Average number of slideshows with more than one valid R-R interval segment	4.429 (2.999)	4.786 (3.286)	4.071 (2.759)
Average number of valid R-R interval segments per person	12.964 (8.002)	13.857 (8.865)	12.071 (7.259)

3.3.2 Multilevel model analysis

3.3.2.1 Physiological stress versus perceived stress

Before investigating whether heart rate variability differed for participants who watched nature slideshows versus participants who watched urban slideshows, it was explored whether there was a relationship between psychological measures of stress from the ecological momentary assessment questionnaire and the physiological measurements collected with the Polar H7 heart rate monitor. Thus, the goal was to investigate whether heart rate variability was an adequate measure for stress. In order to shed light on this question, separate multilevel model analyses were conducted with heart rate variability as a dependent variable and the psychological stress measures as level one (measurement level) predictors. For each of the multilevel model analyses conducted, the following stepwise approach was chosen: First, the empty model was calculated with heart rate variability as the dependent variable. In the next step, to model nesting within participants, a random intercept for participants was added. Finally, the respective psychological measure was added as a predictor at the measurement level (level one). No random slopes were used for this analysis.

Heart Rate: To analyze the relationship between heart rate and psychological stress, separate multilevel models were run for each of the following three psychological variables: stress, time pressure and worry. For the model with stress as a level one predictor, a significant positive main effect for stress was found, indicating that higher stress was associated with higher levels of heart rate (Table 3.28). Importantly, the residuals on the measurement level, $W(834) = 0.870$, $p < 0.000$, as well as on the person level, $W(834) = 0.954$, $p < 0.000$, were both significantly different from the normal distribution. Transforming the dependent variable was not successful at restoring normality. Furthermore, a total of 38 outliers with a standard deviation from the mean of more than 2 were identified. Removing these outliers did not considerably change the outcomes. As with the predictor for stress, for the model with time pressure as a level one predictor, a significant positive main effect was found, indicating that more time pressure was associated with increased heart rate (Table 3.28). Again, the distributions of the residuals at the measurement level, $W(834) = 0.877$, $p < 0.000$, as well as the residuals at the person level, $W(834) = 0.950$, $p < 0.000$, were significantly different from the normal distribution. Data transformations were not successful at restoring normality. In addition, 37 outliers with a standard deviation from the mean of more than 2 were found. Removing these outliers rendered the previously significant main effect for time pressure non-significant at $p = 0.082$. Finally, for the model with worry as a level one predictor, no significant effect was found (Table 3.28). As with the previous models, the residuals on the measurement level, $W(834) = 0.865$, $p < 0.000$, as well as the residuals at the person level, $W(834) = 0.946$, $p < 0.000$, were significantly different from normal. A total of 38 outliers with a standard deviation from the mean above 2 were identified. Removing these outliers did not dramatically change the outcomes reported in Table 3.28.

Table 3.28 Results for the multilevel model analysis with heart rate as a dependent variable.

	Coefficient	***SE***	**p**	**95% *CI***
		Results for the predictor stress		
Intercept	82.211	1.833	0.000	[78.619 85.804]
Stress	1.075	0.429	**0.012**	[0.233, 1.916]
		Results for the predictor time pressure		
Intercept	81.344	1.806	0.000	[77.805, 84.883]
Time pressure	1.323	0.391	**0.001**	[0.557, 2.089]
		Results for the predictor worry		
Intercept	85.528	1.800	0.000	[82.000, 89.055]
Worry	-0.163	0.503	0.746	[-1.148, 0.822]

SDNN: To analyze the relationship between SDNN and psychological stress, separate multilevel models were run for the variables stress, time pressure and worry. As shown in Table 3.29, none of the multilevel models revealed significant main effects. Thus, neither stress, nor time pressure, nor worry could explain significant portions of the variance in SDNN. For all of the three different models, both the residuals on the measurement level (level one) and the residuals on the person level (level two) were significantly different from the normal distribution. A square root transformation was successful at restoring normality for all three predictors on the measurement level. However, the results for the analysis with the transformed variable were not considerably different from the results presented in Table 3.29. In addition, for all three predictors, outliers with a standard deviation from the mean of more than ±2 were identified. For stress, 40 outliers were found, for time pressure 39 and for worry 40. Removing these outliers did not drastically change the outcomes of the analysis.

Table 3.29 Results for the multilevel model analysis with SDNN as a dependent variable.

	Coefficient	***SE***	**p**	**95% *CI***
		Results for the predictor stress		
Intercept	69.429	3.033	0.000	[63.485, 75.374]
Stress	-0.066	0.677	0.922	[-1.394 1.261]
		Results for the predictor time pressure		
Intercept	68.530	2.983	0.000	[62.684, 74.377]
Time pressure	0.252	0.626	0.687	[-0.975, 1.479]
		Results for the predictor worry		
Intercept	67.313	3.034	0.000	[61.366, 73.261]
Worry	0.809	0.792	0.307	[-0.742, 2.361]

RMSSD: To analyze the relationship between RMSSD and psychological stress, again separate multilevel models were run for each of the three psychological stress variables. The results showed a significant negative main effect for stress, indicating that higher stress was associated with lower levels of RMSSD (Table 3.30). Importantly, for the analysis involving the predictor stress, the normality assumption was violated for both the residuals on the measurement level (level one), $W(834) = 0.986$, $p < 0.000$, as well as the residuals on the person level (level two), $W(834) = 0.969$, $p < 0.000$. Data transformations were not successful at restoring normality. In addition, 45 outliers with a standard deviation from the mean of more than ±2 were found. Removing the outliers rendered the significant main effect for stress non-significant at $p = 0.186$. For the analysis including time pressure as a predictor, no significant effects were found. However, the main effect for time pressure was close to significant with a $p = 0.081$. As in the case of the predictor stress, the relationship with RMSSD was negative, indicating a tendency of higher levels of time pressure to be associated with lower levels of RMSSD. Again, both the residuals on the measurement level (level one), $W(834) = 0.987$, $p < 0.000$, as well as the residuals on the person level (level two), $W(834) = 0.967$, $p < 0.000$, were significantly different from the normal distribution. Transforming the dependent variable was not successful at restoring normality. Also, 43 outliers with a standard deviation from the mean larger than ±2 could be found. Dropping these outliers rendered the main effect for time pressure highly non-significant at $p = 0.447$. Finally, no significant effects were found for the model involving worry as a predictor, as shown in Table 3.30. As with the previous analyses, both the residuals on the measurement level (level one), $W(834) = 0.986$, $p < 0.000$, as well as the residuals on the person level (level two), $W(834) = 0.967$, $p < 0.000$, were significantly different from the normal distribution. Transforming the dependent variable was not successful at restoring normality. Furthermore, a total of 46 observations with a standard deviation from the mean larger than ±2 were identified. Dropping these outliers did not considerably influence the results reported in Table 3.30.

Table 3.30 Results for the multilevel model analysis with RMSSD as a dependent variable.

	Coefficient	***SE***	**p**	**95% *CI***
		Results for the predictor stress		
Intercept	35.818	2.231	0.000	[31.445, 40.190]
Stress	-0.827	0.400	**0.039**	[-1.610, -0.044]
		Results for the predictor time pressure		
Intercept	35.374	2.189	0.000	[31.083, 39.664]
Time pressure	-0.637	0.365	0.081	[-1.351, 0.078]
		Results for the predictor worry		
Intercept	33.949	2.212	0.000	[29.614, 38.284]
Worry	-0.174	0.474	0.713	[-1.103, 0.754]

3.3.2.2 Influence of watching slideshows on heart rate variability

In order to investigate whether watching slideshows positively influenced heart rate variability, a three-level multilevel model analysis was conducted with the individual measurements collected before, during and after watching a slideshow on the lowest level (level one). These individual measurements were nested within slideshows (each measurement was related to a specific slideshow), which formed the second level. The slideshows were themselves again nested within participants (level three). As with the previous models, a stepwise model-building approach was chosen. First, random intercepts were added in order to model the nesting of measurements within slideshows within participants. Next, the measurement level (level one) predictor time, as measured by the index of the segment in relation to the slideshow (before the slideshow = 0, during the slideshow = 1 and after the slideshow = 2), was added, in order to test for the presence of a linear effect of time. Finally, the person level (level two) variable for treatment condition was added as a predictor, in order to test whether there were significant differences between groups with respect to the dependent variable. Since this analysis was conducted with a subset ($N = 28$) of all participants that were either part of the nature or urban slideshow condition, no dummy variables for encoding the condition were required. Due to disruption of the data collection, valid R-R interval segments were available for a subset of the slideshows watched only. For this reason, three analyses were conducted: In the first analysis, heart rate variability was analyzed for slideshows for which all three measurements (before, during and after watching a slideshow) were available. Then, a comparison of heart rate variability before versus during watching a slideshow was conducted. Finally, heart rate variability was compared before versus after watching a slideshow.

Heart rate variability before, during and after watching a slideshow: Valid heart rate variability recordings before, during as well as after watching a slideshow were available for 22 of the in total 28 participants. The participants were equally balanced with regard to the treatment condition, with 11 participants in the nature and 11 participants in the urban condition. The total number of slideshows for which valid before- during- and after-recordings were available was 69 (M = 3.136, SD = 1.583). There were five participants for which valid HRV data was available for only one slideshow.

With regard to the model for heart rate, adding a random intercept partitioned the total variance into a rather small amount of person-level variance (σ_v^2 = 7.872) as well as considerable amounts of slideshow-level variance (σ_u^2 = 84.761) and within-subject variance (σ_ε^2 = 60.679). Calculating the variance partition coefficients showed that around 5% (VPC_v = 0.051) of the total variance in heart rate was located between participants (person level), 55% (VPC_u = 0.553) of the total variance was found between slideshows and 40% (VPC_e = 0.396) of the total variance was on the level of the measurements. The final model including time and treatment condition as predictors revealed a significant negative main effect for time, indicating that heart rate slightly decreased over time for both participants in the nature condition and participants in the urban condition (Table 3.31). No significant effect for the treatment conditions was found. While it was expected that heart rate would be lower during and after watching the slideshows for participants in the nature condition, no such differences were expected for participants in the urban slideshow condition. Consequently, hypothesis 4a was not supported by the results. The distribution of the residuals was significantly different from the normal distribution on all three levels. Data transformations were not successful at restoring normality. In addition, the homogeneity of variance was violated on the measurement level, as shown by a significant Levene's test, $F(2, 204) = 3.786$, $p = 0.024$. A total of 7 outliers on the measurement level, 9 outliers on the slideshow level and 9 outliers on the person level with a standard deviation above 2 were identified. Removing these outliers did not drastically influence the results presented in Table 3.31.

With regard to SDNN, adding a random intercept split the total variance into considerable amounts of person-level variance (σ_v^2 = 104.839), slideshow-level variance (σ_u^2 = 174.841) and within-subject variance (σ_ε^2 = 349.743). The variance partition coefficients indicated that around 17% (VPC_v = 0.167) of the total variance in SDNN was located between participants (person level), 28% (VPC_u = 0.278) of the total variance was found between slideshows and 56% (VPC_e = 0.556) of the total variance was on the level of the measurements. For the final model, a significant positive main effect for nature was found, indicating that participants in the nature condition had significantly higher SDNN before, during and after watching the slideshow, compared to participants in the urban condition (Table 3.31). No linear main effect for time was found. While it was predicted that participants in the nature slideshow condition would experience higher SDNN than participants in the urban slideshow condition, there was no significant increase of SDNN over time. The results are thus only partially in line with hypothesis 4c. The normality assumption for the residuals was again violated at all three levels. A logarithmic transformation of the dependent variable was successful at restoring normality at the measurement level and the slideshow level but not the person level. Importantly, the effect for nature remained significant despite the transformation. A total of 9 outliers on the measurement level as well as 9 outliers on the slideshow level with a standard deviation from the mean of more than ±2 could be identified. Removing the outliers did not considerably change the outcomes reported in Table 3.31.

Finally, with regard to the model for RMSSD, adding a random intercept partitioned the total variance into a moderate amount of person-level variance ($\sigma_v^2 = 31.710$) as well as considerable amounts of slideshow-level variance ($\sigma_u^2 = 139.162$) and within-subject variance ($\sigma_\varepsilon^2 = 63.296$). The variance partition coefficients indicated that around 14% ($VPC_v = 0.135$) of the total variance in RMSSD was located between participants (person level), 59% ($VPC_u = 0.594$) of the total variance was found between slideshows and 27% ($VPC_e = 0.270$) of the total variance was on the level of the measurements. The final model revealed no significant effects, as shown in Table 3.31. However, the main effect for time was close to being significant with a $p = 0.052$, indicating that there was a tendency for both participants in the nature condition as well as participants in the urban condition to experience an increase of RMSSD over time. Overall, these results provide no support for hypothesis 4b, which predicted that participants in the nature but not the urban slideshow condition would experience higher RMSSD during and after watching the slideshows, compared to before watching the slideshows. Importantly, the normality assumption for the residuals was violated at all three levels. Transforming the dependent variable was not successful at restoring normality. Also, the homogeneity of variance assumption was violated at the person level for treatment condition, as indicated by a significant Levene's test, $F(1, 205) = 26.605$, $p < 0.000$. A total of 9 outliers on the measurement level, 9 outliers on the slideshow level, as well as 15 outliers on the person level with a standard deviation from the mean of more than ±2 were furthermore found. Removing these outliers further increased the *p*-value for time, rendering it highly non-significant at $p = 0.575$.

Table 3.31 Results for the three-level multilevel model analysis for HRV recordings before versus during versus after slideshows.

	Coefficient	***SE***	**p**	**95% *CI***
		Dependent variable: heart rate		
Intercept	83.567	2.117	0.000	[79.419, 87.716]
Time	-1.281	0.654	**0.050**	[-2.563, 0.001]
Nature condition	0.138	2.797	0.961	[-5.345, 5.620]
		Dependent variable: SDNN		
Intercept	59.317	4.281	0.000	[50.926, 67.708]
Time	0.318	1.592	0.842	[-2.802, 3.437]
Nature condition	13.885	5.554	**0.012**	[2.998, 24.771]
		Dependent variable: RMSSD		
Intercept	29.494	2.823	0.000	[23.960, 35.027]
Time	1.299	0.668	0.052	[-0.011, 2.608]
Nature condition	5.513	3.824	0.149	[-1.983, 13.008]

Note. Time was represented as follows: before-slideshow (=0), during-slideshow (=1) and after-slideshow (=2)

Heart rate variability before versus during watching a slideshow: Valid heat rate variability recordings before and during watching a slideshow were available for 24 of the in total 28 participants. Of these, 13 participants were part of the nature slideshow condition, whereas 11 were assigned to the urban slideshow condition. The total number of slideshows for which valid before- and after-recordings were available was 103 (M = 4.292, SD = 2.368). There were four participants for which valid segments were available for only one slideshow.

With regard to the model for heart rate, adding a random intercept partitioned the total variance into considerable amounts of person-level variance (σ_v^2 = 50.572), slideshow-level variance (σ_u^2 = 90.425) as well as within-subject variance (σ_ε^2 = 71.164). Calculating the variance partition coefficients showed that around 24% (VPC_v = 0.238) of the total variance in heart rate was located between participants (person level), 43% (VPC_u = 0.426) of the total variance was found between slideshows and 34% (VPC_e = 0.335) of the total variance was on the level of the measurements. As shown in Table 3.32, the final model revealed a significant negative main effect for time, indicating a decrease of heart rate while watching the slideshows for all participants. No main effect for treatment condition was found. Again, these results provide no support for hypothesis 4a. While it was expected that heart rate would be lower during compared to before watching the slideshows for participants in the nature slideshow condition, no such differences were expected for the urban slideshow condition. Importantly, the normality assumption for the residuals was violated at all three levels. Transforming the dependent variable was not successful at restoring normality. Furthermore, conducting Levene's tests showed that the homogeneity of variance assumption was violated at the measurement level for time, $F(1, 204) = 5.134$, $p = 0.025$, as well as at the person level for treatment condition, $F(1, 204) = 7.002$, $p = 0.009$. In addition, 4 outliers with a standard deviation from the mean of more than ±2 were identified at the measurement level, 10 outliers at the slideshow level and 6 outliers at the person level. Removing the outliers from the analysis did not drastically influence the results reported in Table 3.32.

With regard to SDNN, adding a random intercept split the total variance into considerable amounts of person-level variance ($\sigma_v^2 = 188.331$), slideshow-level variance ($\sigma_u^2 = 193.410$) and within-subject variance ($\sigma_\varepsilon^2 = 290.342$). The variance partition coefficients indicated that around 28% ($VPC_v = 0.280$) of the total variance in SDNN was located between participants (person level), 29% ($VPC_u = 0.288$) of the total variance was found between slideshows and 43% ($VPC_e = 0.432$) of the total variance was on the level of the measurements. Calculating the final model, it was found that the main effect for time was significant, whereas the main effect for treatment condition was not (Table 3.32). The direction of the effect for time was such that SDNN decreased while watching the slideshow for all participants, in comparison to before watching the slideshow. This result contradicts hypothesis 4c, which predicted that for participants in the nature slideshow condition, SDNN would increase while watching slideshows, compared to before watching slideshows. The residuals at all levels were again distributed significantly different from the normal distribution. A logarithmic transformation of the dependent variable was successful at restoring normality for the residuals at the measurement level and the slideshow level, but not at the person level. Importantly, the transformation did not considerably change the outcomes reported in Table 3.32. Furthermore, the equal variance assumption was found to be violated at the person level for treatment condition, as indicated by a significant Levene's test, $F(1, 204) = 19.944$, $p < 0.000$. Outliers were identified for the measurement level (7), the slideshow level (4) as well as the person level (4). While the main effect for time was still present after dropping the outliers, additionally a significant positive main effect for treatment condition appeared. The effect for treatment condition was such that participants in the nature condition had significantly higher values for SDNN in general, compared to participants in the urban condition. It is important to note that this result might have been caused due to an imbalance in the number of participants in the nature condition versus the urban condition introduced by deleting cases.

Finally, with regard to the model for RMSSD, adding a random intercept partitioned the total variance into a moderate amount of person-level variance ($\sigma_v^2 = 58.686$) as well as considerable amounts of slideshow-level variance ($\sigma_u^2 = 133.308$) and within-subject variance ($\sigma_\varepsilon^2 = 83.002$).

The variance partition coefficients indicated that around 21% (VPC_v = 0.213) of the total variance in RMSSD was located between participants (person level), 49% (VPC_u = 0.485) of the total variance was found between slideshows and 30% (VPC_e = 0.302) of the total variance was on the level of the measurements. As with the previous analyses, a significant main effect for time was found, indicating that RMSSD increased while watching slideshows for all participants, in comparison to RMSSD measurements before watching the slideshow (Table 3.32). There was no main effect for treatment condition. While it was predicted that RMSSD would increase during compared to before watching slideshows primarily for participants in the nature slideshow condition, no such results were expected for participants in the urban slideshow condition. The results are thus not in line with hypothesis 4b. Again, the normality assumption for the residuals was violated at all three levels. A square root transformation was successful at restoring normality of the residuals at the slideshow level but not at the other two levels. Importantly, the results including the transformed dependent variable were comparable to the results presented in Table 3.32. Furthermore, the equal variance assumption was violated for the treatment conditions at the person level, as indicated by a significant Levene's test, $F(1, 204) = 11.183$, $p < 0.000$. In addition, a total of 6 outliers with a standard deviation from the mean larger than ±2 were identified at the measurement level, 10 outliers at the slideshow level and 4 outliers at the person level. Dropping the outliers rendered the previously significant main effect for time non-significant at $p = 0.133$.

Table 3.32 Results for the three-level multilevel model analysis for HRV recordings before versus during slideshows. Time was represented as follows: before-slideshow (=0) and during-slideshow (=1).

	Coefficient	***SE***	**p**	**95% *CI***
		Dependent variable: heart rate		
Intercept	86.433	2.793	0.000	[80.959, 91.908]
Time	-5.169	1.059	**0.000**	[-7.245, -3.092]
Nature condition	-2.915	3.768	0.439	[-10.301, 4.471]
		Dependent variable: SDNN		
Intercept	63.149	5.004	0.000	[53.341, 72.956]
Time	-5.712	2.307	**0.013**	[-10.234, -1.191]
Nature condition	9.538	6.690	0.154	[-3.574, 22.650]
		Dependent variable: RMSSD		
Intercept	28.885	2.999	0.000	[23.006, 34.763]
Time	3.262	1.228	**0.008**	[0.855, 5.669]
Nature condition	5.881	4.033	0.145	[-2.024, 13.786]

Heart rate variability before versus after watching a slideshow: Valid heart rate variability recordings before and after watching a slideshow were available for 23 of the in total 28 participants. Of these, 11 participants were assigned to the nature slideshow condition, whereas 12 participants were part of the urban slideshow condition. The total number of slideshows for which valid before- and after-recordings were available was 78 (M = 3.391, SD = 1.803).

With regard to the model for heart rate, adding a random intercept partitioned the total variance into a very small amount of person-level variance (σ_v^2 = 3.964) as well as considerable amounts of slideshow-level variance (σ_u^2 = 88.548) and within-subject variance (σ_ε^2 = 67.904). Calculating the variance partition coefficients showed that only around 2% (VPC_v = 0.0247) of the total variance in heart rate was located between participants (person level), 55% (VPC_u = 0.552) of the total variance was found between slideshows and 42% (VPC_e = 0.423) of the total variance was on the level of the measurements. As shown in Table 3.33, no significant main effects were found for the final model. The main effect for time, however, was close to reaching significance, indicating a trend (p = 0.077) of both participants in the nature as well as participants in the urban condition to have a lower heart rate after watching slideshows, as compared to before. These results thus provide no support for hypothesis 4a, which predicted that participants in the nature but not the urban slideshow condition would experience lower heart rate after watching the slideshows, compared to before watching the slideshows. Importantly, the residuals for all levels were significantly different from the normal distribution. A logarithmic transformation of the dependent variable was able to restore normality for the residuals on the measurement level, but not for the slideshow or person level. Furthermore, 3 outliers with a standard deviation larger than ±2 were identified at the measurement level as well as 4 outliers on the slideshow level. Removing the outliers from the analysis further increased the p-value of the negative main effect for time to p = 0.123. The remaining results were similar to the results reported in Table 3.33.

With regard to SDNN, adding a random intercept split the total variance into considerable amounts of person-level variance (σ_v^2 = 100.376), slideshow-level variance (σ_u^2 = 202.826) and within-subject variance (σ_ε^2 = 450.089). The variance partition coefficients indicated that around 13% (VPC_v = 0.133) of the total variance in SDNN was located between participants (person level), 27% (VPC_u = 0.269) of the total variance was found between slideshows and 60% (VPC_e = 0.597) of the total variance was on the level of the measurements. The final model revealed a significant main effect for the nature condition, showing that participants watching nature slideshows had generally higher values for SDNN, compared to participants in the urban condition (Table 3.33). This result is partially in line with hypothesis 4c, which predicted that SDNN would be higher after compared to before watching slideshows for participants in the nature slideshow condition only. As with the previous analysis, the normality assumptions were violated for the residuals on all three levels. A logarithmic transformation of the dependent variable was successful at restoring normality of the residuals at the measurement level and the slideshow level but not the person level. The significant result found for the nature condition remained significant despite the data transformation. In addition, there were 5 outliers at the measurement level as well as 8 outliers at the level of the slideshows. Results for the analysis excluding the outliers were comparable to the results reported in Table 3.33.

Finally, with regard to the model for RMSSD, adding a random intercept partitioned the total variance into considerable amounts of person-level variance (σ_v^2 = 53.107), slideshow-level variance (σ_u^2 = 79.477) and within-subject variance (σ_ε^2 = 123.729). The variance partition coefficients indicated that around 21% (VPC_v = 0.207) of the total variance in RMSSD was located between participants (person level), 48% (VPC_u = 0.483) of the total variance was found between slideshows and 31% (VPC_e = 0.310) of the total variance was on the level of the measurements. For the final model including time and treatment condition as predictors, no significant effects were found, as shown in Table 3.33. These results contradict hypothesis 4b, which predicted that participants in the nature slideshow condition would experience significantly higher RMSSD after compared to before watching slideshows. Importantly, the distribution of the residuals at all three levels was significantly different from the normal distribution. A square root transformation was able to restore normality for the slideshow-level residuals but not for the other two levels. The transformation did not drastically influence the outcomes of the analysis reported in Table 3.33. Furthermore, the homogeneity of variance assumption was violated for the treatment condition on the person level. In addition, outliers with a standard deviation from the mean of more than ±2 were identified at the measurement level (3), the slideshow level (6) and the person level (12). Removing the outliers from the analysis did not markedly influence the results shown in Table 3.33.

Table 3.33 Results for the three-level multilevel model analysis for HRV recordings before versus after slideshows.

	Coefficient	***SE***	**p**	**95% *CI***
		Dependent variable: heart rate		
Intercept	84.261	1.998	0.000	[80.346, 88.177]
Time	-2.289	1.294	0.077	[-4.825, 0.247]
Nature condition	-0.249	2.673	0.926	[-5.488, 4.990]
		Dependent variable: SDNN		
Intercept	63.419	4.407	0.000	[54.782, 72.057]
Time	-0.253	3.397	0.941	[-6.911, 6.406]
Nature condition	14.394	5.763	**0.012**	[3.099, 25.689]
		Dependent variable: RMSSD		
Intercept	30.107	3.053	0.000	[24.123, 36.092]
Time	2.105	1.407	0.135	[-0.653, 4.864]
Nature condition	5.548	4.227	0.189	[-2.736, 13.832]

Note. Time was represented as follows: before-slideshow (=0) and after-slideshow (=1)

3.3.2.3 *Influence of gender imbalance on heart rate variability*

Given the substantial gender imbalance in the urban condition, which consisted of only 1 male and 13 female participants, and the known influence of gender on heart rate variability (Bonnemeier et al., 2003; Jensen-Urstad et al., 1997; Stein et al., 1997; Umetani et al., 1998), all analyses with heart rate variability were repeated including gender as a person-level predictor. In almost all cases, no significant main effect for gender was found and adding gender as a predictor did not considerably influence the results reported in earlier sections. However, there was one exception: For the heart rate variability analysis comparing RMSSD before versus during watching a slideshow, a significant negative main effect for gender was found, as shown in Table 3.34. This result indicates that male participants experienced significantly lower RMSSD before as well as during watching a video. A significant main effect for gender was found only for RMSSD. With regard to heart rate and SDNN, there were no differences between male and female participants. Interestingly, in comparison to the analysis run excluding gender as a predictor, adding gender further revealed a significant positive main effect for the nature condition with respect to the urban condition, indicating that participants in the nature condition experienced significantly higher RMSSD before as well as during watching slideshows, compared to participants in the urban condition. A significant positive main effect for time was still present after adding gender as a predictor. Thus, despite adding gender, previously significant main effects remained significant. These results are generally in line with hypothesis 4b, which predicted that RMSSD for participants in the nature condition would be higher during and after watching slideshows, compared to before watching slideshows. Importantly, as in case of the previous analyses, the normality assumption was violated at all three levels. A square root transformation was successful at restoring normality at the person and the slideshows level, but not at the measurement level. The transformation did not drastically influence the outcomes of the analysis reported in Table 3.34. Furthermore, the equal variance assumption was violated for the treatment conditions at the person level, as indicated by a significant Levene's test, $F(1, 204) = 7.390$, $p = 0.007$. In addition, there were 6 outliers at the person level, 11 outliers at the slideshow level as well as 6 outliers at the measurement level. Removing these outliers rendered the previously significant main effect for time non-significant at $p = 0.129$. The main effects for the nature condition and gender remained significant. In sum, gender had a significant effect on the results only in case of the heart rate variability analysis comparing RMSSD before versus during watching a slideshow. Given that gender did not influence results in most cases, there is little concern that the gender imbalance in the urban condition strongly influenced the outcomes with regard to heart rate variability.

Table 3.34 Results for the three-level multilevel model analysis for RMSSD before versus during slideshows including gender as a predictor.

	Coefficient	***SE***	**p**	**95% *CI***
		Dependent variable: RMSSD		
Intercept	30.275	2.692	0.000	[24.999, 35.550]
Time	3.262	1.228	**0.008**	[0.855, 5.669]
Nature condition	8.008	3.655	**0.028**	[0.844, 15.172]
Gender (male)	-9.591	4.220	**0.023**	[-17.862, -1.321]

Note. Time was represented as follows: before-slideshow (=0) and during-slideshow (=1)

3.4 Qualitative analysis

During the second meeting of the experiment, a short interview was conducted. Participants were asked about their overall impression of the experiment, their experience with the apps and devices, as well as their opinion about the questionnaires (for an overview of the interview questions, see Appendix D). Participants in the treatment conditions (either nature slideshows or urban slideshows) were furthermore asked about their opinion of the slideshows that they were asked to watch.

3.4.1 Workload and inference with daily life

Interviews revealed important information with regard to the question of how much participation in the experiment interfered with daily life. The majority of the participants described their overall experience with the experiment as positive. According to the participants, their participation in the experiment did not substantially interfere with their regular lifestyle and they described the experiment as convenient. However, there were a few participants (a total of four) who mentioned that the experiment was different from their expectations in terms of workload. For some, the workload was higher than expected whereas others described the experiment as easier than they had expected prior to the experiment:

> *"However, I had different expectations with regard to the length of the questionnaires. I thought that the questionnaires that I had to fill in during the day were quite long and the questionnaires that I had to fill in in the morning and evening were quite short." (Male, 21, Control)*

> *"It was all very clear. From the email it seemed like it would be a lot more work, with all the notifications and stuff, but it wasn't that bad." (Female, 21, Urban)*

Furthermore, a small number of participants (a total of five) mentioned that the participation in the experiment added to their mental workload, in the sense that it kept them busy in their heads almost constantly. The following comments therefore illustrate that the very nature of the experiment may have increased certain participants' stress levels:

> *"I frequently checked whether the heart rate monitor was still connected with the tablet, so this thought was constantly in my head." (Female, 24, Nature)*

> *"You are busy with it in your head all day long, unconsciously. Maybe I got a bit more stressed because of that." (Female, 20, Nature)*

None of the participants mentioned adjusting their own schedules in order to facilitate the participation in the experiment. However, a few participants (a total of nine) explained that the experiment did not fit their sleep-wake rhythm, especially in the weekends. As a result, participants were for example woken up by the tablet or they missed questionnaires in the early morning because they were sleeping in:

"In the weekend the tablet woke me up. I then immediately filled in the questionnaires, but of course I did not wear the heart rate monitor yet, thus that did not make that much sense, I think." (Female, 24, Nature)

"I only did this [ignoring a questionnaire] in the morning when I was still asleep. Then I stopped the alarm and thought 'I'll fill it in later' and then it was an hour later." (Male, 22, Nature)

"Furthermore, I am a night owl, and because the questionnaires stop a nine o'clock in the evening already, yeah… that wasn't really ideal for me. It would have been better for me to stop at midnight." (Male, 18, Control)

Interestingly, one participant appreciated the rigid schedule of the experiment, as it helped her to maintain a healthier sleep-wake rhythm:

"Especially, because right now with my graduation project, I have quite irregular working hours and because I had to fill in the morning and evening questionnaire, I still had some sort of rhythm. Thus, that was nice [laughing]." (Female, 24, Nature)

During the interviews, participants were also asked about their experience with the notification system of the questionnaire application and the degree to which they were distracted by receiving eight notifications per day. The interviews revealed that the majority of the participants were content with the frequency of the notifications. Knowing the exact number of notifications upfront helped some of the participants (a total of nine) to mentally prepare themselves for their task.

"It was fine. There was quite some time between the questionnaires. It wasn't annoying or anything like that." (Female, 20, Urban)

"However, that was because I knew upfront that the notifications were coming, so I could prepare myself. I knew that the notification could go off any time." (Female, 21, Urban)

While none of the participants were overwhelmed by the amount of notifications, some (a total of 10) remarked that they would not appreciate having more than eight notifications per day:

"It should not have been much more often, because then it would be too irritating or annoying. However, like this, it was still ok." (Female, 21, Control)

When being asked whether the participants experienced the notifications as distracting or disturbing, the majority of the participants denied. Nevertheless, a few participants (in total 16) mentioned that the notifications sometimes distracted them from their current task:

> *"Yeah, there were a few times where I was highly focused on my work and where I tried to work out a problem. All of a sudden, I had to fill in the questionnaire, thus I thought something like 'Damn, fill it in quickly!'" (Female, 21, Nature)*

> *"Yeah, and sometimes I was very busy trying to figure out something and then you all of a sudden get a notification and think: 'Argh, does this have to be now as well?!'" (Male, 22, Control)*

Furthermore, some participants (a total of eight) mentioned that hearing the notifications actually increased their stress levels or that it sometimes was a startling experience:

> *"I think, if you are asked to say how you are feeling, then the alarm tone influences how you are feeling as well, thus it is not 100% neutral. […] At some moments I was very relaxed and then you hear this thing [the tablet] and then you feel a bit stressed just because of that." (Male, 20, Nature)*

> *"However, sometimes it was difficult to think about how I felt before the notification. Cause the notifications are startling, and this feeling then dominates a little bit. Alarms easily startle me." (Female, 21, Control)*

A few participants (a total of nine) also provided feedback with regard to the sound of the notification itself. Specifically, there were two participants which enjoyed the sound of the notification, as the following comment illustrates:

> *"I thought it was a nice sound. I could easily discriminate it from other sounds." (Male, 48, Control)*

However, the larger part of the participants (a total of five) experienced the notification sound as negative. They described the sound as frustrating, sleepy or they associated it with the sound of an alarm clock:

> *"It's not that filling in the questionnaire is the problem, more that the sound of the tablet was frustrating. Maybe a different sound would be better. A friend of mine has this sound as an alarm clock sound. […] It's just one of these alarm sounds; it's not a happy sound or something like that." (Female, 21, Nature)*

> *"Also, that sound you hear every time you get a notification! After a while I started thinking 'Ugh, there it is again…'" (Female, 21, Urban)*

> *"No, but I noticed my colleagues saying 'What a sleepy ringtone you have!'" (Male, 25, Control)*

Furthermore, two participants expressed their frustration about the fact that the sound did not automatically stop after a while, as shown by the following quote:

> *"And the melody did not stop at a given moment, it just went on. Thus, I switched the sound off every evening." (Female, 22, Urban)*

3.4.2 Compliance

Naturally, participants were not always able to fill in all questionnaires or watch all slideshows. The interviews provided insight into why participants sometimes ignored notifications or skipped questionnaires or slideshows.

3.4.2.1 Questionnaire compliance

When asked about the amount of questionnaires participants were able to fill in, all participants admitted that they sometimes missed questionnaires. The most common reasons for missing questionnaires included that participants were sporting, sleeping, in a meeting or discussion, at work, in class, too far away from the tablet, busy with something, out at a party, that they simply did not hear the notification, they had an exam or they were on their bicycle, as shown in Table 3.35.

> *"No, I think I missed a few. I went out one evening and did not bring a bag with me, thus then I could not bring the tablet with me. Other than that, I think I missed one in the weekend, because I was still asleep in the morning. " (Female, 21, Nature)*

> *"No, I did miss a few questionnaires. Either because I had a meeting or because I was sporting, then I probably missed a few." (Male, 25, Control)*

> *"No, I was not able to fill in all questionnaires. For example, at work I could not fill in all of them. When I was busy I missed a few questionnaires." (Male, 26, Control)*

Table 3.35 Most common reasons for missing a questionnaire.

Reason	Number of participants
I was sporting	12
I was sleeping or taking a nap	8
I was in a meeting or discussion	8
I was at work	6
I was in class	6
I was too far away from the tablet	6
I was busy with something	6
I went out or went partying	5
I did not hear the alarm	5
I had an exam	4
I was on my bicycle	3

Given that the notifications were sometimes experienced as distracting or stressful, it comes as no surprise that some participants (a total of 12) mentioned, that they sometimes also ignored notifications. While some did this deliberately, others were planning to answer the questionnaires in a moment but then simply forgot about it. Other common reasons for ignoring notifications were that participants were in a meeting, that they were still halfway asleep, they were in a discussion or they were helping someone, as shown in Table 3.36.

> *"I only did this in the morning when I was still asleep. Then I stopped the alarm and thought 'I will fill it in later' and then it was suddenly an hour later." (Male, 22, Nature)*

> *"Once during a meeting I ignored the notification. I checked after the meeting whether it was still open but it was already gone. Cause yeah, I cannot answer a questionnaire in the middle of a meeting..." (Female, 21, Nature)*

> *"It once happened that I was helping my grandma with the computer and then I heard the tablet and quickly clicked away the sound thinking 'I'll do it in a moment, I am almost done'. But then I completely forgot about it." (Female, 19, Control)*

Table 3.36 Common reasons for ignoring the notifications for filling in a questionnaire.

Reasons	Number of participants
I was in a meeting	5
I thought "I'll do it in a moment"	3
I was still asleep	2
I was in a discussion	2
I was helping someone (e.g., friend or customer)	2

Furthermore, as certain situations did not allow for alarms being activated, quite a few participants (in total 12) mentioned that they switched the tablet to silent. As a result, they were forced to manually check whether they received a notification. A few participants (a total of eight) therefore also mentioned, that vibration alarms would be preferred over sound alarms:

> *"Yeah, sometimes I didn't know whether I missed a notification or not. For example, when I was in class, I had to put the tablet to silent, thus I didn't know whether I missed a questionnaire. That was sometimes bothersome." (Female, 20, Urban)*

> *"I am not sure whether this is possible, but maybe a vibration function on the tablet would be useful. If you are sitting in class, for example, you want to fill in the questionnaire. However, you cannot activate the sound, because the professor won't appreciate it. Thus, you put it to silent." (Male, 22, Control)*

“The only disadvantage was when I was at the TU festival; I couldn’t hear the notifications because of the music. Thus, I had to check every now and then whether I had been notified. […] Well, a vibration alarm would have been nice.” (Female, 21, Urban)

3.4.2.2 Slideshow compliance

Participants were not always able to watch all recommended slideshows either. As shown in Table 3.37, common reasons cited for missing slideshows were that participants could not remember why they missed slideshows, as well as that they were in class, the lab or otherwise busy with something, or that they were distracted and stopped watching the slideshows.

“However, I did sometimes miss the slideshow notifications. I have quite a lot of contact hours, thus once I was in the lab and I did quickly fill in questionnaires in between, however, I did not watch the slideshow.” (Female, 21, Urban)

“I think I have missed two or so slideshows in the afternoon. In the evenings, I always watched the slideshows. I think it was during class that I missed the slideshows in the afternoon.” (Female, 20, Urban)

Table 3.37 Most common reasons for missing a slideshow.

Reason	**Number of participants**	
	Nature	Urban
I don’t know or I don’t remember	5	2
I was in class	0	3
I was busy and did not have time	1	2
I had to work at the lab	0	1
I was distracted and stopped watching	0	1

One important aspect that might have contributed to the likelihood of skipping slideshows was slideshow length. When asked about the length of the slideshows, the majority of the participants described the slideshows as too long, especially when they were asked to watch them during the day while being busy. Participants mentioned that it was difficult to stay focused on the slideshows and that the length of the slideshows was sometimes causing frustration:

“Yeah, too long... It wasn’t interesting. You can probably see quite a lot of irritation in my heartbeat. […] However, while watching the slideshows I thought to myself: ‘Shit, still half way to go!’” (Male, 22, Nature)

“They were a bit long. I found it difficult to stay focused on the slideshows. […]Furthermore, I found it very slow. It took quite long. They were also very similar. As I understood it, the slideshows were all different, but they looked the same to me.” (Male, 20, Nature)

“Hmm, every now and then I was distracted. Especially because the slideshows were quite long, what was it… three minutes? That I then thought: ‘Again such a slideshow…’” (Female, 21, Urban)

A few participants (a total of eight), however, had no issues with the length of the slideshows and recognized that the length of three minutes was necessary in order to achieve an effect:

“Yeah, that was fine, it wasn’t too long. It’s not like you are asked to watch a movie for 15 minutes. However, it shouldn’t be any longer.” (Male, 45, Nature)

“Yeah, three minutes is quite long, but I think it is necessary. Of course your attention is varying while watching the slideshow. I think three minutes are necessary to get relaxed.” (Female, 23, Nature)

When being asked about their concentration while watching the slideshows, the majority of the participants furthermore mentioned that they experienced issues with staying focused on the slideshows. Frequent reasons stated as to why it was hard to stay concentrated included that the slideshow was too long, boring or monotonous, that participants were too busy, that participants were distracted by things in their environment and that their thoughts were wandering. Table 3.38 summarizes the reasons provided by the participants.

“On the first day I had still hopes, thinking ‘Oh, maybe there will be something new this time, something exciting!’ However, after a while my thoughts were more like ‘Oh, it’s always a bit the same, thus I already know what’s coming’, thus my attention weakened. Your willingness to watch a slideshow for three minutes becomes less and less with time.” (Female, 21, Nature)

“Yeah, mostly my concentration was good, but sometimes it was a bit less, because I was sitting somewhere in a room with other people. I was working and the other people were walking around and doing things, and then I was sometimes a bit distracted.” (Female, 24, Nature)

“Well, that was dependent on whether I was busy with something or not. If I wasn’t busy, it was no problem to focus on the slideshow. However, when I was busy with something then I kept thinking about this.” (Male, 20, Nature)

“My thoughts often wandered. I was sometimes distracted by other people and sometimes by my phone. Or sometimes my thoughts simply started wandering. It was very long.” (Male, 23, Urban)

Table 3.38 Most common reasons for concentration difficulties.

Reason for concentration difficulties	Number of participants	
	Nature	Urban
Slideshow was boring, monotonous, does not grab attention	6	7
I was busy with something	4	8
Electronic devices were distracting me (e.g., phone, TV)	3	7
Environment was distracting me (e.g., noise)	5	3
People were distracting me	4	4
I had wandering thoughts	4	4
Slideshow was too long	3	3
I was doing something else meanwhile (e.g., eating)	1	5
I have a bad attention span	3	0
I was tired	0	1

3.4.3 Self-awareness and social perception

An interesting finding was that the mere participation in the experiment had an influence on participants' self-awareness and their awareness of reactions in their social environment.

3.4.3.1 Self-awareness

Interviews revealed that the majority of the participants had the impression that simply filling in the questionnaires had an influence on their thoughts and sometimes also their behavior. Specifically, participants had the impression that answering questionnaires made them more aware of their feelings. For most participants, this increase in awareness was positive. For example, some participants realized that they did not always feel as bad or depressed as they initially thought:

> *"I am a little depressed at the moment and then you always think that everything is bad and awful. But if you fill in such a questionnaire on a regular bases, then you notice 'Well, it's not that bad actually, I don't always feel as bad as expected'. If you feel depressed, you quickly conclude that you constantly feel down. However, if you measure your mood regularly, it puts things more into perspective." (Female, 38, Control)*

> *"However, overall I actually quite enjoyed having these reflective moments in between. […] I sometimes thought that I would feel quite bad, but then I filled in the questionnaire and I realized that it wasn't that bad after all." (Female, 21, Nature)*

Furthermore, for some participants, this increased awareness gave an incentive for change. For example, some participants realized that they should take break, worry less or try to approach things more positively:

> *"I noticed that I am worrying a lot. I noticed that I should try to worry and ruminate less, that I should let things go more often. I am not sure whether I can change that behavior immediately; that is probably very difficult. However, I noticed that I am investing a lot of energy in worrying." (Female, 45, Nature)*

> *"Well, it did influence me in situations where I was quite stressed but wasn't really aware of my stress. Then you fill in the questionnaire and you think 'Oh yeah, maybe I should take things more slowly'. Or I thought things like 'Well, I don't make any progress at the moment, I'll just go do something else'. Thus, it made me a bit more aware of my feelings." (Female, 21, Nature)*

> *"Well, I was reflecting about things like 'Ok, I am not giving a very happy response, but I am feeling ok', thus you begin to think about 'How can I become happier?' or something like that [laughing]. Yeah, you are busier with trying to make yourself feel better. At least I was busy thinking 'Oh, I am indeed not feeling that well, thus I should do something about it' or similar." (Female, 27, Urban)*

While some participants actively changed their behavior in response to their increased awareness, most admitted that it was too hard for them to actually make a change:

> *"Well, on some days I did change my behavior but on other days…well, not [laughing]. However, I did think 'I am feeling stressed at the moment!' and that I then thought 'Well, why is this happening?' and then I realized that there were so many things in my head about all the things I still had to do. So, I wrote down everything so that I did not have to keep it all in my head. And by doing this, it was out of my head and I had a good overview and could work with this summary. Thus, I did try to change things. I wasn't always successful, but I tried [laughing]." (Female, 24, Nature)*

> *"Well, I was more aware of the fact that I should sleep more [smiling]. However, to really change my behavior… that didn't work out yet."(Female, 20, Urban)*

Finally, not all participants experienced their heightened awareness as something positive. For some, it was a reminder of the negative aspects in their lives, as illustrated by the following quotes:

> *"Well, sometimes when I had a lot of pressure but wasn't doing much at a certain moment, and the tablet asked me how much stress I had, I thought 'Well, actually I should be quite stressed'. Thus, reading this question increased my stress. It reminded me of what I still had to do." (Female, 19, Control)*

> *It made me more aware of these aspects. Whether you feel lonely or not, normally you don't think of it like this, at least not me. Thus, it made me more aware of 'Yeah, I am feeling quite lonely, it's actually quite shitty'. (Female, 21, Nature)*

Two participants furthermore mentioned that wearing the heart rate monitor increased their awareness as well. Specifically, participants were more aware of their heart beat and asked themselves whether their current heart beat was healthy, as illustrated by the following quote:

> *"Well, I had the impression that I was paying more attention to my heartbeat. The fact that I was participating in this study made me ask myself: 'Does my heart now beat fast of does my heart beat slowly?' I was much more aware of this. Normally, you don't think about your heart rate but now I was. I wondered if it was positive or negative. […] If your heart is beating fast, then you think you are stressed and not healthy, thus you should better calm down. Yeah, it just raises questions in your head about whether it would be better to be less stressed." (Male, 20, Nature)*

3.4.3.2 Social perceptions

Interestingly, a total of 12 participants mentioned that their participation in the experiment not only increased awareness of their own feelings, but also made them more conscious of reactions in their social environments. To prevent conflicts, participants for example informed their friends about the experiment or asked for permission to use the tablet in other people's presence. Some participants were quite uncomfortable with the thought that the experiment could bother others. While reactions in the participants' environments were sometimes positive:

> *"However, the people I had a meeting with knew of the experiment, thus they thought it was quite funny that they could witness it." (Female, 21, Nature)*

> *"It was actually quite funny to bring along the tablet. I had it with me when I was with my friends, so everyone knew that I was participating in an experiment. Often, the alarm went off when I was with friends. But that was never a problem." (Female, 24, Nature)*

Many reactions were characterized by negative connotations, as the following comments illustrate:

> *"I felt a bit like a medical patient [laughs]. After sporting, I had to put that thing [heart rate monitor] back on, and the people looked at me like 'Do you have a heart disease?' or something like that [laughs]. […] Thoughts passed my head in the line of 'Jesus, it really looks like I am having a disease or similar…', but that's about it." (Male, 18, Control)*

> *"I was scared that the alarm would go off during class. Whenever the alarm went off during class, I tried to mute the tablet as quickly as possible, because I did not want to bother anyone." (Female, 21, Urban)*

"Funny enough, while I was getting used to it [the notifications] after a while, my environment did not get used to it at all, because my environment is constantly changing. Thus, my friends were also quite bothered by it. After a while, they got almost insane because of the sound of the tablet." (Female, 21, Nature)

In addition, a small number of participants (a total of three) asked their social environment for help with keeping track of notifications. Specifically, they asked their friends to inform them in case a notification would go off:

"Most of the times, I asked people to call me if the alarm went off." (Male, 23, Urban)

3.4.4 Impact of the slideshow-manipulation

Participants in the treatment conditions were further interviewed about their experience with watching the slideshows. The core question was whether and how watching the slideshows influenced participants. The majority of the participants mentioned that the slideshows had some sort of influence on their thoughts or feelings. For most of these participants (a total of 13), the influence of the slideshows was both positive and negative, depending on the situation. Specifically, participants mentioned that watching the slideshows was positive when there was enough time to do so, but negative when time was scant or when participants were stressed:

"As long as there is time to watch the slideshows, it is quite positive. However, as soon as you don't have time… well, there is always time but it's not always convenient, then I experienced it as negative, almost. More stress, more distraction… yeah." (Female, 21, Nature)

"If I wasn't busy with anything, I think it [the slideshows] made me calmer and more relaxed. However, when I was busy with something […] it might have made me more stressed…. that I thought something in the lines of 'Ugh, now I have to watch this while I just…'" (Male, 20, Nature)

A few participants (a total of 6) described the influence of the slideshows as very positive, not mentioning any negative aspects. Properties described as positive included that the participants thought the slideshows were relaxing, that they recognized places which triggered positive memories, and that the slideshows simply made participants happy:

"I experienced the slideshows as relaxing or calming, because you are only focused on the slideshows. I really had the impression that I got a bit more relaxed from watching them." (Female, 21, Urban)

"There were also many places that I recognized and often it depicted a nice place, which was connected to good memories." (Female, 20, Urban)

“I think I had a nice slideshow, because nature makes me happy. I had a very nice meadow.” (Female, 21, Nature)

A striking discovery was that quite a few participants (a total of 10) noticed that the weather in their photos was always sunny and warm, which in turn made them happier. This effect was not anticipated and therefore has to be taken into account during the quantitative data analysis, especially since the majority of the participants mentioning the sun were in the “Urban” condition.

“Since the pictures were all sunny, it was nicer to look at them… you get a bit happier.” (Male, 20, Urban)

However, watching the slideshows was not always described as a positive experience. In fact, a substantial amount of participants criticized that the slideshows were long, boring and monotonous, and in some cases even irritating.

“After a while, you’ve had a bit enough of the slideshow. I think that if there had been different slideshows every now and then, then it would have been more interesting.” (Female, 22, Nature)

“I cannot remember a single good memory about the slideshows. Negative because it simply wasn’t interesting. Three minutes is quite long to concentrate on something that you don’t like.” (Male, 22, Nature)

“Oh, the slideshows were terrible! I experienced it only as negative because I wanted to do something else.” (Female, 21, Urban)

An interesting finding was furthermore that a small number of participants (a total of four) experienced the slideshows as empty and sometimes cold:

“There were no people, thus the scene feels a bit cold. In the sense of that it does not trigger that much emotion. If there is someone, you begin to sympathize.” (Female, 28, Urban)

Finally, for some participants (a total of seven), the slideshows were neutral and did not have much of an influence. They did not really see a use in watching the slideshows and described the slideshows as boring and uninteresting:

“No, I don’t think that this is the way how it worked for me, so it was neither positive nor negative. I had the feeling that the slideshows were very repetitive.” (Male, 20, Nature)

Whenever participants were recommended watching a slideshow, they were asked to imagine being at the places shown in the slideshow. Participants used a wide variety of imagination strategies. The most common strategies included triggering memories, imagining walking or cycling at the given location or thinking about how it would feel being there, as shown in Table 3.39.

> *"I often thought that I would be there on my bicycle, because the slideshow showed mostly places where you pass by on your bicycle. […] And for the other photos, I imagined walking there." (Male, 23, Urban)*

> *"Yeah, because I recognized quite a lot of places, it was quite easy to imagine being there. I imagined myself cycling at this place, for example, because I was there in real before. And in case it was an unknown place, then I imagined myself walking there." (Female, 21, Urban)*

> *"I usually tried to imagine that I was hiking at home. Also, on most photos it was sunny, thus I imagined that there was the lovely sun, lovely and warm, with a light breeze [laughing] and yeah… some birds in the background… yeah, simply nice. It worked well [laughing]." (Female, 24, Nature)*

Table 3.39 Most common imagination strategies.

Imagination strategy	**Number of participants**	
	Nature	Urban
Trigger memories	4	7
Walking there	6	4
Cycling there	1	2
Thinking about how it feels there (feeling the sun, wind, hearing birds…)	1	2
Standing in the middle, looking around	1	1

The majority of the participants had mixed feelings about the imagination task, reporting that sometimes, it was easy for them to accomplish this task whereas at other times, they experienced difficulties. Specifically, the imagination task was easier when participants recognized places or when they were able to relate the places to their own experiences.

> *"Yeah, it went quite well, I think. I think I succeeded quite frequently in imagining being there. I go hiking in these sorts of environments quite often. I think that helped me with imagining being in such environments." (Male, 20, Nature)*

> *"Sometimes it was easier than other times. It was easiest when I knew where the place was. If I've been there before, I knew approximately how it would be to be there. However, in case I saw a photo of a location that I did not know, it was a bit more difficult." (Female, 20, Urban)*

Reasons why participants sometimes experienced the imagination task as difficult included that they were unable to relate to the slideshows, that the slideshows were too boring and that there was not enough information. As a potential improvement, several participants (a total of four) recommended using sound or real videos instead of slideshows, in order to make the intervention more engaging.

> *"It wasn't that easy for me. I think it was hard because I thought it were very boring slideshows, thus then it's difficult to stay focused on the photos." (Female, 20, Nature)*

> *"In the beginning of the slideshows it was easier, but towards the end I thought 'Alright, it's again such a photo'. Thus yeah, towards the end it was more difficult. I was hoping that there would maybe be some change, but I had the impression that it showed always the same situations." (Female, 20, Urban)*

> *"Well, it was very boring. It said 'Try to imagine that you are walking there', but this was very difficult for me. […] I think that a movie of someone walking there, maybe without talking, would be better. Make it such that a little bit more is happening." (Male, 22, Nature)*

> *"I asked myself why there is no sound with the slideshows, because it seems to me that this is quite important for a slideshow. Maybe also to make it easier to stay focused. And sound influences you a lot." (Male, 20, Nature)*

3.4.5 Usability issues

While the majority of the participants did not experience any problems with the set-up of the experiment, the interviews nevertheless revealed some important issues with regard to the instructions, devices as well as the questionnaires. The following sections highlight the most important usability issues encountered by participants.

3.4.5.1 Instructions

Participants were thoroughly informed during the first meeting about the use of the Samsung Galaxy Tab 4 tablet and the Polar H7 heart rate monitor, as well as the applications running on the tablet. Furthermore, participants received a booklet with additional information, in case they encountered problems during the experiment. The majority of participants therefore did not experience any issues with regard to the instructions or the use of the devices and application. Problems that occurred with regard to the instructions were exclusively related to the slideshows. One participant was not aware that she was allowed to watch the evening slideshows after midnight and therefore skipped some of them:

> *"I don't think so. I was often busy in the evening. I wanted to watch it later but then they were gone, there was no triangle anymore. I was not sure whether I could still watch them in that case." (Female, 20, Urban)*

Since this participant was among the first to participate, all future participants were explicitly informed that they were allowed to fill in the evening questionnaire and watch the evening slideshows after midnight as well. Another participant forgot to watch the evening slideshow at first, as there were no explicit notifications. However, reading the instruction booklet led to clarification:

> *"No, but I had to read the booklet to understand how it exactly works with watching the slideshows. Because you also have to watch the slideshow before going to bed but there is no extra notification for that, as far as I know. Thus, at first I forgot to watch the slideshow and just filled in the evening questionnaire." (Female, 20, Urban)*

3.4.5.2 Applications

With regard to the applications on the tablet, again, the majority of the participants did not encounter any problems. However, there were some issues that surfaced with the application that was used for filling in the questionnaires as well as the application for making the connection with the heart rate monitor. A few participants (a total of three) were confused by the meaning of the status bar icons that popped-up in case there was a questionnaire to be filled in, or in case the heart rate monitor lost connection. In both cases, the same icon (triangle with an exclamation mark) was used, which introduced ambiguity:

> *"Sometimes I was not sure what the icons on the tablet mean, whether it is a notification or the connection that broke off. Then I checked the notification and was able to see that it, for example, was the connection that stopped." (Female, 21, Urban)*

Similarly, a few participants (a total of two) were confused by the sound that was issued in case the tablet lost connection with the heart rate monitor. Specifically, in case of one participant, the same sound was used by an application on his smartphone, leading to some degree of ambiguity as well:

> *"However, on one occasion, I took off the heart rate monitor, and then all of a sudden there was this sound. The same sound I have on my phone for notifying me of rain. Thus, I thought 'What's that now? I don't get any notification on my phone!? Where does this sound come from?' Then, I realized that it came from the tablet, when the tablet lost connection to the heart rate monitor." (Male, 48, Control)*

With regard to the application for filling in the questionnaires, there was one specific issue which was mentioned frequently and therefore led to confusion with quite a few participants (a total of nine). Specifically, the questionnaire application showed green checkmarks in case the morning and evening questionnaires were submitted on time, and red crosses if the morning or evening questionnaires were still to be completed. However, in cases where participants filled in the evening questionnaire after midnight, these status icons were incorrect, which was mentioned by participants frequently:

> *"Then I watched the slideshow and filled in the evening questionnaire again. However, there was no green checkmark next to the evening questionnaire after filling it in. Maybe that was also because it was after midnight, because I had the same issue a second time." (Female, 20, Urban)*

With regard to the application for making a connection with the heart rate monitor, there was one specific issue which surfaced with three participants. Specifically, these participants did not understand how to select the heart rate monitor from the menu, assuming the application would immediately establish a connection.

> *"However, at the beginning it wasn't clear to me that I had to select the device in the menu to connect to the heart rate monitor. However, after a few minutes trying and searching, I realized that if I selected the device, it would connect. Thus, after doing that, the status bar turned green and a heart appeared in the upper left corner. Thus, I had to experiment a bit in the beginning, but after five minutes, I got how it works." (Male, 45, Nature)*

Furthermore, some participants (a total of four) were a little disappointed that they could not read their actual heart rate in the application:

> *"I was sometimes interested in what my heart rate was. However, while recording, I could not see my own heart rate. Thus, that was sometimes like 'Yeah, now it is recording and I can't see it…' That was unfortunate." (Male, 26, Control)*

3.4.5.3 Devices

With regard to the devices, an important question to be answered was whether wearing the Polar H7 heart rate monitor for six consecutive days would be too uncomfortable for participants. The interviews revealed that the majority of participants were not bothered by the heart rate monitor at all. Most participants mentioned that, after a short phase of finding the correct size and becoming accustomed to the heart rate monitor, the heart rate monitor was barely noticeable:

> *"On the first day, I had the chest strap a bit too tight, but then I made it a bit looser. And yeah, then you don't feel that much of it anymore, thus it was fine. It was not bad." (Female, 21, Control)*

> *"I first had to experiment a bit how high the chest strap has to be, because if you have it a certain height, then it won't get recognized. However, you quickly forget that you are wearing a chest strap." (Male, 22, Nature)*

There was only one participant who mentioned having issues with wearing the heart rate monitor over a longer period of time:

"The heart rate monitor was quite inconvenient, I was very much aware that I was wearing it. I noticed the heart rate monitor much less on the last three days, because I got used to it more and more. However, I did not expect that it would bother me so much at the beginning, but that's how it was." (Female, 21, Nature)

Some participants complained that the heart rate monitor was sometimes bothersome or itching, especially in the evening after a long day of wearing the chest trap. Some participants also noticed marks on their skin in the evening.

"At the beginning, I was paying attention to it [the chest strap]. However, after one or two hours I was used to it. In the evening, it was more uncomfortable because it became irritating. After taking off the chest strap there was a mark on my chest." (Male, 20, Urban)

Furthermore, there were specific situations in which the heart rate monitor was more noticeable. These included situations in which participants were physically active, for example while sporting or cycling, or situations in which they were sitting or bending over.

"It was mostly when I was cycling or when I did physical exercise that I was able to feel the chest strap. However, it was not bothersome." (Female, 21, Urban)

"The heart rate monitor was a bit uncomfortable for me at times, because when you are sitting, well, I have a bit of a belly, then it pushes a bit." (Female, 21, Nature)

By far the most frequent complaint was that the chest strap sometimes got loose or was too wide in general. The reason for this issue might be that the chest strap was only suitable for sizes ranging from M to XL. Table 3.40 shows a summary of the situations in which the heart rate monitor was bothersome.

"No, however, the thing [the chest strap] kept slipping down because I could not make it tighter. For example, while cycling, it always slipped down, thus I am not sure whether data was lost. A smaller one would have been better." (Female, 22, Urban)

Table 3.40 Situations in which the heart rate monitor was bothersome.

Situation	Number of complaints
Too wide or getting loose	10
Sporting	5
Wearing it for a long time	5
Cycling	4
Sitting or bending over	4

With regard to the tablet, approximately half of the participants described bringing the tablet with them as quite inconvenient, whereas the other half of the participants did not experience issues with regard to carrying the tablet. Many participants complained that the tablet was too big and heavy, that it did not fit in their pockets and that they were bothered by the fact that they had to bring a bag specifically for the tablet.

> *"Yeah, that was indeed sometimes a bit bothersome. Because the tablet does not really fit into your pocket and then you always have to bring a bag." (Male, 23, Urban)*

> *"Yeah, to be honest, the tablet was too heavy, because I already have a phone that I think is too heavy, then the tablet and then also the TU backpack and… [phew]. Thus, that was a bit too much." (Female, 28, Urban)*

Furthermore, some participants described places to which they could not bring their tablet. As shown in Table 3.41, common places that were mentioned included participants' workplaces, the sport center, the lab, the sauna, meetings, and parties.

> *"Only on Saturday and Sunday, I had to work at [company name], so I couldn't bring the tablet with me. I was not allowed to fill in questionnaires and could not leave my workplace, because I have to be with the machines at all times." (Male, 45, Nature)*

> *"I also had lab work a few times, thus I wasn't allowed to bring the tablet for safety reasons." (Female, 20, Urban)*

> *"On Saturday I went to the sauna, thus I did not take the tablet with me in the afternoon." (Male, 20, Nature)*

Table 3.41 Situations where tablets were not acceptable or unsuitable.

Situations	Number of participants
Workplace	4
Sporting	3
Meetings	2
Laboratory	2
Sauna	2
Party or excursions	2

Given the tablets were frequently described as inconvenient, it is not surprising that some participants (a total of eight) also mentioned accidentally forgetting the tablet. There was even one participant who lost the tablet altogether.

> *"On one day, I forgot the tablet at home and I had to go back to get it. I just went to the TU for a meeting and during the break I went back home to get it." (Female, 20, Urban)*

Furthermore, as a potential solution, many participants (a total of 13) mentioned that they would have preferred using their own smartphones or a smaller device to participate in the experiment, as the following comments illustrate:

> *"I would have preferred to have an app on my own phone. However, I don't know if that it possible. It wasn't that bad but it was sometimes a bit difficult. Maybe you could also get a smaller device, like a cheaper phone that does support the things you need." (Male, 23, Urban)*

Finally, it has to be mentioned that not all participants disliked the format of the tablet and approximately half of the participants had no issues with bringing a bag with them. Some participants even liked the size of the tablet, and therefore had a positive experience.

> *"The tablet is very small, that's convenient… Yeah, it fits nicely in your bag, thus no problem. It was ideal, really. I was thinking 'Oh, that's a nice size to have as a tablet' [laughing]. Ideal if you are travelling a lot, as you can bring it with you easily. It was not at all too big." (Female, 27, Urban)*

3.4.5.4 Questionnaires

The majority of the participants did not experience any difficulties with answering the questionnaires. Most participants mentioned that, after an initial phase of getting used to the questions, they were quite fast with providing answers:

> *"At first, I thought 'That's a lot of questions!' However, if you have filled them in a few times, you become much quicker at it, because it's always the same questions, of course." (Female, 21, Urban)*

However, there were also two participants who realized that, while getting much faster with time, they did not pay as much attention to the questions anymore. One of these two participants therefore recommended changing the order of the questions every now and then:

> *"If the order of the questions in the questionnaire would vary a bit, then you wouldn't brush over them so quickly. […] You know the questions, and then you sometimes react too quickly. Sometimes, you click on 'Next' and then you think 'Oh, I should have chosen a different answer' or something like that, yeah." (Male, 48, Control)*

Furthermore, some participants (a total of 12) experienced difficulties with answering the questions. For example, some participants found it hard to translate their feelings to a number on a scale and were therefore unsure which option to pick:

> *"However, with some questions, you have these extremes and it was not always clear to me what there is in between. Happy or sad… […] I found it difficult to decide what middle option represents and where I am on the scale." (Male, 26, Control)*

Another problem which was mentioned more frequently was that participants sometimes made mistakes with reversed questions, as illustrated by these comments:

> *"I had some difficulties with some questions. For example, with the questions following the question 'I am worrying', the scale goes from 'not at all' to 'very much', thus they are all positive when you give a low score. However, with the question 'I feel good', it's all of a sudden the other way round." (Female, 21, Nature)*

4 Discussion

The present ecological momentary intervention study was aimed at investigating the influence of watching restorative nature slideshows on a mobile device over a period of six days on psychological variables including perceived stress, mood, worry, rumination and mind-wandering as well as the physiological variables of heart rate and heart rate variability. Moreover, the effectivity of such a restorative nature video intervention was compared to watching slideshows with urban content as well as not watching any slideshows at all. It was hypothesized that participants in the nature slideshow condition would experience lower stress, worry, rumination and mind-wandering as well as better mood than participants in the urban slideshow or the control condition. Furthermore, it was predicted that for participants in the nature slideshow condition, physiological measurements would improve significantly during and after watching slideshows, in comparison to before-slideshow measurements. The results showed that, contrary to expectations, regularly watching nature slideshows over a period of six days was not associated with significant improvements with regard to the psychological variables assessed. Instead, it was found that (a) participation in the experiment was associated with an increase in stress and decline in well-being over the course of the experiment for all participants, irrespective of experimental condition, and that (b) being assigned to either one of the two treatment conditions (nature slideshows or urban slideshows) and consequently being required to regularly watch slideshows further contributed to the workload experienced. With regard to the physiological data collected, there was evidence that the mere act of taking a break to watch a slideshow was already beneficial in terms of physiological restoration, irrespective of treatment condition. Overall, the outcomes indicate that the nature slideshow intervention administered in the present study was not successful at reducing stress.

4.1 Psychological effectiveness of the nature intervention

4.1.1 Perceived stress

Particularly with regard to the psychological outcome variables, little support for a health-promoting effect of the nature slideshow intervention could be found. Hypothesis 1 predicted that participants in the nature slideshow condition would experience lower levels of stress than participants in the other two conditions. However, contrary to expectations, the ecological momentary assessment data revealed a trend toward an increase in perceived stress for all participants over the course of the six-day-long main experiment, irrespective of experimental condition (Table 4.1). Moreover, results showed that participants in the treatment conditions (nature slideshows and urban slideshows) experienced significantly more time pressure than participants in the control condition. The nature intervention administered in the current study was therefore not successful at confirming the restorative and stress-reducing properties of mediated nature reported by previous research (van den Berg et al., 2015; Berman et al., 2008; Berto, 2005; Beute & de Kort, 2014; Bowler et al., 2010; Bratman et al., 2012; Mantler & Logan, 2015; Ulrich et al., 1991; Velarde et al., 2007). Qualitative results from the interviews suggest that there were several aspects about the experiment that might have contributed to the observed increase in perceived stress and time pressure. First, while participants mentioned that interference of the experiment with their daily lives was minimal, several participants indicated that the number of notifications administered daily was at the upper limit of their tolerance threshold. In the present study, a sampling frequency of eight notifications was chosen to ensure that sufficient data was available even in case participants would miss certain notifications. Insights from previous research suggest that eight to twelve signals daily for studies that are run for the duration of one or two weeks provide satisfactory results (Christensen, Barrett, Bliss-Moreau, Lebo, & Kaschub, 2003; Reis & Gable, 2000). However, especially in combination with the slideshow interventions, the imposed workload might have been too large. In addition, the interviews revealed that some participants experienced the notifications as stressful or startling at times. Opinions about the notification sound varied substantially, with several participants expressing their strong dislike of the sound. Thus, hearing multiple notifications daily might have increased participants' levels of frustration and stress. Furthermore, due to the fact that the tablet did not support vibration notifications, participants were forced to manually poll for notifications in situations where the sound of the tablet had to be switched off (e.g., during class), keeping participants mentally busy. With regard to the slideshows, participants reported that they generally enjoyed watching the slideshows, but only in situations where they were not currently busy with something else. In addition, a great majority experienced the slideshows as too long. In sum, the outcomes suggest that the participation in this experiment placed a considerable burden on participants and possibly led to an increase in perceived stress over time. Importantly, aspects such as the number of notifications, the notification sound and the slideshow length may have contributed to overall perceptions of stress and time pressure.

An interesting finding was that the overall mental health scores painted an entirely different picture with regard to perceived stress, compared to the EMA questionnaires. More specifically, while the ecological momentary assessment data showed a trend toward an increase in perceived stress over time, the repeated measures data revealed that participants overall perceived significantly less stress (PSS-10) after the main EMI experiment, compared to before. While this decrease was slightly steeper for participants in the nature condition, there was no significant difference between treatment groups. As in case of the EMA questionnaires, these results therefore provide no support for the superiority of the nature slideshows in reducing global perceived stress, as compared to the urban slideshow or the no slideshow condition. In addition to the significant overall reduction in perceived stress, the repeated measures analysis revealed a trend toward an overall decrease in somatic complaints (SCL-90-R SOM) as well. As in case of perceived stress (PSS-10), no significant differences between treatment groups could be found. Importantly, it is unclear what might have caused the contradicting results for the global perceived stress data and the EMA questionnaires. However, a known issue with self-report questionnaires is that they require respondents to recall events retrospectively, potentially introducing a retrospective recall bias (Beute et al., 2016; Scollon et al., 2009; Shiffman et al., 2008). For example, the PSS-10 asks participants to rate their stress-related feelings and thoughts during the *last month*. EMA has the advantage that the issue of recall bias is reduced, since participants are commonly asked to rate current or recent experiences as opposed to events from the past (Beute et al., 2016; Scollon et al., 2009; Shiffman et al., 2008). Consequently, there are several studies which reported similar discrepancies between self-report measures and ESM or EMA data (e.g., Ebner-Priemer et al., 2006; Herman & Koran, 1998; Solhan, Trull, Jahng, & Wood, 2009; Shiffman et al., 1997; Stone, Broderick, Shiffman, & Schwartz, 2004). Another aspect which might have introduced inaccuracies with regard to the global perceived stress scores is the decision to shorten the assessment timespan for the PSS-10 to *one week*, as opposed to *one month* as in the original questionnaire. While Cohen (2014) states that the PSS-10 should be applicable for shorter timespans as well, there is no data to support the suitability of the PSS-10 for timespans as short as one week.

4.1.2 Mood

Hypothesis 2 predicted that participants in the nature slideshow condition would experience better mood than participants in the urban slideshow or the control condition. However, as shown in Table 4.1, no significant results for the mood dimensions tense arousal (relaxed vs. tense) and anger were obtained. With regard to energetic arousal (energetic vs. tired), a significant decrease in energy over the course of the experiment was found for all participants, irrespective of experimental condition. This outcome provides further support for the interpretation that participation in the experiment was effortful and exhaustive, and that consequently, health and well-being deteriorated over time for all participants. Results further revealed a trend for participants in the nature condition to experience lower levels of happiness (hedonic tone) and energy (energetic arousal), compared to participants in the urban condition. If anything, the outcomes therefore suggest that participants in the nature condition fared worse in terms of mood, compared to participants in the urban condition. In sum, hypothesis 2 is not supported by the data of the current study. Importantly, these outcomes contradict results from a wide range of studies which found positive effects of nature exposure on mood and affect (e.g., van den Berg et al., 2003; Berman et al., 2008; Beute & de Kort, 2014; Bratman et al., 2015a; Geniole et al., 2016; Hartig et al., 2003; Roe & Aspinall, 2011; Tyrväinen et al., 2014; Ulrich et al., 1991; Valtchanov et al., 2010). It is important to note, however, that support from previous literature for the beneficial effects of nature is by no means uniform and that there exist several other studies which similarly failed to confirm the positive effects of nature exposure on mood (e.g., Beute & de Kort, 2013; Gidlow et al., 2016; Johansson, Hartig, & Staats, 2011). From a theoretical perspective, the outcomes of the current experiment contradict the psycho-evolutionary framework by Ulrich (1983), which is based on the proposition that restorative nature environments exert their beneficial effects on health and well-being by increasing positive affect. An important aspect of Ulrich's (1983) theory is that nature environments are expected to elicit immediate affective reactions even before extensive cognitive processing of the environment has taken place. In the present study, no mood assessments were conducted right after exposure to the slideshows. Instead, psychological state was assessed at eight randomly spread occasions daily, with a temporal distance of minimum one and up to two hours between questionnaire notifications. Consequently, the design of the current study did not allow for testing of the immediate effects of mediated nature exposure. There is thus a possibility that the effects of the slideshows were too short-lived to be recognized by the EMA questionnaires. Another explanation for why the slideshows failed to have an impact on mood is that the scenes depicted might not have been polarizing or impactful enough to elicit strong affective reactions. Qualitative results from the interviews showed that many participants experienced the slideshows as uninteresting, boring or monotonous. Some participants mentioned getting frustrated just by the thought of having to watch a slideshow. This feedback indicates that the slideshows were not interesting enough to catch people's attention or to elicit positive emotions. Instead, the slideshows themselves might have been a source of frustration and stress. In addition, there were several slideshow properties which might have uniformly influenced mood for both participants in the nature and participants in the urban slideshow condition. More specifically, several participants noticed the sun in both the nature and the urban slideshows. Given that the presence of the sun in the images was received positively, it might have improved mood not only for participants in the nature slideshow condition but also for participants watching urban slideshows. Furthermore, several participants commented that the absence of people in the slideshows gave the scenes a cold feel. These two examples illustrate the even subtle aspects in content had consequences in terms of how the slideshows were interpreted emotionally. An interesting finding was that there was a trend for participants in the nature slideshow condition to experience lower levels of happiness and energy. A potential explanation for this outcome is that the urban slideshows might have triggered more positive memories compared to the nature slideshows. Scenes depicted in the urban slideshows consisted of, among others, various well-known places in the city of Eindhoven. Consequently, several participants mentioned that looking at these urban scenes sparked positive memories from the past. Nature scenery was capable of triggering positive memories as well; however, feedback was not as pronounced as in case of the urban slideshows. Overall, while the ecological momentary assessment data does not provide any information on the immediate effects of the slideshows on mood, the results show that the nature slideshows failed to have a significant positive impact on mood over the entire course of the experiment.

4.1.3 Worry, rumination and mind-wandering

Hypothesis 3 predicted that participants in the nature slideshow condition would experience less worry, rumination and mind-wandering, compared to participants in the urban slideshow or the control condition. Contrary to expectations, no significant effects were found for worry or rumination (Table 4.1). With regard to mind-wandering, results revealed that mind-wandering decreased significantly over the course of the experiment for all participants, irrespective of experimental condition. Overall, these results provide no support for the restorative capabilities of the nature slideshows administered in the current study with regard to worry, rumination or mind-wandering. Consequently, hypothesis 3 is rejected. Importantly, the results observed in the present study contradict previous research about rumination (Bratman et al., 2015a; Bratman et al., 2015b) and worry (Bratman et al., 2015a; Teas et al., 2007; Ulrich et al., 1991) which found evidence for the positive effects of nature exposure. It is unclear why the present study was unable to find any significant effects for the nature slideshows. However, it is possible that, as previously explained in case of the mood variables, the temporal distance between the nature slideshow exposure and the administration of the EMA questionnaires was too large in order for effects on worry, rumination or mind-wandering to surface. Bratman and colleagues (2015b), Teas and colleagues (2007), as well as Ulrich and colleagues (1991) all assessed psychological state immediately following the nature manipulation. In case of the study conducted by Bratman and colleagues (2015a), there was a 15-minute break between nature exposure and psychological assessment. The temporal distance between exposure and assessment was thus considerably shorter for these studies, in comparison to the present experiment. Qualitative results from the interviews provided little insight regarding the topics of worry and rumination. Some participants mentioned that participation in the experiment kept them mentally busy, as they continuously thought about whether the heart rate monitor was connected correctly or whether they missed any notifications. Particularly in situations where the sound of the tablet had to be switched off, participants were required to remind themselves of manually checking the tablet for notifications. According to the feedback received from participants, participation in the experiment could therefore have led to an increase in worry or rumination. However, despite these qualitative results, the quantitative analysis of the EMI questionnaire data found no support for this notion. In conclusion, given the limited number of studies that experimentally investigated the relationship between nature exposure and worry, rumination and mind-wandering, further research is required to get a better estimate of the robustness of such effects.

4.1.4 Additional psychological variables

Several additional psychological variables were assessed with the EMA questionnaires. As shown in Table 4.1, it was found that there was a significant decrease in well-being and sleep quality over the course of the experiment for all participants, irrespective of experimental condition. These results are in line with the increase in perceived stress as well as the decrease in energy (energetic arousal) described earlier and provide further support for the interpretation that participation in the experiment caused considerable workload and stress. In addition, it was found that well-being was significantly lower for participants in the nature condition, compared to participants watching urban slideshows (Table 4.1). This outcome clearly contradicts the notion that nature exposure is beneficial for well-being and is in sharp contrast to the wide support for the health-promoting effects of nature provided by previous research (van den Berg et al., 2015; Beute & de Kort, 2014; Berto, 2014; Bowler et al., 2010; Bratman et al., 2012; Haluza et al., 2014; Lee et al., 2009; Mantler & Logan, 2015; Song et al., 2014; Tyrväinen et al., 2014; Velarde et al., 2007). According to the Attention Restoration Theory by Kaplan (1995), nature benefits well-being by promoting recovery from directed attention fatigue and by replenishing the ability to focus. While the current degree of attention was not measured directly in this study, the EMA questionnaires assessed self-control by asking participants about their momentary level of concentration and patience as well as their ability to make decisions. It was found that there was a trend toward a significant decrease in self-control over time for all participants – a result which contradicts Kaplan's (1995) theoretical framework. The significant decrease of energy (energetic arousal) over time and the trend toward lower levels of energy for participants in the nature condition compared to participants in the urban condition that was observed in the current study is in contradiction to the Attention Restoration Theory as well. Importantly, Kaplan (1995) describes several properties that are required in order for an environment to be capable of facilitating restoration from attention fatigue. These properties include inherent fascination, opportunity for getting away, rich and extensive experience and compatibility with one's personal needs (Kaplan, 1995). Given the feedback received from participants, it is questionable whether the nature intervention administered in this study offered the properties described by Kaplan (1995). As mentioned earlier, several participants described the slideshows as boring, monotonous or uninteresting. Consequently, many participants had difficulties with staying focused on the slideshows, particularly because the slideshows did not grab their attention or because of distractions in their environment. Overall, this feedback therefore suggests that the slideshow intervention more likely increased as opposed to reduced attention fatigue.

In terms of the psychological effectiveness of the nature slideshow intervention, it can be concluded that the intervention was not successful at reducing perceived stress or increasing well-being. Instead, the results indicate that being assigned to the nature slideshow condition was associated with significantly lower ratings for well-being, compared to participants in the urban slideshow condition. In addition, there was a trend for participants in the nature slideshow condition to experience less happiness and lower levels of energy, in comparison to participants in the urban condition. Thus, against the expectations, the results suggest that participants in the nature condition were worse off than participants in the urban condition. Results further showed that participants experienced a general increase in tiredness and to some degree perceived stress as well as a decrease in well-being, sleep quality and to some degree self-control, irrespective of experimental condition. Participation in the experiment therefore appears to have imposed considerable workload and consequently led to a deterioration of health and well-being over time. The outcome that participants in the slideshow treatment conditions (nature slideshows as well as urban slideshows) experienced significantly more time pressure suggests that the task of watching slideshows has further increased perceived workload.

Table 4.1 Overview of EMA questionnaire results.

	Time	Nature vs. Control	Urban vs. Control	Nature vs. Urban
Perceived stress	⇡time	—	—	—
Time pressure	—	⇡nature	↑urban	—
Worry	—	—	—	—
Mind-wandering	↓time	—	—	—
Happiness	—	—	—	⇣nature
Relaxation	—	—	—	—
Energy	↓time	—	—	⇣nature
Anger and irritation	—	—	—	—
Well-being	↓time	—	—	↓nature
Self-control	⇣time	—	—	—
Sleep quality	↓time	—	—	—
Satisfaction	—	—	—	—

Note. ↑= significant increase at $p \leq 0.05$, ↓ = significant decrease at $p \leq 0.05$, ⇡ = marginally significant increase at $p \leq 0.1$, ⇣ = marginally significant decrease at $p \leq 0.1$, — = no significant result

4.2 Physiological effectiveness of the nature intervention

4.2.1 Heart rate and heart rate variability

With regard to the physiological effects of the nature intervention, hypothesis 4 predicted that participants in the nature condition would demonstrate lower heart rate (hypothesis 4a) and higher heart rate variability as measured by RMSSD (hypothesis 4b) and SDNN (hypothesis 4c) during and after watching the slideshows, compared to measurements collected before the onset of the slideshows. No such effects were expected for participants in the urban slideshow or the control condition. Results showed that support for the beneficial physiological effects of the nature slideshows was mixed (see Table 4.2). To reiterate the HRV analysis strategy employed, heart rate variability indices were calculated for the following three time points of interest: before the slideshows, during the slideshows and after the slideshows. Three separate analyses were conducted. First, changes in HRV over all three time points of interest were analyzed (before, during and after the slideshows). Second, changes in HRV were analyzed comparing two time points of interest only, namely before versus during the slideshows as well as before versus after the slideshows.

4.2.1.1 Effect of the nature intervention on heart rate

All three analyses indicated that there was a general decrease in heart rate while watching slideshows, independent of the condition of participants. While in case of the before-during-after and the before-during HRV comparison this relationship was significant, results for the before-after comparison revealed a trend only. This outcome suggests that the mere act of watching slideshows, independently of the type of slideshow, was capable of reducing heart rate and inducing a state of relaxation. Given that the nature slideshows were not significantly better at reducing heart rate in comparison to the urban slideshows, hypothesis 4a was not confirmed. The results of the present study contradict outcomes from previous research which found nature to be superior at reducing heart rate (e.g., de Kort et al., 2006; Laumann et al., 2003; Song et al., 2014; Ulrich et al., 1991). It is important to note, however, that outcomes for physiological variables differ greatly between studies and that the effects of nature exposure on heart rate are far from stable. Consequently, there are several studies which similarly failed to find significant differences between nature and urban environments with regard to heart rate (e.g., Beute & de Kort, 2014; Gladwell et al., 2012; Valtchanov et al., 2010). A possible explanation that could account for the lack of significant differences between slideshow groups is that both the nature as well as the urban slideshows displayed calming properties. This interpretation is supported by the qualitative outcomes which showed that among the limited number of participants who described the slideshows as relaxing, there were not only participants from the nature but also participants from the urban group. While the qualitative results revealed limited information on what participants were doing while watching the slideshows, it is plausible that the task of watching the slideshows required participants to disengage from their current activity, potentially leading to a decrease of heart rate in all participants.

4.2.1.2 Effect of the nature intervention on heart rate variability

In comparison to heart rate, the outcomes for heart rate variability revealed a less obvious pattern (Table 4.2). More specifically, results indicated that RMSSD significantly increased over time for the before-during comparison and that there was a trend for RMSSD to increase for the before-during-after comparison for all participants, independently of treatment condition. Importantly, no significant differences between groups were observed. Consequently, hypothesis 4b, which predicted that nature slideshows would be better at improving values for RMSSD, was not confirmed. The outcomes contradict several previous studies which found beneficial effects of nature exposure on RMSSD (Brown et al., 2013; Gladwell et al., 2012; Gladwell et al., 2016) and, more generally, parasympathetic activity (Annerstedt et al., 2013; Gladwell et al., 2012; Song et al., 2014). At the same time, two recent studies found no significant differences between walks in nature versus urban environments with regard to heart rate variability (Brown et al., 2014; Gidlow et al., 2016), indicating that support for the beneficial effects of nature exposure on RMSSD is not universal. Importantly, the improvements for RMSSD found in the current experiment are in line with the results obtained for heart rate, indicating that watching slideshows, irrespective of slideshow content, had a calming effect on cardiovascular indices.

Hypothesis 4c predicted that participants in the nature slideshow condition would display higher SDNN during and after watching slideshows, compared to before measures. In line with previous research (e.g., Gladwell et al., 2012; Gladwell et al., 2016), results showed that SDNN was significantly higher for the before-during-after comparison as well as for the before-after comparison for participants in the nature slideshow condition, compared to participants watching urban slideshows. Thus, there was partial support for hypothesis 4c, suggesting that watching nature slideshows was associated with generally higher values for SDNN. However, a significant effect for time was absent in these analyses, indicating that there was no increase in SDNN over time. Instead, a significant effect for time in the opposite direction for the before-during comparison was found, signaling a decrease of SDNN during compared to before watching slideshows for all participants, irrespective of treatment condition. It is unclear what might have caused these contradicting results. However, as described in more detail in the next section, outcomes were contradictory for SDNN with regard to the relationship between psychological and physiological stress as well. Consequently, the results found for SDNN in the present study should be interpreted cautiously. In addition, there are several other explanations that may account for the mixed results found for heart rate variability. More specifically, the connection between the Polar H7 chest strap and the tablet was at times unstable. As a consequence, connection was lost easily, resulting in missing data. Furthermore, there were situations in which the Polar H7 stopped working entirely, causing substantial data loss. It is unclear what might have provoked the failure of the device. In addition, a considerable amount of HRV segments had to be discarded due to the presence of noise. Valid HRV segments were therefore available for a subset of the slideshows and questionnaires only. Furthermore, due to the study design chosen, it was impossible to control for distractions in the environment or aspects such as current activity, posture, speech or breathing depth or pace. Consequently, it is unclear to which degree these factors may have influenced the outcomes for heart rate variability. In sum, there are several aspects which may have compromised HRV data quality. It is therefore advisable to interpret the heart rate variability outcomes carefully.

Table 4.2 Overview of the physiological effects of watching nature slideshows on heart rate and heart rate variability.

	Heart rate	SDNN	RMSSD
		Results for before vs. during vs. after slideshow	
Time	↓time	—	⇡time
Nature vs. urban	—	↑nature	—
		Results for before vs. during slideshow	
Time	↓time	↓time	↑time
Nature vs. urban	—	—	—
		Results for before vs. after slideshow	
Time	⇣time	—	—
Nature vs. urban	—	↑nature	—

Note. ↑= significant increase at $p \leq 0.05$, ↓ = significant decrease at $p \leq 0.05$, ⇡ = marginally significant increase at $p \leq 0.1$, ⇣ = marginally significant decrease at $p \leq 0.1$, — = no significant result

4.2.2 Relationship between psychological and physiological stress

As shown in Table 4.3, partial support for the expected relationship between perceived and physiological stress was found. More specifically, it was revealed that participants with higher momentary perceived stress or time pressure experienced significantly higher heart rate (Table 4.3). This result is in line with findings from a variety of other studies (Lackschewitz et al., 2008; Lucini et al., 2002; Myrtek et al., 1996; Sloan et al., 1994; Taelman et al., 2009; Visnovcova et al., 2014). Hypothesis 5a, which predicted a significant positive relationship between perceived stress and heart rate, could therefore be confirmed by the results of the current study. Outcomes of the current study furthermore revealed that neither perceived stress nor time pressure were able to predict SDNN (Table 4.3). Given the outcomes from previous studies, which found perceived stress to be negatively related to SDNN (Lackschewitz et al., 2008; Visnovcova et al., 2014), this result is unexpected. With regard to RMSSD, on the other hand, results of the current study showed a significant negative relationship with perceived stress (Table 4.3). In addition, increased time pressure was associated with lower RMSSD as well, although only marginally (Table 4.3). Participants with high stress and time pressure therefore experienced lower parasympathetic modulation, a result which is in line with results from previous research (Hintsanen et al., 2007; Lackschewitz et al., 2008; Myrtek et al., 1996; Visnovcova et al., 2014; Vrijkotte et al., 2000; Weber et al., 2010). Overall, these results provide partial support for Hypothesis 5b, which predicted a negative relationship between perceived stress and heart rate variability as measured by RMSSD and SDNN: While higher perceived stress and to some degree also time pressure were reflected in lower RMSSD, perceived stress did not affect SDNN. Importantly, the missing relationship between psychological and physiological stress for SDNN indicates that the SDNN results found for the slideshows should be interpreted with caution. Notwithstanding the mixed outcomes obtained for the relationship between psychological and physiological stress, the results of the present study are promising. Most studies which found evidence for a relationship between psychological and physiological stress were conducted in the laboratory (Hintsanen et al., 2007; Lackschewitz et al., 2008; Lucini et al., 2002; Taelman et al., 2009; Visnovcova et al., 2014; Weber et al., 2010). The outcomes of the present study suggest that the relationship between psychological and physiological stress may persist even in situations where rigorous control of environmental factors is impossible.

Table 4.3 Overview of the relationship between stress and heart rate as well as heart rate variability.

	Heart rate	**SDNN**	**RMSSD**
Stress	↑	—	↓
Time pressure	↑	—	⇣
Worry	—	—	—

Note. ↑= significant increase at $p \leq 0.05$, ↓ = significant decrease at $p \leq 0.05$, ⇡ = marginally significant increase at $p \leq 0.1$, ⇣ = marginally significant decrease at $p \leq 0.1$, — = no significant result

4.3 Potential explanations for the (lack of) outcomes

Overall, the outcomes show that, contrary to expectations, the nature slideshow intervention administered in the present study was not successful at reducing stress or improving well-being. There are several explanations which might account for this result. Outcomes from the EMA questionnaires as well as the interviews suggest that the experiment has placed a considerable burden on participants, potentially leading to an increase in stress and a decrease in well-being. Thus, there is a possibility that the restorative effects of the nature slideshows were too subtle to be able to counteract the negative effects of the additional workload imposed on participants. Furthermore, one of the major limitations of this experiment is that, due to the fact that the experiment took place in participants' personal environments, it was not possible to ensure that participants actually watched the slideshows. While timestamps saved upon completion of the slideshows gave an indication of whether the slideshows were aborted or not, it is impossible to tell from the results whether participants looked at the slideshows for the entire time they were playing. There is thus the possibility that the nature slideshows failed to have an effect due to poor compliance with the instructions. In addition, the results from the interviews indicate that participants had difficulties with staying focused on the slideshow content and that they were sometimes completing other task in parallel while watching the slideshows, thereby possibly compromising the effectiveness of the intervention. Another explanation for why the slideshow intervention was unsuccessful is that the photos were incapable of inducing emotional reactions that were strong or persistent enough to be recognized by the questionnaires. The feedback from participants that both nature and urban slideshows were perceived as boring, monotonous or even irritating suggests that the slideshows were not interesting and pleasant enough to induce strong positive emotions. Previous research shows that nature environments generally elicit greater preference than urban environments (van den Berg et al., 2003; Beute & de Kort, 2013). However, in the current study, no questionnaires were delivered right after watching the slideshows. The immediate effects of the slideshows – particularly the questions to what degree the intervention was experienced as positive and whether the nature slideshows were indeed preferred over the urban slideshows – were therefore not assessed by the current experiment. Consequently, it is unclear whether the nature intervention had the desired effects.

The finding that the nature intervention administered in the present experiment was not capable of improving well-being is in sharp contrast to the wide support for the restorative effects of nature exposure from previous research (Beute & de Kort, 2014; Berto, 2014; Bowler et al., 2010; Bratman et al., 2012; Haluza et al., 2014; Mantler & Logan, 2015; Velarde et al., 2007). However, it must be noted that there are several methodological differences between the present research and previous studies, which found evidence for the health-promoting effects of nature. First, the present experiment was designed as an ecological momentary intervention and therefore took place in participants' own environments. On the other hand, previous research was mostly conducted either in the laboratory (e.g., Annerstedt et al., 2013; van den Berg et al., 2003; van den Berg et al., 2015; Berman et al., 2008; Berto, 2005; Beute & de Kort, 2014; Brown et al., 2013; de Kort et al., 2006; Laumann et al., 2003; Ulrich et al., 1991; Valtchanov et al., 2010) or under semi-controlled conditions in the field (e.g., walking or sitting for a set amount of time in a predefined environment, as for example in case of Berman et al., 2008; Bratman et al., 2015a; Bratman et al., 2015b; Geniole et al., 2016; Hartig et al., 2003; Lee et al., 2009; Qin et al., 2013; Song et al., 2014; Teas et al., 2007; Tyrväinen et al., 2014). The difference in study design has important implications with regard to the interpretation of the results. By signing up for a controlled laboratory or field experiment, participants make the conscious decision to set aside time to participate, thereby being free of other responsibilities at the time of participation. In the case where interventions are administered in participants' personal environments, however, numerous competing demands and distractions might be present. It is thus expected that results for ecological momentary intervention studies are less pronounced compared to studies with more rigorous control of environmental factors. Furthermore, while it is a common practice in laboratory studies to experimentally induce stress with tasks that are specifically designed to increase cognitive load or social evaluative threat (e.g., Stroop task, memory tests, arithmetic tests or the Trier Social Stress Test, as for example in case of Annerstedt et al., 2013; van den Berg et al., 2015; Beute & de Kort, 2014; Brown et al., 2013; de Kort et al., 2006; Laumann et al., 2003; Ulrich et al., 1991), it is plausible that stress experienced in everyday life is qualitatively different from stress caused by acute laboratory stressors. It is thus possible that participants' restorative needs in the present study were too low or dissimilar compared to laboratory studies, in order for the beneficial effect of nature exposure to surface. Another conceptual difference between this study and previous research is the temporal difference between the exposure to an environment and the time at which effects are assessed. As mentioned earlier, in most studies, effects of a nature manipulation are assessed immediately following exposure (e.g., van den Berg et al., 2015; Beute & de Kort, 2014; Bratman et al., 2015b; Brown et al., 2013; de Kort et al., 2006; Teas et al., 2007; Ulrich et al., 1991). In the present experiment, psychological state was instead assessed at eight randomly spread occasions daily, with a temporal distance of minimum one and up to two hours between questionnaire notifications. It is thus possible that the beneficial effects of the nature slideshows were too short-lived and therefore could not be captured by the EMA questionnaires of the current study. Finally, it is important to note that the present research is distinct from most previous studies that investigated the restorative effects of nature in terms of length. While it is common for EMI studies to take place over longer time periods ranging from several days up to months or years (Heron & Smyth, 2010), most studies in the realm of nature restoration are of much shorter duration. Notable exceptions include the studies conducted by Gladwell and colleagues (2016) who investigated the effects of lunchtime walks on heart rate variability measured the following night, Lee and colleagues (2009) who compared the effects of viewing real forest landscapes with viewing urban environments among healthy individuals over a period of three days, as well as Brown and colleagues (2014) who examined the effects of lunchtime walks in nature versus built environments in an eight-week-long randomized control trial. Given the fact that the majority of studies investigated short-term effects of nature on health and well-being (Haluza et al., 2014; Thompson Coon et al., 2011; Velarde et al., 2007), the long-term effects of nature exposure are not well understood. This study therefore made an attempt at filling this gap. It can be concluded that the present experiment exhibits several conceptual and methodological differences compared to previous studies which may potentially account for the fact that the beneficial effects of mediated nature exposure could not be confirmed.

4.4 Implications for future research

Despite the fact that this study has found little support for the restorative effect of a mediated nature intervention as administered on a mobile device over the course of a six-day-long ecological momentary intervention study, insights gathered from the present experiment have important implications for future research. The main outcomes for the ecological momentary assessment data overall indicate that over the course of the six days of the main experiment, participants generally experienced an increase in perceived stress as well as a decrease in energy, well-being, sleep quality and to some degree self-control. Furthermore, it was found that participants in the slideshow conditions experienced significantly more time pressure than participants in the control condition and that participants in the nature condition displayed lower levels of well-being and to some degree happiness and energy, compared to participants in the urban condition. These results are in sharp contrast to the wide support for the restorative effects of nature found by previous research (Beute & de Kort, 2014; Berto, 2014; Bowler et al., 2010; Bratman et al., 2012; Haluza et al., 2014; Mantler & Logan, 2015; Velarde et al., 2007). However, as discussed earlier, there are important methodological differences between these studies and the present work. The outcomes of the current study therefore suggest that real-life environments might require different types of stress-reducing interventions than laboratory or semi-controlled field environments. For example, under severe time pressure or when dealing with many competing demands, there may be more appropriate or effective strategies for coping with stress than watching nature slideshows or spending time in real nature. An important question that has to be answered is thus how a stress-reducing intervention designed for everyday situations should look like.

Qualitative results from the interviews revealed that many participants experienced the slideshows as boring, monotonous and in some cases even frustrating. This feedback indicates that the movies were not interesting enough to catch people's attention or to elicit positive emotions. Instead, the slideshows themselves might have been a source of frustration and stress.

Results from previous studies show that factors such as immersion and image quality are very important determinants of the overall success and restorative potential of a visual nature intervention (Biederman & Vessel, 2006; de Kort et al., 2006; Tinio & Leder, 2006). Opportunities for improvement with regard to slideshow content and degree of immersion may thus include improving image quality, using real videos instead of slideshows, using virtual reality headsets such as the Samsung Galaxy Gear VR or Google Cardboard to deliver the intervention or combining images with sound. Nature sounds in particular were found to have positive effects with regard to stress reduction (Alvarsson, Wiens, & Nilsson, 2010; Annerstedt et al., 2013). Given the evidence that the mere act of taking a break to watch a slideshow was already beneficial in terms of physiological restoration, an alternative idea might be to provide an intervention which does not involve watching slideshows at all and instead simply asks participants to take a short break to relax. Of particular interest in this regard are insights from the field of mindfulness-based therapy, an approach which makes use of mediation techniques in order to bring one's undivided attention to the present moment (Baer, 2003; Hofmann, Sawyer, & Witt, 2010).

The outcomes of this study also have important practical implications with regard to the design decisions for future EMI experiments. For example, participants mentioned that watching slideshows was experienced positively only if they had enough time to follow the instructions. Consequently, the strategy to recommend slideshows in situations where participants were experiencing high levels of stress might not have had the desired effect. An alternative approach might be to give participants more freedom in choosing when to watch a slideshow or follow an intervention. One drawback of EMA and EMI studies is that the study protocol requires substantial effort from participants (Beute et al., 2016; Scollon et al., 2009; Shiffman et al., 2008). Results from the EMA questionnaires as well as the interviews revealed that the frequent administration questionnaires and slideshow interventions throughout the day has generated considerable workload and stress. For future studies, it is recommended to design the EMI applications such that participation is effortless and low in terms of frustration potential. This includes choosing a notification sound which is of limited duration and verifiably pleasant or neutral. Furthermore, offering an option for vibration notifications instead of sound notifications is crucial, to account for situations in which mobile devices have to be silenced.

4.5 Limitations

This study had several limitations. First, participants of this study were mostly students. It is therefore difficult to estimate to what degree the findings can be generalized to a broader population. Furthermore, there was a substantial gender imbalance for the urban slideshow condition. Given the fact that previous research has found evidence for a gender effect on heart rate variability (Bonnemeier et al., 2003; Jensen-Urstad et al., 1997; Stein et al., 1997; Umetani et al., 1998), this imbalance may thus have had an influence on the outcomes observed. While the multilevel model analyses with gender as a predictor have provided limited support for this concern, the possibility that gender may have had an impact on results cannot be ruled-out completely. Another drawback of this study is its rather small sample size, with only 14 participants per condition. It is therefore possible that more subtle effects of the nature intervention were not discovered by the current study. In addition, the assumptions for the multilevel model analyses conducted were consistently violated. Concern is also warranted with regard to the outliers identified. More specifically, there were several cases in which it was found that excluding outliers rendered previously significant effects non-significant. As a consequence, the results of the present study have to be interpreted with caution. In addition, due to the fact that this study was conducted as an ecological momentary intervention, it was not possible to control for environmental influences to the same degree as in case of laboratory studies. This is of particular concern with regard to the slideshow interventions administered, as it was not possible to validate whether participants indeed watched the slideshows and if so, whether they were doing something else meanwhile. Distractions in the environment or activities carried out in parallel to watching the slideshows may thus have influenced the outcomes. Similar concerns exist with regard to the heart rate variability measures collected, as indices of heart rate variability are very sensitive to even subtle aspects such as posture, breathing or speech (Berntson et al., 1997; Garde et al., 2002). In addition, there are several other aspects which might have compromised the data quality of the heart rate variability recordings. More specifically, the connection between the polar H7 chest strap and the tablet was sometimes unstable, resulting in data loss. Moreover, due to the presence of noise, a substantial amount of HRV segments had to be discarded. Valid HRV data was therefore available only for a subset of the questionnaires and slideshows. Qualitative results from the interviews further indicate that there might have been issues with regard to compliance. Particularly, participants with sleep-wake rhythms different from the one imposed by the EMI protocol might have had less opportunities to answer questionnaires. Similarly, qualitative results showed that there were distinctive situations and environments in which participants were unable to comply with the EMI protocol, such as for example at the workplace, during class or in the lab. Finally, outcomes from the interviews indicate that the issue of reactivity might have been a problem as well. More specifically, several participants mentioned that answering questions several times a day has influenced their thoughts and feelings about certain aspects in their lives and even motivated them to alter their behavior. There is thus the possibility that the participation in the experiment itself might have had an influence on the outcomes of the present research.

4.6 Conclusion

Contrary to the results from previous research, the outcomes of the current study show that a nature slideshow manipulation administered in the context of a six-day-long ecological momentary intervention study failed to provide support for the health-promoting effects of exposure to mediated nature. With regard to the psychological variables assessed, results found that participation in the experiment was associated with an increase in stress and decline in well-being over the course of the experiment for all participants, indicating that the participation in this experiment was exhausting and placed a considerable burden on participants. Furthermore, there was evidence that being assigned to either one of the two treatment conditions (nature slideshows or urban slideshows) and consequently being required to regularly watch slideshows further contributed to the workload experienced. With regard to the physiological measures, there was evidence that the mere act of taking a break to watch a slideshow was already beneficial in terms of physiological restoration, irrespective of treatment condition. Overall, there was thus little evidence that the nature slideshow intervention administered in the current study led to significant improvements in terms of psychological or physiological health. The outcomes indicate that mediated nature interventions that were found to have restorative properties in a laboratory context might not be as easily transferable into an everyday setting as hypothesized. Instead, the results of the present study suggest that real-life environments might require different types of stress-reducing interventions than laboratory or semi-controlled field settings. Future research should therefore investigate whether alternative approaches – for example more immersive interventions or interventions based on the principles of mindfulness – are more successful at reducing stress and improving well-being.

5 References

Abràmoff, M. D., Magalhães, P. J., & Ram, S. J. (2004). Image processing with ImageJ. *Biophotonics international*, 11(7), 36-42.

Acharya, U. R., Joseph, K. P., Kannathal, N., Lim, C. M., & Suri, J. S. (2006). Heart rate variability: a review. *Medical and biological engineering and computing*, 44(12), 1031-1051.

Adam, T. C., & Epel, E. S. (2007). Stress, eating and the reward system. *Physiology & behavior*, 91(4), 449-458.

Aertgeerts, B., Buntinx, F., Ansoms, S., & Fevery, J. (2001). Screening properties of questionnaires and laboratory tests for the detection of alcohol abuse or dependence in a general practice population. *British Journal of General Practice*, 51(464), 206-217.

Agelink, M. W., Boz, C., Ullrich, H., & Andrich, J. (2002). Relationship between major depression and heart rate variability: Clinical consequences and implications for antidepressive treatment. *Psychiatry research*, 113(1), 139-149.

Akerstedt, T., Hume, K. E. N., Minors, D., & Waterhouse, J. I. M. (1994). The subjective meaning of good sleep, an intraindividual approach using the Karolinska Sleep Diary. *Perceptual and motor skills*, *79*(1), 287-296.

Alvarsson, J. J., Wiens, S., & Nilsson, M. E. (2010). Stress recovery during exposure to nature sound and environmental noise. *International journal of environmental research and public health*, 7(3), 1036-1046.

Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., Hansen A. M., & Währborg, P. (2013). Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study. *Physiology & behavior*, 118, 240-250.

Arrindell, W.A., Ettema, J.H.M. (1986). *SCL-90: Handleiding bij een multidimensionele psychopathologie-indicator.* Amsterdam, Netherlands: Pearson.

Baer, R. A. (2003). Mindfulness training as a clinical intervention: A conceptual and empirical review. *Clinical psychology: Science and practice*, 10(2), 125-143.

Barutcu, I., Esen, A. M., Kaya, D., Turkmen, M., Karakaya, O., Melek, M., Esen, O. B., & Basaran, Y. (2005). Cigarette smoking and heart rate variability: dynamic influence of parasympathetic and sympathetic maneuvers. *Annals of noninvasive electrocardiology*, 10(3), 324-329.

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine*, 25(24), 3186-3191.

Beck, A. T., Steer, R. A., Ball, R., & Ranieri, W. F. (1996). Comparison of Beck Depression Inventories-IA and-II in psychiatric outpatients. *Journal of personality assessment*, 67(3), 588-597.

van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental preference and restoration: (How) are they related? *Journal of environmental psychology*, 23(2), 135-146.

van den Berg, M. M., Maas, J., Muller, R., Braun, A., Kaandorp, W., van Lien, R., van Poppel, M. N., van Mechelen, W., & van den Berg, A. E. (2015). Autonomic Nervous System Responses to Viewing Green and Built Settings: Differentiating Between Sympathetic and Parasympathetic Activity. *International journal of environmental research and public health*, 12(12), 15860-15874.

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological science*, 19(12), 1207-1212.

Berntson, G. G., Bigger, J.T. Jr, Eckberg, D.L., Grossman, P., Kaufmann, P. G., Malik, M., Nagaraja, H. N., Porges, S. W., Saul, J. P., Stone, P. H., & van der Molen, M. W. (1997). Heart rate variability: origins, methods, and interpretive caveats. *Psychophysiology*, 34(6), 623-648.

Berntson, G. G., & Cacioppo, J. T. (2007). Integrative Physiology: Homeostasis, Allostasis, and the Orchestration of Systemic Physiology. In J. T. Cacioppo, L. G. Tessinary, & G. G. Berntson (Eds.), *The handbook of psychophysiology*, (pp. 433-452). New York, NY: Cambridge University Press.

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of environmental psychology*, 25(3), 249-259.

Berto, R. (2014). The role of nature in coping with psycho-physiological stress: a literature review on restorativeness. *Behavioral sciences*, 4(4), 394-409.

Beute, F., & de Kort, Y. A. (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.

Beute, F., & de Kort, Y. A. (2014). Salutogenic effects of the environment: Review of health protective effects of nature and daylight. *Applied Psychology: Health and Well-Being*, 6(1), 67-95.

Beute, F., de Kort, Y., & IJsselsteijn, W. (2016). Restoration in Its Natural Context: How Ecological Momentary Assessment Can Advance Restoration Research. *International journal of environmental research and public health*, 13(4), 420.

Biederman, I., & Vessel, E. (2006). Perceptual Pleasure and the Brain A novel theory explains why the brain craves information and seeks it through the senses. *American scientist*, 94(3), 247-253.

Bigger, J. T., Fleiss, J. L., Steinman, R. C., Rolnitzky, L. M., Kleiger, R. E., & Rottman, J. N. (1992). Frequency domain measures of heart period variability and mortality after myocardial infarction. *Circulation*, 85(1), 164-171.

Bilchick, K. C., Fetics, B., Djoukeng, R., Fisher, S. G., Fletcher, R. D., Singh, S. N., Nevo, E., & Berger, R. D. (2002). Prognostic value of heart rate variability in chronic congestive heart failure (Veterans Affairs' Survival Trial of Antiarrhythmic Therapy in Congestive Heart Failure). *The American journal of cardiology*, 90(1), 24-28.

Björntorp, P. (2001). Do stress reactions cause abdominal obesity and comorbidities? *Obesity reviews*, 2(2), 73-86.

Bonnemeier, H., Wiegand, U. K., Brandes, A., Kluge, N., Katus, H. A., Richardt, G., & Potratz, J. (2003). Circadian profile of cardiac autonomic nervous modulation in healthy subjects. *Journal of cardiovascular electrophysiology*, 14(8), 791-799.

Bonnet, M., Tancer, M., Uhde, T., & Yeragani, V. K. (2005). Effects of caffeine on heart rate and QT variability during sleep. *Depression and anxiety*, 22(3), 150-155.

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(1), 456.

Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015a). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning*, 138, 41-50.

Bratman, G. N., Hamilton, J. P., & Daily, G. C. (2012). The impacts of nature experience on human cognitive function and mental health. *Annals of the New York Academy of Sciences*, 1249(1), 118-136.

Bratman, G. N., Hamilton, J. P., Hahn, K. S., Daily, G. C., & Gross, J. J. (2015b). Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proceedings of the national academy of sciences*, 112(28), 8567-8572.

Brosschot, J. F. (2010). Markers of chronic stress: Prolonged physiological activation and (un) conscious perseverative cognition. *Neuroscience & Biobehavioral Reviews*, 35(1), 46-50.

Brosschot, J. F., Gerin, W., & Thayer, J. F. (2006). The perseverative cognition hypothesis: A review of worry, prolonged stress-related physiological activation, and health. *Journal of psychosomatic research*, 60(2), 113-124.

Brosschot, J. F., Van Dijk, E., & Thayer, J. F. (2007). Daily worry is related to low heart rate variability during waking and the subsequent nocturnal sleep period. *International Journal of Psychophysiology*, 63(1), 39-47.

Brotman, D. J., Golden, S. H., & Wittstein, I. S. (2007). The cardiovascular toll of stress. *The Lancet*, *370*(9592), 1089-1100.

Brown, T. A., Antony, M. M., & Barlow, D. H. (1992). Psychometric properties of the Penn State Worry Questionnaire in a clinical anxiety disorders sample. *Behaviour research and therapy*, 30(1), 33-37.

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(11), 5562-5569.

Brown, D. K., Barton, J. L., Pretty, J., Gladwell, V. F. (2014). Walks4Work: Assessing the role of the natural environment in a workplace physical activity intervention. *Scandinavian journal of work, environment & health*, 40(4), 390.

Cacioppo, J. T., & Gardner, W. L. (1999). Emotion. *Annual review of psychology*, 50(1), 191-214.

Carrasco, G. A., & Van de Kar, L. D. (2003). Neuroendocrine pharmacology of stress. *European journal of pharmacology*, 463(1), 235-272.

Carter, J. B., Banister, E. W., & Blaber, A. P. (2003). Effect of endurance exercise on autonomic control of heart rate. *Sports medicine*, 33(1), 33-46.

Carver, C. S., & Connor-Smith, J. (2010). Personality and coping. *Annual review of psychology*, 61, 679-704.

Carver, C. S., Scheier, M. F., & Segerstrom, S. C. (2010). Optimism. *Clinical psychology review*, 30(7), 879-889.

Centraal Bureau voor de Statistiek (2014). *Jaarrapport 2014: Landelijke Jeugdmonitor* (ISBN: 978-90-357-1537-0). The Hague, Netherlands: Centraal Bureau voor de Statistiek. Retrieved May 30, 2016, from https://www.cbs.nl/nl-nl/publicatie/2014/50/jaarrapport-2014-landelijke-jeugdmonitor

Chalmers, J. A., Quintana, D. S., Abbott, M. J., & Kemp, A. H. (2014). Anxiety disorders are associated with reduced heart rate variability: a meta-analysis. *Frontiers in psychiatry*, 5, 80.

Chandola, T., Heraclides, A., & Kumari, M. (2010). Psychophysiological biomarkers of workplace stressors. *Neuroscience & Biobehavioral Reviews*, 35(1), 51-57.

Charmandari, E., Tsigos, C., & Chrousos, G. (2005). Endocrinology of the stress response. *Annual Review of Physiology*, 67, 259-284.

Chrousos, G. P. (2009). Stress and disorders of the stress system. *Nature Reviews Endocrinology*, 5(7), 374-381.

Cohen, S. (2014, February 17). *The Perceived Stress Scale: Frequently Asked Questions.* Retrieved May 30, 2016, from http://www.psy.cmu.edu/~scohen/PSSfaqs.doc

Cohen, S., & Janicki-Deverts, D. (2012). Who's stressed? Distributions of psychological stress in the United States in probability samples from 1983, 2006, and 20091. *Journal of Applied Social Psychology*, 42(6), 1320-1334.

Cohen, S., Janicki-Deverts, D., & Miller, G. E. (2007). Psychological stress and disease. *JAMA*, 298(14), 1685-1687.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of health and social behavior*, 24 (4), 385-396.

Cohen, S., Kessler, R. C., & Gordon, L. U. (1997). Strategies for measuring stress in studies of psychiatric and physical disorders. In S. Cohen, R. C. Kessler, & L. U. Gordon (Eds.), *Measuring stress: A guide for health and social scientists* (pp. 3-26). New York, NY: Oxford University Press.

Collins, S. M., Karasek, R. A., & Costas, K. (2005). Job strain and autonomic indices of cardiovascular disease risk. *American journal of industrial medicine*, 48(3), 182-193.

Christensen, T. C., Barrett, L. F., Bliss-Moreau, E., Lebo, K., & Kaschub, C. (2003). A practical guide to experience-sampling procedures. *Journal of Happiness Studies*, 4(1), 53-78.

Connor-Smith, J. K., & Flachsbart, C. (2007). Relations between personality and coping: a meta-analysis. *Journal of personality and social psychology*, 93(6), 1080- 1107.

Costigan, S. A., Eather, N., Plotnikoff, R. C., Taaffe, D. R., Pollock, E., Kennedy, S. G., & Lubans, D. R. (2015). Preliminary efficacy and feasibility of embedding high intensity interval training into the school day: a pilot randomized controlled trial. *Preventive Medicine Reports*, 2, 973-979.

Csikszentmihalyi, M., Larson, R., & Prescott, S. (1977). The ecology of adolescent activity and experience. *Journal of youth and adolescence*, 6(3), 281-294.

Dallman, M. F. (2010). Stress-induced obesity and the emotional nervous system. *Trends in Endocrinology & Metabolism*, 21(3), 159-165.

Davis, M., Montgomery, I., & Wilson, G. (2002). Worry and heart rate variables: Autonomic rigidity under challenge. *Journal of anxiety Disorders*, 16(6), 639-659.

Dekker, J. M., Crow, R. S., Folsom, A. R., Hannan, P. J., Liao, D., Swenne, C. A., & Schouten, E. G. (2000). Low heart rate variability in a 2-minute rhythm strip predicts risk of coronary heart disease and mortality from several causes The ARIC Study. *Circulation*, 102(11), 1239-1244.

Denissen, J. J., Geenen, R., van Aken, M. A., Gosling, S. D., & Potter, J. (2008). Development and validation of a Dutch translation of the Big Five Inventory (BFI). *Journal of personality assessment*, 90(2), 152-157.

Derogatis, L. R., & Unger, R. (2010). Symptom checklist-90-revised. In I. B. Weiner & W. E. Craighead (Eds.), *Corsini encyclopedia of psychology* (Vol. 4, pp. 1743-1744). Hoboken, NJ: John Wiley & Sons, Inc.

Dhabhar, F. S. (2014). Effects of stress on immune function: the good, the bad, and the beautiful. *Immunologic research*, 58(2-3), 193-210.

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychological bulletin*, 130(3), 355.

Diefendorff, J. M., Hall, R. J., Lord, R. G., & Strean, M. L. (2000). Action–state orientation: Construct validity of a revised measure and its relationship to work-related variables. *Journal of Applied Psychology*, 85(2), 250-263.

Dobkin, B. H., & Dorsch, A. (2011). The promise of mHealth daily activity monitoring and outcome assessments by wearable sensors. *Neurorehabilitation and neural repair*, 25(9), 788-798.

van der Does, A. J. W. (2002). *Handleiding. De Nederlandse versie vande Beck Depression Inventory – Second edition (BDI-II-NL).* Amsterdam, Netherlands: Harcourt.

Ebner-Priemer, U. W., Kuo, J., Welch, S. S., Thielgen, T., Witte, S., Bohus, M., & Linehan, M. M. (2006). A valence-dependent group-specific recall bias of retrospective self-reports: A study of borderline personality disorder in everyday life. *The Journal of nervous and mental disease*, 194(10), 774-779.

Ernst, G. (2014). *Heart rate variability*. London, England: Springer.

Folkman, S. (1984). Personal control and stress and coping processes: a theoretical analysis. *Journal of personality and social psychology*, 46(4), 839-852.

Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., Patel, V., & Haines, A. (2013). The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. *PLOS Medicine*, 10(1).

Free, C., Phillips, G., Felix, L., Galli, L., Patel, V., & Edwards, P. (2010). The effectiveness of M-health technologies for improving health and health services: a systematic review protocol. *BMC research notes*, 3(250).

Friedman, B. H. (2007). An autonomic flexibility–neurovisceral integration model of anxiety and cardiac vagal tone. *Biological psychology*, 74(2), 185-199.

Furlan, R., Guzzetti, S., Crivellaro, W., Dassi, S., Tinelli, M., Baselli, S., Cerutti, Lombardi, F., Pagani, M., & Malliani, A. (1990). Continuous 24-hour assessment of the neural regulation of systemic arterial pressure and RR variabilities in ambulant subjects. *Circulation*, 81(2), 537-547.

Ganzel, B. L., Morris, P. A., & Wethington, E. (2010). Allostasis and the human brain: Integrating models of stress from the social and life sciences. *Psychological review*, 117(1), 134.

Garde, A., Laursen, B., Jørgensen, A., & Jensen, B. (2002). Effects of mental and physical demands on heart rate variability during computer work. *European journal of applied physiology*, 87(4-5), 456-461.

Geniole, S. N., David, J. P., Euzébio, R. F., Toledo, B. Z., Neves, A. I., & McCormick, C. M. (2016). Restoring Land and Mind: The Benefits of an Outdoor Walk on Mood Are Enhanced in a Naturalized Landfill Area Relative to Its Neighboring Urban Area. *Ecopsychology*, 8(2), 107-120.

Gerritsen, J., Dekker, J. M., TenVoorde, B. J., Kostense, P. J., Heine, R. J., Bouter, L. M., Heethaar, R. M., & Stehouwer, C. D. (2001). Impaired autonomic function is associated with increased mortality, especially in subjects with diabetes, hypertension, or a history of cardiovascular disease – The Hoorn study. *Diabetes care*, 24(10), 1793-1798.

Gerteis, A. K. S., & Schwerdtfeger, A. R. (2016). When rumination counts: Perceived social support and heart rate variability in daily life. *Psychophysiology*, 53(7), 1034–1043.

Gidlow, C. J., Jones, M. V., Hurst, G., Masterson, D., Clark-Carter, D., Tarvainen, M. P., Smith, G., & Nieuwenhuijsen, M. (2016). Where to put your best foot forward: Psycho-physiological responses to walking in natural and urban environments. *Journal of Environmental Psychology*, 45, 22-29.

Gladwell, V. F., Brown, D. K., Barton, J. L., Tarvainen, M. P., Kuoppa, P., Pretty, J., Suddaby, J. M., & Sandercock, G. R. H. (2012). The effects of views of nature on autonomic control. *European journal of applied physiology*, 112(9), 3379-3386.

Gladwell, V. F., Kuoppa, P., Tarvainen, M. P., & Rogerson, M. (2016). A Lunchtime Walk in Nature Enhances Restoration of Autonomic Control during Night-Time Sleep: Results from a Preliminary Study. *International journal of environmental research and public health*, 13(3), 280.

Glaesmer, H., Rief, W., Martin, A., Mewes, R., Brähler, E., Zenger, M., & Hinz, A. (2012). Psychometric properties and population-based norms of the Life Orientation Test Revised (LOT-R). *British journal of health psychology*, 17(2), 432-445.

Gold, P. W., Machado-Vieira, R., & Pavlatou, M. G. (2015). Clinical and biochemical manifestations of depression: relation to the neurobiology of stress. *Neural plasticity*, 2015, 1-11.

Goldsmith, R. L., Bloomfield, D. M., & Rosenwinkel, E. T. (2000). Exercise and autonomic function. *Coronary artery disease*, 11(2), 129-135.

Gruica, B., Wang, H. Y., Lang, N. P., & Buser, D. (2004). Impact of IL-1 genotype and smoking status on the prognosis of osseointegrated implants. *Clinical Oral Implants Research*, 15(4), 393-400.

Gunnar, M., & Quevedo, K. (2007). The neurobiology of stress and development. *Annual Review of Psychology*, 58, 145-173.

Guo, Y. F., & Stein, P. K. (2003). Circadian rhythm in the cardiovascular system: chronocardiology. *American heart journal*, 145(5), 779-786.

Hafkenscheid, A. (1993). Psychometric evaluation of the symptom checklist (SCL-90) in psychiatric inpatients. *Personality and Individual Differences*, 14(6), 751-756.

Hall, M., Vasko, R., Buysse, D., Ombao, H., Chen, Q., Cashmere, J. D., Kupfer, D., & Thayer, J. F. (2004). Acute stress affects heart rate variability during sleep. *Psychosomatic medicine*, 66(1), 56-62.

Haluza, D., Schönbauer, R., & Cervinka, R. (2014). Green perspectives for public health: a narrative review on the physiological effects of experiencing outdoor nature. *International journal of environmental research and public health*, 11(5), 5445-5461.

Hammen, C. (2005). Stress and depression. *Annual Review of Clinical Psychology*, 1, 293-319.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of environmental psychology*, 23(2), 109-123.

Hayano, J., Yamada, M., Sakakibara, Y., Fujinami, T., Yokoyama, K., Watanabe, Y., & Takata, K. (1990). Short-and long-term effects of cigarette smoking on heart rate variability. *The American journal of cardiology*, 65(1), 84-88.

van der Heiden, C. (2009). *Metacognitieve therapie bij gegeneraliseerde angst*. Houten, Netherlands: Bohn Stafleu van Loghum.

van der Heiden, C., Muris, P., Bos, A. E., van der Molen, H., & Oostra, M. (2009). Normative data for the Dutch version of the Penn State Worry Questionnaire. *Netherlands Journal of Psychology*, 65(2), 69-75.

Herman, S., & Koran, L. M. (1998). In vivo measurement of obsessive-compulsive disorder symptoms using palmtop computers. *Computers in Human Behavior*, 14(3), 449-462.

Heron, K. E., & Smyth, J. M. (2010). Ecological momentary interventions: incorporating mobile technology into psychosocial and health behaviour treatments. *British journal of health psychology*, 15(1), 1-39.

Het, S., Ramlow, G., & Wolf, O. T. (2005). A meta-analytic review of the effects of acute cortisol administration on human memory. *Psychoneuroendocrinology*, 30(8), 771-784.

Hintsanen, M., Elovainio, M., Puttonen, S., Kivimäki, M., Koskinen, T., Raitakari, O. T., & Keltikangas-Järvinen, L. (2007). Effort—reward imbalance, heart rate, and heart rate variability: the cardiovascular risk in young finns study. *International journal of behavioral medicine*, 14(4), 202-212.

Hippisley-Cox, J., & Coupland, C. (2012). Identifying patients with suspected pancreatic cancer in primary care: derivation and validation of an algorithm. *Br J Gen Pract*, 62(594), e38-e45.

Hjortskov, N., Rissén, D., Blangsted, A. K., Fallentin, N., Lundberg, U., & Søgaard, K. (2004). The effect of mental stress on heart rate variability and blood pressure during computer work. *European journal of applied physiology*, 92(1-2), 84-89.

Hofmann, S. G., Sawyer, A. T., Witt, A. A., & Oh, D. (2010). The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. *Journal of consulting and clinical psychology*, 78(2), 169-183.

Hoshikawa, Y., & Yamamoto, Y. (1997). Effects of Stroop color-word conflict test on the autonomic nervous system responses. *American Journal of Physiology-Heart and Circulatory Physiology*, 272(3), H1113-H1121.

Huikuri, H. V., Niemelä, M. J., Ojala, S., Rantala, A., Ikäheimo, M. J., & Airaksinen, K. E. (1994). Circadian rhythms of frequency domain measures of heart rate variability in healthy subjects and patients with coronary artery disease. Effects of arousal and upright posture. *Circulation*, 90(1), 121-126.

Huikuri, H. V., Ylitalo, A., Pikkujämsä, S. M., Ikäheimo, M. J., Airaksinen, K. J., Rantala, A. O., Lilja, M., & Kesäniemi, Y. A. (1996). Heart rate variability in systemic hypertension. *The American journal of cardiology*, 77(12), 1073-1077.

Ingjaldsson, J. T., Laberg, J. C., & Thayer, J. F. (2003). Reduced heart rate variability in chronic alcohol abuse: relationship with negative mood, chronic thought suppression, and compulsive drinking. *Biological psychiatry*, 54(12), 1427-1436.

Jensen-Urstad, K., Storck, N., Bouvier, F., Ericson, M., Lindbland, L. E., & Jensen-Urstad, M. (1997). Heart rate variability in healthy subjects is related to age and gender. *Acta Physiologica Scandinavica*, 160(3), 235-241.

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

John, O. P., Naumann, L. P., & Soto, C. J. (2008). Paradigm shift to the integrative Big Five trait taxonomy: History, measurement, and conceptual issues. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of personality: Theory and research* (pp. 114-158). New York, NY: Guilford Press.

Joseph, J. J., & Golden, S. H. (2016). Cortisol dysregulation: the bidirectional link between stress, depression, and type 2 diabetes mellitus. *Annals of the New York Academy of Sciences*.

Kamath, M. V., Watanabe, M., & Upton, A. (Eds.). (2012). *Heart rate variability (HRV) signal analysis: clinical applications*. Boca Raton, FL: CRC Press.

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when an experience-sampling study of working memory and executive control in daily life. *Psychological science*, 18(7), 614-621.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of environmental psychology*, 15(3), 169-182.

Kemeny, M. E. (2003). The psychobiology of stress. *Current directions in psychological science*, 12(4), 124-129.

Kemp, A. H., Quintana, D. S., Gray, M. A., Felmingham, K. L., Brown, K., & Gatt, J. M. (2010). Impact of depression and antidepressant treatment on heart rate variability: a review and meta-analysis. *Biological psychiatry*, 67(11), 1067-1074.

Key, B. L., Campbell, T. S., Bacon, S. L., & Gerin, W. (2008). The influence of trait and state rumination on cardiovascular recovery from a negative emotional stressor. *Journal of Behavioral Medicine*, 31(3), 237-248.

King, S. L., & Hegadoren, K. M. (2002). Stress hormones: how do they measure up? *Biological research for nursing*, 4(2), 92-103.

Kleiger, R. E., Miller, J. P., Bigger, J. T., & Moss, A. J. (1987). Decreased heart rate variability and its association with increased mortality after acute myocardial infarction. *The American journal of cardiology*, 59(4), 256-262.

Kleiger, R. E., Stein, P. K., & Bigger, J. T. (2005). Heart rate variability: measurement and clinical utility. *Annals of Noninvasive Electrocardiology*, 10(1), 88-101.

ten Klooster, P. M., Weekers, A. M., Eggelmeijer, F., van Woerkom, J. M., Drossaert, C. H. C. M., Taal, E., Rasker, J. J., & Baneke, J. J. (2010). Optimisme en/of pessimisme: factorstructuur van de Nederlandse Life Orientation Test-Revised. *Psychologie en Gezondheid*, 38(2), 89-100.

Knepp, M. M., & Friedman, B. H. (2008). Cardiovascular activity during laboratory tasks in women with high and low worry. *Biological Psychology*, 79(3), 287-293.

Kohn, P. M., & Macdonald, J. E. (1992). The Survey of Recent Life Experiences: A decontaminated hassles scale for adults. *Journal of behavioral medicine*, 15(2), 221-236.

Koole, S. L., & Jostmann, N. B. (2004). Getting a grip on your feelings: effects of action orientation and external demands on intuitive affect regulation. *Journal of personality and social psychology*, 87(6), 974- 990.

Koole, S. L., & van den Berg, A. E. (2005). Lost in the wilderness: terror management, action orientation, and nature evaluation. *Journal of personality and social psychology*, 88(6), 1014-1028.

Kopp, M. S., Thege, B. K., Balog, P., Stauder, A., Salavecz, G., Rózsa, S., Purebl, G., & Ádám, S. (2010). Measures of stress in epidemiological research. *Journal of Psychosomatic Research*, 69(2), 211-225.

de Kort, Y. A. W., Meijnders, A. L., Sponselee, A. A. G., & IJsselsteijn, W. A. (2006). What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of environmental psychology*, 26(4), 309-320.

Koskinen, P., Virolainen, J., & Kupari, M. (1994). Acute alcohol intake decreases short-term heart rate variability in healthy subjects. *Clinical Science*, 87(2), 225-230.

Kuhl, J. (1981). Motivational and functional helplessness: The moderating effect of state versus action orientation. *Journal of Personality and Social Psychology*, 40(1), 155-170.

Kuhl, J. (1994). Action versus state orientation: Psychometric properties of the action control scale (ACS-90). In J. Kuhl & J. Beckmann (Eds.), *Volition and personality: Action versus state orientation* (pp. 47-59). Seattle, WA: Hogrefe & Huber Publishing.

Kyrou, I., & Tsigos, C. (2009). Stress hormones: physiological stress and regulation of metabolism. *Current opinion in pharmacology*, 9(6), 787-793.

Lackschewitz, H., Hüther, G., & Kröner-Herwig, B. (2008). Physiological and psychological stress responses in adults with attention-deficit/hyperactivity disorder (ADHD). *Psychoneuroendocrinology*, 33(5), 612-624.

Laumann, K., Gärling, T., & Stormark, K. M. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of environmental psychology*, 23(2), 125-134.

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., Wüst, S., Pruessner, J. C., Rietschel, M., Deuschle, M., & Meyer-Lindenberg, A. (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature*, *474*(7352), 498-501.

Lee, E. H. (2012). Review of the psychometric evidence of the perceived stress scale. *Asian Nursing Research*, 6(4), 121-127.

Lee, A. L., Ogle, W. O., & Sapolsky, R. M. (2002). Stress and depression: possible links to neuron death in the hippocampus. *Bipolar disorders*, 4(2), 117-128.

Lee, J., Park, B. J., Tsunetsugu, Y., Kagawa, T., & Miyazaki, Y. (2009). Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. *Scandinavian Journal of Forest Research*, 24(3), 227-234.

Liao, D., Cai, J., Brancati, F. L., Folsom, A., Barnes, R. W., Tyroler, H. A., & Heiss, G. (1995). Association of vagal tone with serum insulin, glucose, and diabetes mellitus—the ARIC Study. *Diabetes research and clinical practice*, 30(3), 211-221.

Liao, D., Cai, J., Rosamond, W. D., Barnes, R. W., Hutchinson, R. G., Whitsel, E. A., Rautaharju, P., & Heiss, G. (1997). Cardiac Autonomic Function and Incident Coronary Heart Disease: A Population-based Case-Cohort Study The ARIC Study. *American Journal of Epidemiology*, 145(8), 696-706.

Liu, C. (2015). *Worldwide Internet and Mobile Users: e-Marketer's Updated Estimates for 2015*. Retrieved from eMarketer database.

Lombardi, F., Sandrone, G., Pernpruner, S., Sala, R., Garimoldi, M., Cerutti, S., Baselli, G., Pagani, M., & Malliani, A. (1987). Heart rate variability as an index of sympathovagal interaction after acute myocardial infarction. *The American journal of cardiology*, 60(16), 1239-1245.

Lucini, D., Norbiato, G., Clerici, M., & Pagani, M. (2002). Hemodynamic and autonomic adjustments to real life stress conditions in humans. *Hypertension*, 39(1), 184-188.

Lukach, A. J., Jedrziewski, M. K., Grove, G. A., Mechanic-Hamilton, D. J., Williams, S. S., Wollam, M. E., & Erickson, K. I. (2016). Rhythm experience and Africana culture trial (REACT!):

A culturally salient intervention to promote neurocognitive health, mood, and well-being in older African Americans. *Contemporary clinical trials*, 48, 41-45.

Lupien, S. J., Maheu, F., Tu, M., Fiocco, A., & Schramek, T. E. (2007). The effects of stress and stress hormones on human cognition: Implications for the field of brain and cognition. *Brain and cognition*, 65(3), 209-237.

Luxton, D. D., McCann, R. A., Bush, N. E., Mishkind, M. C., & Reger, G. M. (2011). mHealth for mental health: Integrating smartphone technology in behavioral healthcare. *Professional Psychology: Research and Practice*, 42(6), 505.

Maas, J., Verheij, R. A., de Vries, S., Spreeuwenberg, P., Schellevis, F. G., & Groenewegen, P. P. (2009). Morbidity is related to a green living environment. *Journal of epidemiology and community health*, *63*(12), 967-973.

Maas, J., Verheij, R. A., Groenewegen, P. P., De Vries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: how strong is the relation?. *Journal of epidemiology and community health*, 60(7), 587-592.

Malouff, J. M., Thorsteinsson, E. B., & Schutte, N. S. (2005). The relationship between the five-factor model of personality and symptoms of clinical disorders: a meta-analysis. *Journal of Psychopathology and Behavioral Assessment*, 27(2), 101-114.

Mantler, A., & Logan, A. C. (2015). Natural environments and mental health. *Advances in Integrative Medicine*, 2(1), 5-12.

Marin, M. F., Lord, C., Andrews, J., Juster, R. P., Sindi, S., Arsenault-Lapierre, G., Fiocco, A. J., & Lupien, S. J. (2011). Chronic stress, cognitive functioning and mental health. *Neurobiology of learning and memory*, 96(4), 583-595.

Marzano, L., Bardill, A., Fields, B., Herd, K., Veale, D., Grey, N., & Moran, P. (2015). The application of mHealth to mental health: opportunities and challenges. *The Lancet Psychiatry*, 2(10), 942-948.

Matthews, G., Jones, D. M., & Chamberlain, A. G. (1990). Refining the measurement of mood: The UWIST mood adjective checklist. *British journal of psychology*, 81(1), 17-42.

McEwen, B. S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, 840(1), 33-44.

McEwen, B. S. (2005). Glucocorticoids, depression, and mood disorders: structural remodeling in the brain. *Metabolism*, 54(5), 20-23.

McEwen, B. S. (2012). Brain on stress: how the social environment gets under the skin. *Proceedings of the National Academy of Sciences*, 109 (suppl. 2), 17180-17185.

McEwen, B. S., & Sapolsky, R. M. (1995). Stress and cognitive function. *Current opinion in neurobiology*, 5(2), 205-216.

McEwen, B. S., & Seeman, T. (1999). Protective and damaging effects of mediators of stress: elaborating and testing the concepts of allostasis and allostatic load. *Annals of the New York Academy of Sciences*, 896(1), 30-47.

McEwen, B. S., & Wingfield, J. C. (2003). The concept of allostasis in biology and biomedicine. *Hormones and behavior*, 43(1), 2-15.

Meyer, T. J., Miller, M. L., Metzger, R. L., & Borkovec, T. D. (1990). Development and validation of the Penn State worry questionnaire. *Behaviour research and therapy*, 28(6), 487-495.

Miller, D. B., & O'Callaghan, J. P. (2002). Neuroendocrine aspects of the response to stress. *Metabolism*, 51(6), 5-10.

Moksnes, U. K., & Espnes, G. A. (2016). Stress: Concepts, Models, and Measures. In M. E. Alvarenga & D. Byrne (Eds.) *Handbook of Psychocardiology* (pp. 143-162). Springer.

Monroe, S. M. (2008). Modern approaches to conceptualizing and measuring human life stress. *Annual Review Clinical Psychology*, 4, 33-52.

Morey, J. N., Boggero, I. A., Scott, A. B., & Segerstrom, S. C. (2015). Current directions in stress and human immune function. *Current opinion in psychology*, 5, 13-17.

Murata, K., Araki, S., Yokoyama, K., Sata, F., Yamashita, K., & Ono, Y. (1994). Autonomic neurotoxicity of alcohol assessed by heart rate variability. *Journal of the autonomic nervous system*, 48(2), 105-111.

Myrtek, M., Weber, D., Brügner, G., & Müller, W. (1996). Occupational stress and strain of female students: results of physiological, behavioral, and psychological monitoring. *Biological psychology*, 42(3), 379-391.

Nesse, R. M., Bhatnagar, S., & Young, E. A. (2007). Evolutionary Origins and Functions of the Stress Response. In *Encyclopedia of Stress.* (pp. 965-970). Elsevier Inc.

Niedermaier, O. N., Smith, M. L., Beightol, L. A., Zukowska-Grojec, Z., Goldstein, D. S., & Eckberg, D. L. (1993). Influence of cigarette smoking on human autonomic function. *Circulation*, 88(2), 562-571.

Nolan, J., Batin, P. D., Andrews, R., Lindsay, S. J., Brooksby, P., Mullen, Baig, W., M., Flapan, A. D., Cowley, A., Prescott, R. J., Neilson, J. M. M., & Fox, K. A. A. (1998). Prospective study of heart rate variability and mortality in chronic heart failure results of the United Kingdom heart failure evaluation and assessment of risk trial (UK-Heart). *Circulation*, 98(15), 1510-1516.

Nolen-Hoeksema, S. (2000). The role of rumination in depressive disorders and mixed anxiety/depressive symptoms. *Journal of abnormal psychology*, 109(3), 504.

Nutsford, D., Pearson, A. L., & Kingham, S. (2013). An ecological study investigating the association between access to urban green space and mental health. *Public health*, 127(11), 1005-1011.

Osman, A., Downs, W. R., Barrios, F. X., Kopper, B. A., Gutierrez, P. M., & Chiros, C. E. (1997). Factor structure and psychometric characteristics of the Beck Depression Inventory-II. *Journal of Psychopathology and Behavioral Assessment*, 19(4), 359-376.

Ottaviani, C., Shapiro, D., Davydov, D. M., Goldstein, I. B., & Mills, P. J. (2009). The autonomic phenotype of rumination. *International Journal of Psychophysiology*, 72(3), 267-275.

Pariante, C. M., & Lightman, S. L. (2008). The HPA axis in major depression: classical theories and new developments. *Trends in neurosciences*, 31(9), 464-468.

Peckett, A. J., Wright, D. C., & Riddell, M. C. (2011). The effects of glucocorticoids on adipose tissue lipid metabolism. *Metabolism*, 60(11), 1500-1510.

Peltola, M. (2012). Role of editing of R-R intervals in the analysis of heart rate variability. *Frontiers in Physiology*, 3(148), 1-10.

Piazza, J. R., Almeida, D. M., Dmitrieva, N. O., & Klein, L. C. (2010). Frontiers in the use of biomarkers of health in research on stress and aging. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 65(5), 513-525.

Pieper, S., & Brosschot, J. F. (2005). Prolonged stress-related cardiovascular activation: Is there any? *Annals of Behavioral Medicine*, 30(2), 91-103.

Pieper, S., Brosschot, J. F., van der Leeden, R., & Thayer, J. F. (2007). Cardiac effects of momentary assessed worry episodes and stressful events. *Psychosomatic Medicine*, 69(9), 901-909.

Ponikowski, P., Anker, S. D., Chua, T. P., Szelemej, R., Piepoli, M., Adamopoulos, S., Webb-Peploe, K., Harrington, D., Banasiak, W., Wrabec, K., & Coats, A. J. (1997). Depressed heart rate variability as an independent predictor of death in chronic congestive heart failure secondary to ischemic or idiopathic dilated cardiomyopathy. *The American journal of cardiology*, 79(12), 1645-1650.

Porges, S. W. (1995). Cardiac vagal tone: a physiological index of stress. *Neuroscience & Biobehavioral Reviews*, 19(2), 225-233.

Qin, J., Zhou, X., Sun, C., Leng, H., & Lian, Z. (2013). Influence of green spaces on environmental satisfaction and physiological status of urban residents. *Urban forestry & urban greening*, 12(4), 490-497.

Rasmussen, H. N., Scheier, M. F., & Greenhouse, J. B. (2009). Optimism and physical health: A meta-analytic review. *Annals of behavioral medicine*, 37(3), 239-256.

Reis, H. T., & Gable, S. L. (2000). Event-sampling and other methods for studying everyday experience. In H. T. Reis & C.M. Judd (Eds.), *Handbook of research methods in social and personality psychology* (pp. 190-222). Cambridge, United Kingdom: Cambridge University Press.

Rick, A. D., & Vanheule, S. (2007). Pilot Study: Does the Five Shot Questionnaire Give an Indication of the Severity of Alcohol Use–Related Problems? *Substance use & misuse*, 42(10), 1593-1601.

Riese, H., Van Doornen, L. J., Houtman, I. L., & De Geus, E. J. (2004). Job strain in relation to ambulatory blood pressure, heart rate, and heart rate variability among female nurses. *Scandinavian journal of work, environment & health*, 30(6), 477-485.

van Rijsoort, S., Emmelkamp, P., & Vervaeke, G. (1999). The Penn State Worry Questionnaire and the Worry Domains Questionnaire: structure, reliability and validity. *Clinical Psychology & Psychotherapy*, 6(4), 297–307.

Roberti, J. W., Harrington, L. N., & Storch, E. A. (2006). Further psychometric support for the 10-item version of the perceived stress scale. *Journal of College Counseling*, 9(2), 135-147.

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(1), 103-113.

Roe, J. J., Thompson, C. W., Aspinall, P. A., Brewer, M. J., Duff, E. I., Miller, D., Mitchell, R. & Clow, A. (2013). Green space and stress: Evidence from cortisol measures in deprived urban communities. *International Journal of Environmental Research and Public Health*, *10*(9), 4086-4103.

Roelofs, J., van Breukelen, G., de Graaf, L. E., Beck, A. T., Arntz, A., & Huibers, M. J. (2013). Norms for the Beck Depression Inventory (BDI-II) in a large Dutch community sample. *Journal of Psychopathology and Behavioral Assessment*, 35(1), 93-98.

Roenneberg, T., Kuehnle, T., Juda, M., Kantermann, T., Allebrandt, K., Gordijn, M., & Merrow, M. (2007). Epidemiology of the human circadian clock. *Sleep medicine reviews*, 11(6), 429-438.

Roenneberg, T., Wirz-Justice, A., & Merrow, M. (2003). Life between clocks: daily temporal patterns of human chronotypes. *Journal of biological rhythms*, 18(1), 80-90.

Rossinen, J., Viitasalo, M., Partanen, J., Koskinen, P., Kupari, M., & Nieminen, M. S. (1997). Effects of acute alcohol ingestion on heart rate variability in patients with documented coronary artery disease and stable angina pectoris. *The American journal of cardiology*, 79(4), 487-491.

Rottenberg, J. (2007). Cardiac vagal control in depression: a critical analysis. *Biological psychology*, 74(2), 200-211.

Sandercock, G. R., Bromley, P. D., & Brodie, D. A. (2005). Effects of exercise on heart rate variability: inferences from meta-analysis. *Medicine & Science in Sports & Exercise*, 37(3), 433-439.

Sauro, M. D., Jorgensen, R. S., & Teal Pedlow, C. (2003). Stress, glucocorticoids, and memory: a meta-analytic review. *Stress*, 6(4), 235-245.

Sarason, I. G., Johnson, J. H., & Siegel, J. M. (1978). Assessing the impact of life changes: development of the Life Experiences Survey. *Journal of consulting and clinical psychology*, 46(5), 932- 946.

Scheier, M. F., Carver, C. S., & Bridges, M. W. (1994). Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): a reevaluation of the Life Orientation Test. *Journal of personality and social psychology*, 67(6), 1063.

Schmitz, N., Hartkamp, N., Kiuse, J., Franke, G. H., Reister, G., & Tress, W. (2000). The symptom check-list-90-R (SCL-90-R): a German validation study. *Quality of Life Research*, 9(2), 185-193.

Schroeder, E. B., Chambless, L. E., Liao, D., Prineas, R. J., Evans, G. W., Rosamond, W. D., & Heiss, G. (2005). Diabetes, glucose, insulin, and heart rate variability the atherosclerosis risk in communities (ARIC) study. *Diabetes care*, 28(3), 668-674.

Schroeder, E. B., Liao, D., Chambless, L. E., Prineas, R. J., Evans, G. W., & Heiss, G. (2003). Hypertension, blood pressure, and heart rate variability the Atherosclerosis Risk In Communities (ARIC) study. *Hypertension*, 42(6), 1106-1111.

Scollon, C. N., Prieto, C. K., & Diener, E. (2009). Experience sampling: promises and pitfalls, strength and weaknesses. In E. Diener (Ed.), *Assessing well-being* (pp. 157-180). Dordrecht, Netherlands: Springer.

Segal, D. L., Coolidge, F. L., Cahill, B. S., & O'Riley, A. A. (2008). Psychometric properties of the Beck Depression Inventory—II (BDI-II) among community-dwelling older adults. *Behavior Modification*, 32(1), 3-20.

Segerstrom, S. C., & Miller, G. E. (2004). Psychological stress and the human immune system: a meta-analytic study of 30 years of inquiry. *Psychological bulletin*, 130(4), 601.

Seppä, K., Lepistö, J., & Sillanaukee, P. (1998). Five-Shot Questionnaire on Heavy Drinking. *Alcoholism: Clinical and Experimental Research*, 22(8), 1788-1791.

Shiffman, S., Hufford, M., Hickcox, M., Paty, J. A., Gnys, M., & Kassel, J. D. (1997). Remember that? A comparison of real-time versus retrospective recall of smoking lapses. *Journal of consulting and clinical psychology*, 65(2), 292.

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology*, 4, 1-32.

Singh, J. P., Larson, M. G., Tsuji, H., Evans, J. C., O'Donnell, C. J., & Levy, D. (1998). Reduced heart rate variability and new-onset hypertension insights into pathogenesis of hypertension: the Framingham heart study. *Hypertension*, 32(2), 293-297.

Singh, J. P., Larson, M. G., O'Donnell, C. J., Wilson, P. F., Tsuji, H., Lloyd-Jones, D. M., & Levy, D. (2000). Association of hyperglycemia with reduced heart rate variability (The Framingham Heart Study). *The American journal of cardiology*, 86(3), 309-312.

Sloan, R. P., Shapiro, P. A., Bagiella, E., Boni, S. M., Paik, M., Bigger, J. T., Steinman, R.C., & Gorman, J. M. (1994). Effect of mental stress throughout the day on cardiac autonomic control. *Biological psychology*, 37(2), 89-99.

Smith, T. W., & MacKenzie, J. (2006). Personality and risk of physical illness. *Annual Review of Clinical Psychology*, 2, 435-467.

Solhan, M. B., Trull, T. J., Jahng, S., & Wood, P. K. (2009). Clinical assessment of affective instability: comparing EMA indices, questionnaire reports, and retrospective recall. *Psychological assessment*, 21(3), 425.

Sondermeijer, H. P., van Marle, A. G., Kamen, P., & Krum, H. (2002). Acute effects of caffeine on heart rate variability. *The American journal of cardiology*, 90(8), 906-907.

Song, C., Ikei, H., Igarashi, M., Miwa, M., Takagaki, M., & Miyazaki, Y. (2014). Physiological and psychological responses of young males during spring-time walks in urban parks. *Journal of physiological anthropology*, 33(1), 1.

Sonne, T., & Jensen, M. M. (2014). Race By Hearts. In Y. Pisan, N. M. Sgouros, & T. Marsh (Eds.), *Entertainment Computing–ICEC 2014* (pp. 125-132). Berlin Heidelberg, Germany: Springer.

Srivastava, S., John, O. P., Gosling, S. D., & Potter, J. (2003). Development of personality in early and middle adulthood: set like plaster or persistent change? *Journal of personality and social psychology*, 84(5), 1041.

Startup, H. M., & Erickson, T. M. (2006). The Penn State Worry Questionnaire (PSWQ). *Worry and its psychological disorders: Theory, assessment and treatment* (pp. 101-120). Chichester, England: John Wiley & Sons, Ltd.

Stein, P. K., Kleiger, R. E., & Rottman, J. N. (1997). Differing effects of age on heart rate variability in men and women. *The American journal of cardiology*, 80(3), 302-305.

Steptoe, A., Hamer, M., & Chida, Y. (2007). The effects of acute psychological stress on circulating inflammatory factors in humans: a review and meta-analysis. *Brain, behavior, and immunity*, 21(7), 901-912.

Sterling, P., & Eyer, J. (1988). Allostasis: A new paradigm to explain arousal pathology. In S. Fisher, & J. Reason (Eds.), *Handbook of Life Stress, Cognition and Health* (pp. 629- 649). New York, NY: John Wiley & Sons.

Sternberg, E. M. (2001). Neuroendocrine regulation of autoimmune/inflammatory disease. *Journal of Endocrinology*, 169(3), 429-435.

Stojanovich, L. (2010). Stress and autoimmunity. *Autoimmunity reviews*, 9(5), A271-A276.

Stone, A. A., Broderick, J. E., Shiffman, S. S., & Schwartz, J. E. (2004). Understanding recall of weekly pain from a momentary assessment perspective: absolute agreement, between-and within-person consistency, and judged change in weekly pain. *Pain*, 107(1), 61-69.

Strecher, V. (2007). Internet methods for delivering behavioral and health-related interventions (eHealth). *Annual Review of Clinical Psychology*, 3, 53-76.

Sztajzel, J. (2004). Heart rate variability: a noninvasive electrocardiographic method to measure the autonomic nervous system. *Swiss medical weekly*, 134(35-36), 514-522.

Taelman, J., Vandeput, S., Spaepen, A., & Van Huffel, S. (2009). Influence of mental stress on heart rate and heart rate variability. In J. Vander Sloten, P. Verdonck, M. Nyssen, & J. Haueisen (Eds.), *4th European conference of the international federation for medical and biological engineering* (pp. 1366-1369). Berlin Heidelberg, Germany: Springer.

Tarvainen, M. P., Niskanen, J. P., Lipponen, J. A., Ranta-Aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV–heart rate variability analysis software. *Computer methods and programs in biomedicine*, 113(1), 210-220.

Task Force of the European Society of Cardiology. (1996). Heart rate variability standards of measurement, physiological interpretation, and clinical use. *European Heart Journal*, 17, 354-381.

Teas, J., Hurley, T., Ghumare, S., & Ogoussan, K. (2007). Walking outside improves mood for healthy postmenopausal women. *Clinical Medicine Insights. Oncology*, 1, 35-43.

Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, *36*(2), 747-756.

Thayer, J. F., Hall, M., Sollers, J. J., & Fischer, J. E. (2006). Alcohol use, urinary cortisol, and heart rate variability in apparently healthy men: Evidence for impaired inhibitory control of the HPA axis in heavy drinkers. *International Journal of Psychophysiology*, 59(3), 244-250.

Thayer, J. F., Yamamoto, S. S., & Brosschot, J. F. (2010). The relationship of autonomic imbalance, heart rate variability and cardiovascular disease risk factors. *International journal of cardiology*, 141(2), 122-131.

Tinio, P. P., & Leder, H. (2009). Natural scenes are indeed preferred, but image quality might have the last word. *Psychology of Aesthetics, Creativity, and the Arts*, 3(1), 52.

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(5), 1761-1772.

Tsigos, C., & Chrousos, G. P. (2002). Hypothalamic–pituitary–adrenal axis, neuroendocrine factors and stress. *Journal of psychosomatic research*, 53(4), 865-871.

Tsuji, H., Larson, M. G., Venditti, F. J., Manders, E. S., Evans, J. C., Feldman, C. L., & Levy, D. (1996). Impact of reduced heart rate variability on risk for cardiac events The Framingham Heart Study. *Circulation*, 94(11), 2850-2855.

Tsuji, H., Venditti, F. J., Manders, E. S., Evans, J. C., Larson, M. G., Feldman, C. L., & Levy, D. (1994). Reduced heart rate variability and mortality risk in an elderly cohort. The Framingham Heart Study. *Circulation*, 90(2), 878-883.

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.

Udupa, K., Sathyaprabha, T. N., Thirthalli, J., Kishore, K. R., Lavekar, G. S., Raju, T. R., & Gangadhar, B. N. (2007). Alteration of cardiac autonomic functions in patients with major depression: a study using heart rate variability measures. *Journal of affective disorders*, 100(1), 137-141.

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). Springer.

Ulrich, R. (1984). View through a window may influence recovery. *Science*, 224(4647), 224-225.

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(3), 201-230.

Umetani, K., Singer, D. H., McCraty, R., & Atkinson, M. (1998). Twenty-four hour time domain heart rate variability and heart rate: relations to age and gender over nine decades. *Journal of the American College of Cardiology*, 31(3), 593-601.

Vahle-Hinz, T., Bamberg, E., Dettmers, J., Friedrich, N., & Keller, M. (2014). Effects of work stress on work-related rumination, restful sleep, and nocturnal heart rate variability experienced on workdays and weekends. *Journal of occupational health psychology*, 19(2), 217-230.

Valtchanov, D., Barton, K. R., & Ellard, C. (2010). Restorative effects of virtual nature settings. *Cyberpsychology, Behavior, and Social Networking*, *13*(5), 503-512.

Vegiopoulos, A., & Herzig, S. (2007). Glucocorticoids, metabolism and metabolic diseases. *Molecular and cellular endocrinology*, 275(1), 43-61.

Velarde, M. D., Fry, G., & Tveit, M. (2007). Health effects of viewing landscapes–Landscape types in environmental psychology. *Urban Forestry & Urban Greening*, 6(4), 199-212.

Verkuil, B., & Brosschot, J. F. (2012). The online version of the Dutch Penn State Worry Questionnaire: Factor structure, predictive validity and reliability. *Journal of anxiety disorders*, 26(8), 844-848.

Verkuil, B., Brosschot, J. F., Borkovec, T. D., & Thayer, J. F. (2009a). Acute autonomic effects of experimental worry and cognitive problem solving: Why worry about worry? *International journal of clinical and health psychology*, 9(3), 439-453.

Verkuil, B., Brosschot, J. F., de Beurs, D. P., & Thayer, J. F. (2009b). Effects of explicit and implicit perseverative cognition on cardiac recovery after cognitive stress. *International Journal of Psychophysiology*, 74(3), 220-228.

Visnovcova, Z., Mestanik, M., Javorka, M., Mokra, D., Gala, M., Jurko, A., Calkovska, A., & Tonhajzerova, I. (2014). Complexity and time asymmetry of heart rate variability are altered in acute mental stress. *Physiological measurement*, 35(7), 1319.

Vollrath, M. (2001). Personality and stress. *Scandinavian Journal of Psychology*, 42(4), 335-347.

Vrijkotte, T. G., Van Doornen, L. J., & De Geus, E. J. (2000). Effects of work stress on ambulatory blood pressure, heart rate, and heart rate variability. *Hypertension*, 35(4), 880-886.

Wahlström, J., Hagberg, M., Johnson, P., Svensson, J., & Rempel, D. (2002). Influence of time pressure and verbal provocation on physiological and psychological reactions during work with a computer mouse. *European journal of applied physiology*, 87(3), 257-263.

Wakabayashi, I. (2008). Associations of alcohol drinking and cigarette smoking with serum lipid levels in healthy middle-aged men. *Alcohol and alcoholism*, 43(3), 274-280.

Wardle, J., Chida, Y., Gibson, E. L., Whitaker, K. L., & Steptoe, A. (2011). Stress and Adiposity: A Meta-Analysis of Longitudinal Studies. *Obesity*, 19(4), 771-778.

Weber, C. S., Thayer, J. F., Rudat, M., Wirtz, P. H., Zimmermann-Viehoff, F., Thomas, A., Perschel, F. H., Arck, P. C., & Deter, H. C. (2010). Low vagal tone is associated with impaired post stress recovery of cardiovascular, endocrine, and immune markers. *European journal of applied physiology*, 109(2), 201-211.

Woody, M. L., McGeary, J. E., & Gibb, B. E. (2014). Brooding rumination and heart rate variability in women at high and low risk for depression: group differences and moderation by COMT genotype. *Journal of abnormal psychology*, 123(1), 61-67.

Xhyheri, B., Manfrini, O., Mazzolini, M., Pizzi, C., & Bugiardini, R. (2012). Heart rate variability today. *Progress in cardiovascular diseases*, 55(3), 321-331.

Zlomke, K. R. (2009). Psychometric properties of internet administered versions of Penn state worry questionnaire (PSWQ) and depression, anxiety, and stress scale (DASS). *Computers in Human Behavior*, 25(4), 841-843.

Appendix A Participant flow diagram

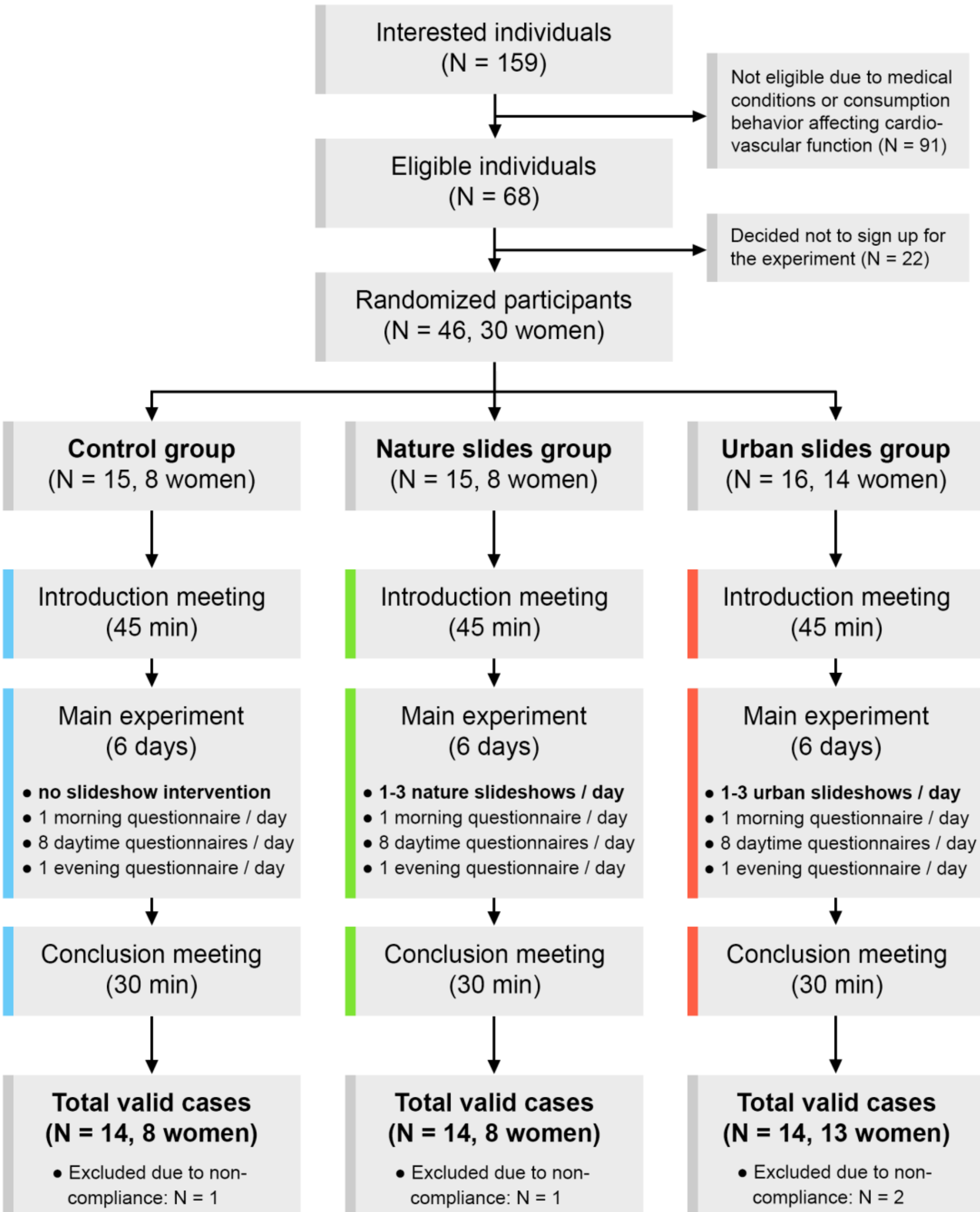

Figure A.1 Participant flow diagram.

Appendix B Screenshots

B.1 Main screens

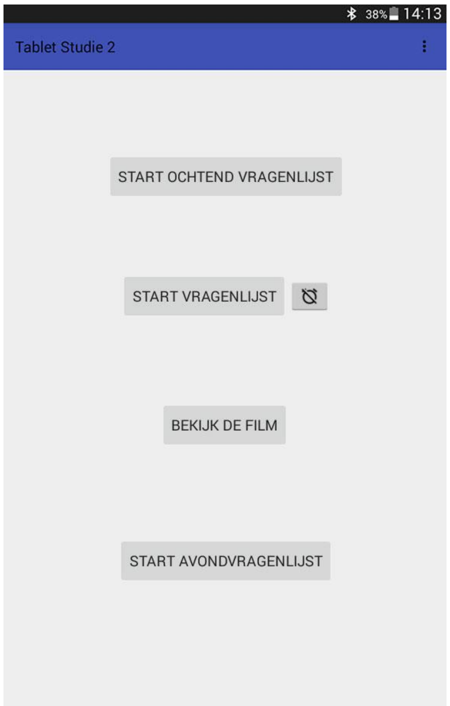

Figure B.1 Main screen of questionnaire app.

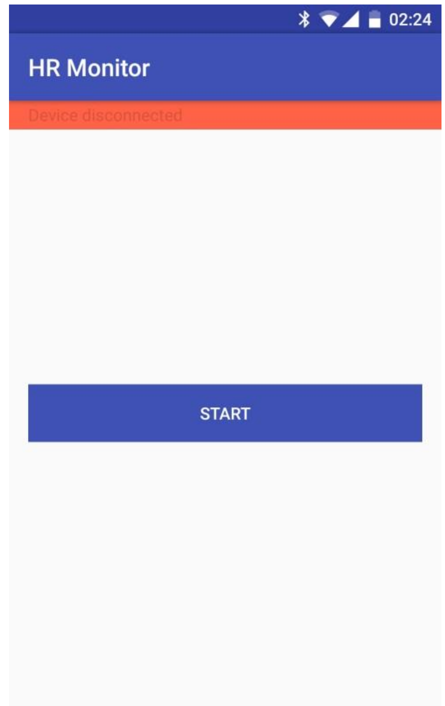

Figure B.2 Main screen heart rate monitor app.

B.2 Slideshows

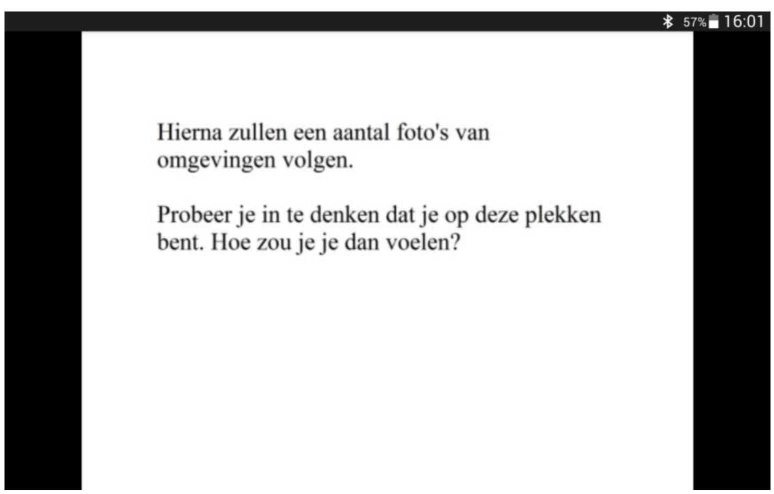

Figure B.3 Slideshow introduction screen.

B.3 Questionnaires

Figure B.4 Morning questionnaire, part 1.

Figure B.5 Morning questionnaire, part 2.

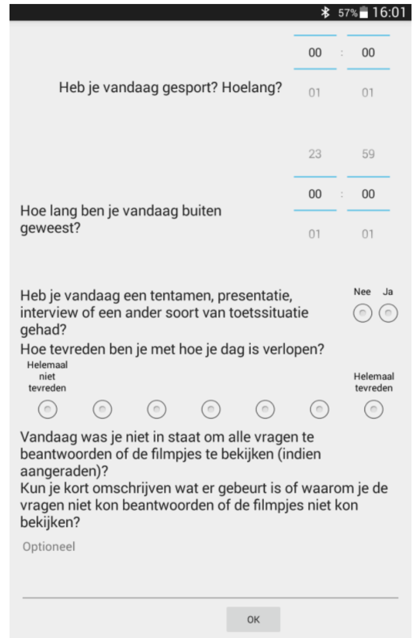

Figure B.6 Evening questionnaire.

Figure B.7 Daytime questionnaire, part 1.

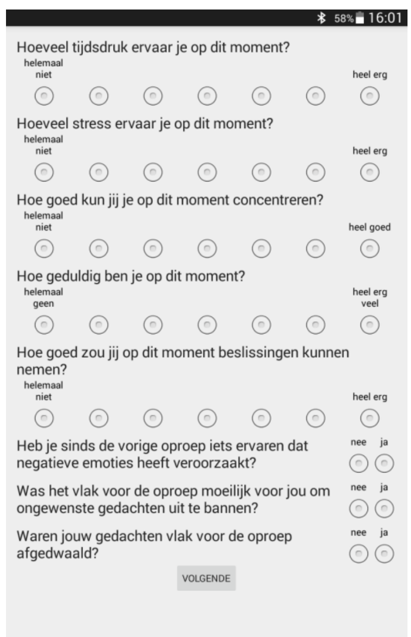

Figure B.8 Daytime questionnaire, part 2.

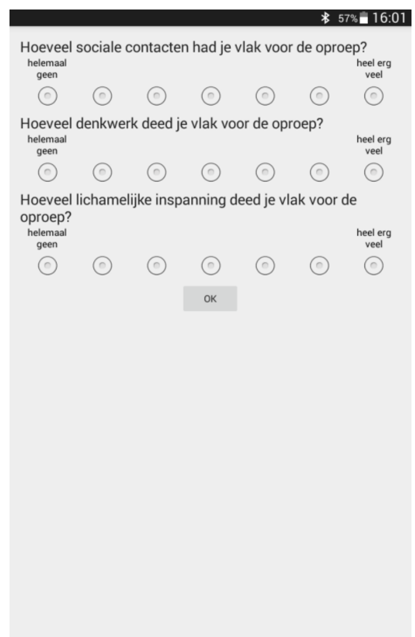

Figure B.9 Daytime questionnaire, part 3.

Appendix C Descriptive statistics

Table C.1 Descriptive statistics and comparisons between groups.

	Control (**N = 14**) *M (SD)*	**Nature slides** (**N = 14**) *M (SD)*	**Urban slides** (**N = 14**) *M (SD)*	F **(2,39)** H **(2)** χ^2**(2)**	P	ω_P^2 E_R^2 V
Age	25.214 (8.322)	25.000 (8.656)	21.857 (2.627)	0.643[a]	0.725	0.016[d]
Gender *Female / Male*	8 / 6	8 / 6	13 / 1	5.570[c]	**0.062**	0.364[e]
BDI-II Screen [f]	11.500 (9.222)	12.714 (8.489)	13.769 (12.173)	0.270[a]	0.874	0.007[d]
PSS-10 Screen	18.643 (4.940)	20.286 (5.539)	19.643 (6.675)	0.536[a]	0.765	0.013[d]
PSS-10 Pre	15.643 (8.509)	18.857 (7.645)	15.714 (6.044)	0.845	0.437	-0.007
SCL-90-R Dep Pre	12.643 (9.692)	17.357 (12.055)	14.071 (9.417)	1.006[a]	0.605	0.025[d]
SCL-90-R Som Pre	6.214 (4.300)	8.643 (5.257)	8.357 (4.534)	1.110	0.340	0.005
SCL-90-R DEP Pre	0.790 (0.606)	1.085 (0.753)	0.879 (0.589)	1.006[a]	0.605	0.025[d]
SCL-90-R Som Pre	0.518 (0.358)	0.720 (0.438)	0.696 (0.378)	1.110	0.340	0.005
PSWQ	52.786 (15.197)	56.143 (12.328)	56.714 (11.499)	0.367	0.695	-0.031
LOT-R	12.643 (4.448)	12.357 (4.144)	12.500 (3.695)	0.017	0.983	-0.049
ACS-90 AOD	4.643 (3.650)	5.357 (2.437)	6.571 (3.131)	2.999[a]	0.223	0.073[d]
ACS-90 AOF	5.857 (3.060)	3.929 (3.269)	5.214 (2.940)	3.084[a]	0.214	0.075[d]
ACS-90 AOD *Action / State*	4 / 10	4 / 10	6 / 8	0.857[c]	0.651	0.143[e]
ACS-90 AOF *Action / State*	8 / 6	2 / 12	5 / 9	5.600[c]	0.061	0.365[e]
Extraversion	3.036 (0.937)	3.152 (0.844)	3.464 (0.601)	2.278[a]	0.320	0.056[d]
Neuroticism	3.161 (0.860)	3.375 (0.873)	3.402 (0.712)	0.365	0.697	-0.031
Openness	3.521 (0.668)	3.507 (0.855)	3.857 (0.332)	2.042[b]	0.153	0.047
Conscientiousness	3.230 (0.533)	3.302 (0.589)	3.516 (0.471)	1.090	0.346	0.004
Agreeableness	3.556 (0.429)	3.643 (0.615)	3.817 (0.549)	0.865	0.429	-0.006
FSQ (Alcohol) [f]	1.679 (1.339)	2.214 (1.122)	2.346 (1.049)	2.268[a]	0.322	0.055[d]
Smoking [f] *Yes / No*	2 / 12	4 / 10	2 / 11	1.116[c]	0.572	0.165[e]
Coffee *Yes / No*	11 / 3	12 / 2	10 / 4	0.848[c]	0.654	0.142[e]

Sporting *Yes / No*	12 / 2	13 / 1	14 / 0	2.154[c]	0.341	0.226[e]
Working *Yes / No*	6 / 8	5 / 9	6 / 8	0.198[c]	0.906	0.069[e]
Green Living *Yes / No*	5 / 9	7 / 7	8 / 6	1.336[c]	0.513	0.178[e]

Note. [a] = Kruskal-Wallis test due to violation of the normality assumption, [b] = Welch's F test due to violation of the homogeneity of variance assumption, [c] = Chi-squared test, [d] = Epsilon-squared (E_R^2) effect size for the Kruskal-Wallis test, [e] = Cramer's V effect size for Chi-squared test, [f] = One response missing in the urban slideshow group

Appendix D Interview questions

General questions

Hoe ervaarde je het experiment de afgelopen zes dagen?

Was er iets positiefs aan je deelname in het experiment?

Was er iets negatiefs aan je deelname in het experiment?

Hoe ervaarde je het gebruik van de apps op de tablet?

Waren er problemen met het gebruik van de apps?

Had je problemen met het volgen van de instructies (bijvoorbeeld het beantwoorden van de vragen of het dragen van de hartslagmeter) tijdens de afgelopen zes dagen? Indien ja, wat soort van problemen heb je gehad?

Hoe ervaarde je het dragen van de hartslagmeter tijdens de afgelopen zes dagen?

Hoe was je ervaring met het meeneemen van de tablet de afgelopen zes dagen?

Questionnaires

Hoe ervaarde je het invullen van de vragenlijsten tijdens de afgelopen zes dagen?

Was je in staat om alle vragenlijsten in te vullen de afgelopen zes dagen? Indien niet, waarom was je niet in staat om alle vragenlijsten in te vullen?

Waren er moment waarbij je de notificaties voor het invullen van de vragenlijsten negeerde de afgelopen zes dagen? Indien ja, waarom heb je de notificaties genegeerd?

Hoe heb je de frequentie van de notificaties ervaren tijdens de afgelopen zes dagen?

Was je door de notificaties afgeleid of hebben de notificaties je dagelijkse routines verstoord de afgelopen zes dagen? Indien ja, op welke wijze hebben de notificaties je afgeleid?

Heeft het invullen van de vragenlijsten je op een enige manier beïnvloed? Indien ja, op welke wijze heeft het invullen van de vragenlijsten je beïnvloed?

Heeft het invullen van de vragenlijsten je gedachten of gevoelens beïnvloed? Indien ja, op welke wijze heeft het invullen van de vragenlijsten je gedachten of gevoelens beïnvloed?

Videos

Wat zijn je gevoelens over de video's die je hebt bekeken de afgelopen zes dagen?

Was er iets positiefs over de video’s die je hebt bekeken de afgelopen zes dagen?

Was er iets negatiefs over de video’s die je hebt bekeken de afgelopen zes dagen?

Wat denk je over de inhoud van de video's die je hebt bekeken de afgelopen zes dagen?

Wat is je mening over de lengte van de video's die je hebt bekeken de afgelopen zes dagen?

Aan het begin van de video's werd je gevraagd je in te denken dat je op deze plekken bent. Hoe was je ervaring met “je in te denken dat je op deze plekken bent”? Hoe heb je dit gedaan?

Was je in staat om alle video’s te bekijken de afgelopen zes dagen? Indien niet, waarom was je niet in staat om alle video’s te bekijken?

Hoe was je concentratie tijdens het kijken van de video’s?

Was het moeilijk je op de video's te concentreren tijdens het kijken van de video’s? Indien ja, waarom was het moeilijk?

Was je soms afgeleid tijdens het kijken van de video’s? Indien ja, waardoor was je afgeleid?

Heeft het kijken van de video’s je op een bepaalde manier beïnvloed? Indien ja, op welke wijze heeft het kijken van de video’s je beïnvloed?

Heeft het kijken van de video’s je gedachten of gevoelens beïnvloed? Indien ja, op welke wijze heeft het kijken van de video’s je gedachten of gevoelens beïnvloed?

Was het kijken van de video’s op een bepaalde manier positief of negatief voor je? Indien ja, hoe was het positief of negatief?