

Nature and Public Health

Aspects of Promotion, Prevention, and Intervention

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Abstract

Nature's potentially positive effect on wellbeing may serve as an important resource for population health. Based on theories mainly derived from environmental psychology this resource has been explored in varied scientific studies the last century. This has rendered a substantial amount of empirical evidence for different beneficial effects of natural environments on health.

The aim of this thesis was to consider these effects from a public health perspective. The state of the art for nature as intervention was explored by a systematic review designed in accordance with the Cochrane principles. Different landscape types' effect on stress and mental health were studied by one cross-sectional survey study and one longitudinal epidemiological study. Finally physiological stress recovery reactions by a standardized nature setting were examined in an experimental randomized between-group study in a virtual reality laboratory.

The different methodological aspects contributed to a broad entrance to the subject. In combination with the broad subject as such this spawned reflections upon the scientific approach and the thesis aims to some extent to mirror these reflections from an interdisciplinary and transdisciplinary viewpoint.

A very short and simplified conclusion of the thesis would be that a small evidence base of the efficiency of nature assisted therapy is in line with the findings of certain nature qualities as resources for recovery from stress and reducing the risk for mental health problems, and that this may partly be mediated by an active relaxation mechanism within the parasympathetic nerve system.

The findings may have implications for the contemporary disease scenario and the expected rise in non-communicable diseases and mental disorders. Policies and actions for public health should consider populations' living environments and promote access to nature.

Keywords: stress, mental health, population, salutogenic, green care, transdisciplinarity, broadleaved forest, GIS, landscape characters, epidemiology, virtual reality, soundscape

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Dedication

to Cecil

"A mind is like a parachute.
It doesn't work if it's not open."

-Frank Zappa

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List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Annerstedt M, Währborg P. (2011) Nature Assisted Therapy – Systematic review of controlled and observational studies. *Scand J of Publ Health*, 39:371-88 (Annerstedt & Währborg, 2011)

II Annerstedt M, Norman J, Boman M, Andersson L, Grahn P, Währborg P. (2010). Finding stress relief in a forest. *Ecological Bulletins* 53;33-42 (Annerstedt, 2010b)

III Annerstedt M, Östergren P-O, Björk J, P Grahn, Skärbäck E, Währborg P. (2011). Recreational characters and mental health – results from a longitudinal cohort study in southern Sweden. Submitted for publication

IV Annerstedt M, Jönsson P, Wallergård M, Johansson G, Währborg P. (2011). Virtual nature environment with nature sound exposure – inducement of stress recovery by enhanced parasympathetic activity. Submitted for publication

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My contribution to the papers included in this thesis was as follows:

- I Together with Peter Währborg I planned the review and decided upon the chosen design. I performed the literature search and selected the relevant papers to be included. In case of doubt the selection was discussed with Peter Währborg. Together with Peter Währborg the quality analyses of included papers were performed. I am the first and corresponding author of the manuscript
- II Together with the other authors the study was planned and designed. I analyzed relevant data. I am the first and corresponding author of the manuscript.
- III Together with the other authors I planned and designed the study. I treated and analyzed most of the data. I am the first and corresponding author of the manuscript.
- IV Together with the other authors I planned and designed the experiment. I participated in the experiments, taking responsibility for most of the information to the test participants, as well as collecting some of the data. I draw conclusions referring to green spaces and environmental impact. I am the first and corresponding author of the manuscript.

Abbreviations

ART	Attention Restoration Theory
CI	Confidence Interval
CORINE	Coordination of Information on the Environment
DAF	Directed Attention Fatigue
DALY	Disability Adjusted Life Year
<i>D</i>	Fractal Dimension
EBM	Evidence-Based Medicine
EBP	Evidence-Based Practice
ECG	Electrocardiogram
EEG	Electroencephalography
EQ-5D	EuroQol
GHQ-12	General Health Questionnaire
GIS	Geographic Information System
GRADE	Grading of Recommendations, Assessment, Development and Evaluation
HIA	Health Impact Assessment
HPA	Hypothalamus-Pituitary-Adrenal
HF-HRV	High Frequency Heart Rate Variability
HR	Heart Rate
LS	Level of Stress
MRC	Medical Research Council
MTD	Marktäckedatabasen [Land cover database]
NAT	Nature Assisted Therapy
NCDs	Non Communicable Diseases
OR	Odds Ratio
PM MW	Peak Matched Multiple Windows

POMS	Profile of Mood States
PTSD	Post Traumatic Stress Disorder
RERI	Relative Excess Risk due to Interaction
SAM	Sympatho-Adrenal-Medullary
SBU	Statens beredning för medicinsk utvärdering [Swedish Council on Health Technology Assessment]
SCI-93	Stress and Crisis Inventory
SES	Socio Economic Status
STAI	Spielberger State and Trait Anxiety Inventory
TR	Transdisciplinary Research
TSST	Trier Social Stress Test
TWA	T-Wave Amplitude
VAS	Visual Analogue Scale
VE	Virtual Environment
VR	Virtual Reality
VRET	Virtual Reality Exposure Therapy
YLD	Years Lost due to Disability
WHO	World Health Organization

1 Introduction

1.1 Scientific frame and research on interconnections

Since the rise of the scientific era the aim of research has been to describe and understand varied components of universe. Through increasingly advanced methods, tools, and theories, many mysteries of cosmos have become revealed to mankind. This has included elucidation of the smallest particles of organisms, as well as monitoring the planetary system.

Concerning the specific field dealing with health and disease it is obvious that medical research has since the last century been very successful in discovering the intricate biological systems of the body, describing pathological processes, and the pharmacological interventions necessary to recover. However, in spite of the medical successes and land-winning advances throughout the last century, populations are now facing an epidemic of mental disorders and other non-communicable diseases (NCDs). These diseases provoke the traditional way of looking upon health and disease and are thus, at least partly, resistant to ordinary treatment options. They are not caused by one single bacterium, are not to be explained by one single pathological process within the body, but rather reflect a mismatch between the individual and her circumstances, her surrounding environment. This should direct the focus of research to the linkages, the interconnections between human beings and the environment (see figure 1).

“Being an intellectual creates a lot of questions and no answers.”
Janis Joplin (1943-1970)

This thesis derives from an innate need to confronting questions of the modern disease scenario and how to find ways for implying novel research ideas and novel approaches to health promotion, prevention, and intervention. I have dealt with a specific approach and element of interconnectivity – the *natural environment of people and its impact on health*.

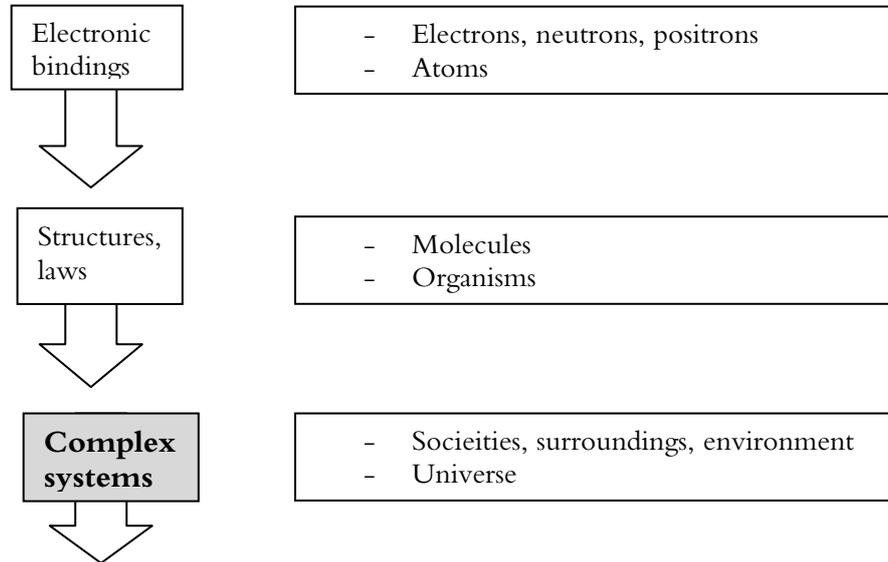


Figure 1. Between every object studied there are linkages to other objects or particles, creating complicated systems. Further ahead in the hierarchy of objects and systems, the linkages become more and more complex, but nevertheless necessary to describe, delineate, and understand.

Performing research on the borderline of objects logically evokes specific concerns and complications. Can the studies be detailed and specific enough? Can they be designed to cover all potential confounders? Can the knowledge reach enough depth to actually be called scientific research? Is the complexity of the systems too large to be covered within the frame of a thesis?

Above all, and like in the case of most research, I believe that among the most important answers to the above mentioned questions are humbleness and precaution. I will make an attempt, by argumentation and the included studies of this thesis, to defend the belief that research on complex systems and interconnections between human beings and their surroundings *is*

possible, but most importantly I believe that the discussion must continue, must be taken further and developed within open-minded and innovative scientific frames. In this context the thesis may be considered as a resource to be fed back into the scientific system for further refinement.

1.2 Historical background to the subject of nature and health

Theories about nature's impact on health can be traced as far back as to ancient Greece and Hippocrates' (460-377 f.Kr.) garden for patients, as well as to ancient Egypt where court physicians prescribed garden walks for mentally ill royalty (Davis, 1998). There are also examples of the use of horticulture as an accepted treatment approach in mental institutions during the late 1700s and early 1800s. At this time one discovered that the more exploited a city was, the higher mortality rate did it suffer from. This insight led to the development of more nature friendly cities with parks, and boulevards lined by suitable trees (Ottosson, 2007; Grahn, 2005; Walker & Duffield, 1983).

During the early 1900's the use of horticultural methods for therapy expanded to varied populations, such as the mentally handicapped, at-risk youth, and war veterans. In the 1930s the medical science reached many new landmarks and from the 1940s the interest for nature and gardening as a medical therapy declined (Grahn, 2010).

Not until the beginning of the 1980s did the theories about nature's impact on health see a new light and the research started developing, mainly within the research frame of environmental psychology and landscape architecture, but it has later also been influenced by research from neuroscientific cognition studies, as well as perception- and intervention research from varied disciplines.

1.3 Theoretical background

The theories of how nature influences health have been inspired by reflections on how everyday demands and health relate to the environment. According to Frederick Law Olmsted (1822-1903) the never-ending pressure from everyday life caused feelings of melancholia (Olmsted, 1865), and symptoms close to those that are nowadays defined as stress related. He described how restoration was facilitated in an environment that allowed relaxation and that this environment was most easily found in nature.

Another inspiring pioneer of the subject is Edward Osborne Wilson (1929-), whose “biophilia hypothesis” claims our innate emotional affiliation to other living organisms (Wilson, 1984), and has spawned research suggesting our relationship with nature as fundamental to achieving and sustaining good health.

There are two major different theories that have hitherto influenced most of the research concerned with nature and health. Both are rooted in the tradition of natural environments’ psychological values, but are also closely linked to theories of stress, mental fatigue, and restoration.

1.3.1 The Attention Restoration Theory (ART)

According to this theory, which is partly based on the concepts presented by the philosopher and psychologist William James (James, 1890), two diverse types of attention are functioning within the human mind – directed and spontaneous.

Directed attention is in action when concentrating and focusing on a certain stimulus. Among large amounts of stimuli it is capable of sorting and selecting the important from the unimportant. The essential mechanism is the *central inhibition capacity* – to keep concentration on the required matter other concurring stimuli have to be suppressed and *inhibited*. This mechanism is largely under intentional control and is effortful. Hence directed attention is a resource that may be depleted, the inhibitory mechanism will become fatigued with prolonged or intensive use, as a consequence of too much demanding challenges (Kaplan *et al.*, 1998; Kaplan & Talbot, 1983). Loss of inhibitory capacity has negative consequences, such as increased error in performance of tasks, being more and more fatigued, feeling reduced self-control which eventually cause stress and irritability.

Since directed attention is important for selecting focus both in thought and perception a depletion of this resource, directed attentional fatigue (DAF), constitutes impairment to mental competence (Kaplan, 2001; Kaplan & Kaplan, 1989). If the resource becomes completely emptied we experience exhaustion. To recover from DAF we have to be in environments wherein we can rely on the *spontaneous attention*.

The spontaneous attention, fascination, is an involuntary and non-effortful kind of action. It is an automatic mechanism, triggered by spontaneous fascination for stimuli. When the involuntary, spontaneous attention is engaged, the demands on directed attention are diminished, thus

rendering a chance for restoration of attention, and bringing mental competence back to normal.

Involuntary attention occurs in settings where the amount of stimuli is adequate and manageable, often referred to as restorative environments. According to ART there are four conceptual properties of a restorative environment (Kaplan *et al.*, 1998; Kaplan, 1995):

- Being away: being distant, either physically or conceptually, from the everyday environment
- Fascination: containing patterns that hold one's attention effortlessly
- Extent: having scope and coherence that allow one to remain engaged
- Compatibility: fitting with and supporting what one wants or is inclined to do

Natural environments have been suggested to inherently draw on spontaneous attention, and have been shown to be strong in the above mentioned restorative properties (Herzog *et al.*, 1997). It is also claimed that nature is rich in attributes and happenings that human beings are biologically conditioned to perceive as fascinating, like trees, greenery, and sunsets (Kaplan & Talbot, 1988).

When a person can rely on fascination in ongoing activity (such as experiencing nature when walking), demands on the central inhibition capacity are relaxed and a capacity for directing attention can be renewed. Rachel and Stephen Kaplan assert that natural environments are rich in pleasing features that evoke moderate, or "soft", fascination that permits a more reflective mode.

The theory has gained some empirical support, mainly in quasi-experimental studies, where individuals' cognitive competence has significantly increased by regular visits to nature (Hartig *et al.*, 2003; Wells, 2000; Tennessen & Cimprich, 1995; Hartig *et al.*, 1991a).

1.3.2 Affective Aesthetic Theory

This theory differs from ART in its focus on psychological and affective reactions, rather than cognitive ones (Ulrich, 1983). These reactions are assumed to have evolved from visual stimuli, typical for any environment. The theory considers the *stress reduction* to be achieved in nature as the main factor for nature's health effects, and is sometimes called Stress Reduction Theory.

In concordance with the definition of stress as a reactive process (both psychological and physiological) induced by external or internal taxing stimuli, which results in regulatory changes in behaviour and biological functions in order to recreate bodily balance (Währborg, 2009), the theory considers stress *relief* to occur in the same inherent and reflexive pattern. By a certain visual stimulus we innately and immediately react with wellbeing, calmness, and relief from stress – all restorative responses (Ulrich, 1983). In this perspective visual stimuli from nature, such as water or greenery, would induce this instinctive, positive, affective relaxation-response, due to their evolutionary origin as prototypes for survival and safety. This illustrates the theory's inspiration from early evolutionary explanatory models, like the biophilia hypothesis (Wilson, 1984), and another denotation for the theory is Psycho-Evolutionary Theory.

Affective Aesthetic Theory proposes that restoration can occur when a scene elicits feelings of mild to moderate interest, pleasantness, and peacefulness. For someone experiencing stress, and needing to restore resources for activity, it could be adaptive to continue experiencing/viewing a nature setting in a non-vigilant way. Whether experiencing continues that way, depends initially (and most of all) on visual characteristics of the nature setting that rapidly evoke a general affective response. Evolution, according to Roger Ulrich (Ulrich, 1999), has left humans with "...a biologically prepared capacity for acquiring and retaining restorative responses to certain nature settings and content (vegetation, flowers, water), but...no such disposition for more built environments and their materials" [p. 52 (Ulrich, 1993b)]. Hence the theory assigns a restorative advantage to more savannah-like natural environments. A scene with moderate and ordered complexity, moderate depth, a focal point, and natural contents such as vegetation and water is expected to evoke interest and positive affect, hold attention, and thereby displace or restrict negative thoughts and allow arousal heightened by stress to drop to a more moderate level, as demonstrated by for example lower blood pressure, heart rate, and muscle tensions.

Empirical support for this theory has been achieved by studies mainly focusing on short, restorative experiences, showing for example immediately induced blood pressure reduction from contact with nature (Ulrich *et al.*, 1991; Ulrich, 1981; Ulrich, 1979).

1.3.3 Mechanistic theories

Fractal dimension

In the framework of fractal geometry Benoît B. Mandelbrot described the pattern of self-similarity across different spatial scales (Mandelbrot, 1977), and how this is exhibited by many natural forms (e.g. coastlines, woody plants and trees, clouds, snowflakes). For example a tree, or a cauliflower, consist of similar patterns recurring on finer and finer magnifications, and the patterns observed are all described by the same statistics. The fractal dimension (D) quantifies the fractal scaling relationship between the patterns observed at varied magnifications (Mandelbrot & Blumen, 1989). Within this concept a theory of fractal characteristics as a fundament for human preference for natural landscapes has evolved (see figure 2).

Several studies have investigated patterns' fractal characters and related them to perceived visual quality (Pentland, 2009; Geake & Landini, 1997; Knill *et al.*, 1990) and ratings of images with varied D have revealed an aesthetically preferred value of 1.3 . This value corresponds to fractals frequently found in natural environments and it has been suggested that people's preference is actually *set* at 1.3 due to continuous visual exposure to nature's patterns throughout evolution (Aks & Sprott, 1996).



Figure 2. Fractals in nature as expressed by a defoliated tree. The varied magnifications of the pattern are shown.

This intriguing theory has been tested within research of nature and health by Electroencephalography (EEG) recordings. Fractal stimuli quantified by $D=1.3$ induce the largest changes in EEG responses, corresponding to

maximal alpha responses in the frontal region and the highest beta responses in the parietal region (Hägerhäll *et al.*, 2008). This suggests that *D* could be part of the explanation on the connection between human preference and well-being, and naturalness (Hägerhäll *et al.*, 2004).

Brain mechanisms and tranquillity

The mental state tranquillity is characterized by calmness and self-reflection and is more likely to occur in environments associated with peace and quiet (Herzog & Barnes, 1999), like open and natural landscapes, rivers, and seas (Pheasant *et al.*, 2008; Kaplan & Kaplan, 1989). Are the neural mechanisms related to tranquil stimuli associated with a better wellbeing and a healthy mental state?

This was investigated in a recently published study where the modulating effect of environmental tranquil scenes on effective connectivity between auditory cortex and medial prefrontal cortex was examined with functional resonance magnetic imaging (Hunter *et al.*, 2010). The medial frontal cortex is involved in self-reflection (Gusnard *et al.*, 2001) and empathy (Farrow *et al.*, 2001), as well as related processes of theory of mind (Van Overwalle, 2009). The experiment showed that scenes associated with subjective tranquillity were associated with strengthened connectivity between auditory cortex and medial prefrontal cortex, hence giving neurobiological support to the theory of natural scenes as particularly efficient in evolving states of self-reflection and a tranquil mental state (Johnson *et al.*, 2002; Kaplan & Kaplan, 1989).

In general, without special affinity to any theory, many studies have shown the importance of access to green areas and nature for people's wellbeing in many different aspects – decreased stress (Grahn & Stigsdotter, 2003), better capacity for coping (Ottosson, 2007), sustained and better effect of physical activity (Thompson Coon *et al.*, 2011; Maas *et al.*, 2008), less violence (Kuo & Sullivan, 2001), reduced health inequalities due to differences in socioeconomic status (SES) (Mitchell & Popham, 2008), improved self esteem and mood (Barton & Pretty, 2010), better attention capacity in preschool children (Mårtensson *et al.*, 2009), and higher quality of life (Norman *et al.*, 2010).

1.4 Public health and the modern disease scenario

1.4.1 What is health?

According to the World Health Organization (WHO), health is a state of complete physical, mental, and social well-being and not merely the absence of infirmity (WHO, 1946). The relation between health and disease can be delineated by three different models (Hallqvist & Janlert, 1991):

- The absence model. This is a biomedical perspective where disease is represented by the presence of a diagnosable pathologic state somewhere in the organism, and health is thus the same as absence of disease.
- The continuum model. According to this salutogenic view (Antonovsky, 1996) health and disease can be considered as extremes on each end of a continuum, where on a person can be located on varied spots on this dynamic scale.
- The multidimensional model. From this view the individual's *experience* of wellbeing or quality of life affects the relation between health and disease. Health and disease are considered as two different *dimensions* and health is seen as a resource, experience, or process.

1.4.2 The capacity to adapt

What seems to be obvious is that the concept of health, and the corresponding concept of disease are complex and multivariate constructs. Health- and disease panoramas may also be considered as dynamical cultural concepts and as such changing with time and place (Währborg, 2009). From this viewpoint health becomes much a question of *capacity to adapt* to current circumstances and environment (Giacaman *et al.*, 2009). Since the cultural and social changes of society have accelerated during the last decades this capacity for adapting is challenged, something that may, at least partly, explain the current increase in NCDs and mental disorders such as burnout syndrome, stress related states, and depression.

One aspect of the capacity to adapt is included in the concept of *coping* (Lazarus & Folkman, 1984; Lazarus, 1966). This concept is often used in relation to stress and stress related disorders, and captures cognitive and behavioural efforts to handle internal or external demands on a person. Depending on a person's ability for coping varied strategies can be applied for adapting to a certain situation. One way to cope may be to try and eliminate any threat or obstacle, and another way may be to change one's

own behaviour or attitude towards the current situation. A person's coping skills are associated with risk of becoming ill, recovery, and quality of life. They also influence the tendency for stress and stress reactions (Währborg, 2009).

1.4.3 Global Burden of Disease (GBD)

Apart from mental diseases NCDs comprise diabetes, cardiovascular diseases, cancer, and chronic respiratory diseases, together responsible for 35 million deaths per year globally (Schunemann, 2009). A common factor for NCDs is their relative preventability. By implementing strategies for healthy life styles and modifying risk factors, such as inactivity, unhealthy diet, and non-restorative environments, the challenge of NCDs may probably to some extent be addressed.

According to The GBD Study (Lopez *et al.*, 2006; Murray *et al.*, 1996) psychosocially related disorders and NCDs will constitute a substantial amount of the total disease burden in most parts of the world within a close future (see table 1). Neuropsychiatric conditions are predicted to be the most important causes of disability, responsible for about one third of Years Lost due to Disability (YLD) among adults (WHO, 2009; WHO, 2008), especially among young (15-44 years) women, where depression is the leading cause of disease burden in both high-income, and low- and middle income countries.

1.4.4 Stress, mental health, and NCDs

Research concerned with stress and its effects on bodily functions has developed since the 1930s (Selye, 1936). Stress can be defined as a negative, emotional experience accompanied by predictable biochemical, physiological, cognitive, and behavioural changes that may be directed towards altering the stressful event or to adapting to its effects (Folkow, 2009; McEwen, 2000; McEwen, 1998a).

2004	As % of total DALYs	Rank	Rank	As % of total DALYs	2030
Disease or injury					Disease or injury
Lower respiratory infections	6.2	1	1	6.2	Unipolar depressive disorders
Diarrhoeal diseases	4.8	2	2	5.5	Ischaemic heart disease
Unipolar depressive disorders	4.3	3	3	4.9	Road traffic accidents
Ischaemic heart disease	4.1	4	4	4.3	Cerebrovascular disease
HIV/AIDS	3.8	5	5	3.8	COPD
Cerebrovascular disease	3.1	6	6	3.2	Lower respiratory infections
Prematurity & low birth weight	2.9	7	7	2.9	Hearing loss, adult onset
Birth asphyxia & birth trauma	2.7	8	8	2.7	Refractive errors
Road traffic accidents	2.7	9	9	2.5	HIV/AIDS
Neonatal infections and other ^a	2.7	10	10	2.3	Diabetes mellitus
COPD	2.0	13	11	1.9	Neonatal infections and other ^a
Refractive errors	1.8	14	12	1.9	Prematurity & low birth weight
Hearing loss, adult onset	1.8	15	15	1.9	Birth asphyxia & birth trauma
Diabetes mellitus	1.3	19	18	1.6	Diarrhoeal diseases

Table 1. Estimations of changes in GBD between 2004 and 2030, demonstrating an increase in unipolar depressive disorder and ischaemic heart disease.

DALY: Disability Adjusted Life Years

COPD: chronic obstructive pulmonary disease.

^aThis category also includes other non-infectious causes arising in the perinatal period apart from prematurity, low birth weight, birth trauma and asphyxia. These non-infectious causes are responsible for about 20% of DALYs shown in this category.

Source: Health statistics and informatics, WHO, The Global Burden of Disease: 2004 update (WHO, 2008)

The concept of stress is closely related to a “*capacity to adapt*” and as formerly mentioned stress may be considered as a reactive response to any taxing external or internal stimuli, where varied organs react in order to adapt to the challenging situation and recreate a bodily balance (McEwen, 1998b). These adaptation processes, regulated from the brain, have as a mutual goal to maintain “constancy through change”, something that is captured in the term “allostasis”. Allostasis is about the brain coordinating adaptive changes in the body, including changes in behaviour (McEwen & Wingfield, 2003; Slater, 1999; Sterling & Eyer, 1988).

The physiological pathways of stress reactions are mediated by the autonomic nerve system. In a stress situation an activation of the sympathetic nerve system occurs with consequent release of adrenaline and noradrenalin by the Sympatho-Adrenal-Medullary-system (SAM). In addition, or rather as an intertwining component, an activation of the Hypothalamus-Pituitary-Adrenal-axis (HPA-axis) occurs, eventually resulting in release of glucocorticoids. Depending on the character of the stressor the speed and magnitude of the responses from the sympathetic and glucocorticoid branches vary respectively.

Particular for the stress reactions is their generality, giving that the same kind of reactions occur as responses to either physical or psychological insults, as well as to the *anticipation* of those. This generality, as well as the often chronic character of today’s stressors, are partly responsible for the harmful and pathological effects of stress. The cumulative adverse biological effects of chronic or recurring stress responses may, in conjunction with other vulnerability factors, lead to mental and physical health risks (McEwen, 1998a).

In order to delineate stress mechanisms, and their role in disease development, contemporary stress research focuses on complex multivariate models, which explore underlying mechanisms over time (Währborg, 2009; Rose *et al.*, 2005). Experience of early environments and genetic predisposition are examined as determinants of neural responses to stress as well as resources for coping with stress (Craik, 1981). Psychological and social factors for combating stress and its negative impact are also studied (Taylor *et al.*, 2000).

There is a close relationship between stress, NCDs and mental disorders. The detrimental effects of stress are considerable risk factors in play within the development of diabetes and cardiovascular diseases as well as depression (Jadad *et al.*, 1997; Stamps, 1990). There is also some evidence that stress is involved in development of cancer (Simcox, 2007; King & Flenady, 2002).

Hence, one way to reduce the current increase of NCDs would be to implement environments suitable for stress relief, for example natural environments.

1.5 Evidence-Based Medicine (EBM), and how to value complex interventions in public health care

Summarizing scientific knowledge necessitates an apprehension of available evidence. Within *evidence-based medicine* (EBM) and practice the positivistic view has been predominant. The value of evidence has mainly been correlated to the research method used and the power of the statistic analysis. Hence hierarchical ranking orders of evidence have been constructed where the strongest evidence for therapeutic interventions is provided by systematic reviews of randomized, triple-blind, placebo-controlled trials (Karanicolas *et al.*, 2008). In contrast patient testimonials, case reports, and expert opinions have little value of proof. Different grading systems have been developed in order to apply the best available evidence gained from science for clinical decision making.

During the last years several systems have been evolved based on slightly different parameters for judging, such as considerations of balance between benefits and harms, quality of evidence, translation of evidence into specific circumstances, certainty of the baseline risk, and costs.

In order to try and overcome inconsistencies among systems the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system has been developed (Atkins *et al.*, 2004), and it is now applied by the Swedish Council on Health Technology Assessment (SBU). Within the GRADE system the strength of evidence is ranked in four levels, based on study design (broadly categorized as observational studies or randomized trials), study quality (based on detailed study method and execution assessed by appropriate and adequate criteria), consistency (referring to the similarity of estimates of effect across studies), and directness (referring to the extent to which the people, interventions, and outcome measures are similar to those of interest). By combining the four components the quality of evidence is defined into four levels:

- Strong scientific evidence. Studies of high or moderate quality without weakening factors (such as serious limitations, inconsistencies in the results, uncertainty about directness, imprecise data, high probability of

reporting bias) at a combined judgement. Further research is very unlikely to change the confidence in the estimated effect.

- Moderate scientific evidence. Studies of high or moderate quality with occasional weakening factors. Further research is likely to have an important impact on the confidence, and the estimated effect may be changed.
- Low scientific evidence. Studies with high or moderate quality with several weakening factors. Further research is very likely to have an important impact, and the estimated effect is likely to be changed.
- Very low scientific evidence. Studies of low quality or contradictory. Any estimate of effect is very uncertain.

1.5.1 Complex interventions

Even though the GRADE system takes many aspects and parameters into account for judging, it is still a difficult task to rigorously and objectively evaluate research and studies on complex interventions (Friedli & King, 1998; Stephenson & Imrie, 1998). This has for example been recognized and discussed by the Medical Research Council (MRC) (Campbell *et al.*, 2000). A complex intervention is defined as any therapy made up of various interconnecting parts and nature assisted therapy could be considered a typical example. Other examples are community interventions, group interventions like group psychotherapies or school based interventions for reducing smoking, and health promotion interventions to reducing alcohol consumption or supporting dietary change.

Since complex interventions are subject to more variation than ordinary drug interventions the design of any trial is consequently more complicated. In order to delineate a transparent design for a trial of a complex intervention several steps have been suggested: First evidence that the intervention might have the desired effect has to be identified. This may be achieved from both qualitative and quantitative research. Hereafter an optimal study design of an initial exploratory trial may be developed and tested for consistency. A control intervention must also be defined, where one possible solution could be a randomized waiting list study. Assessment of effect size and outcome measures (including economic measures) for the main trial should also be piloted. Finally methodological issues for a main trial must be considered and examine the implementation of the intervention into practice (Campbell *et al.*, 2000).

1.6 Associations, methods, and mechanisms

A general problem in studies concerned with associations between nature and health has been the lack of a clear direction in the cause-effect relationship. Many studies have shown that there is some association between access to green areas, although the causality has remained unclear. This issue can partly be approached by longitudinal study design, but also by more profoundly scrutinizing the mechanistic relationships between nature and health.

It has already been discussed that nature assisted therapy is a complex *intervention*, partly due to the problems of identifying the underlying mechanisms by which nature affects health outcomes. The same reasoning is naturally applicable to questions of nature environments' role in *promoting* health or *preventing* disease.

One way of approaching this obstacle is through more standardized research methods; where single parameters and variables can be controlled and where more advanced measurements can be applied.

Standardized nature

Natural environments are per se dynamic settings and also often inconvenient for using sophisticated research equipment. By “standardizing” a natural environment in a setting where more complicated research methods could function and sufficient control could be attained, we might come closer to the answer of what particular components of nature are efficient to what particular aspects of health. It would also provide opportunities for exploring the physiological mechanisms in action when humans interact with nature.

However, the question is if a standardized, “non-natural” nature environment would have the same effects as a “true” one, and if so what sensory input is necessary to provide this sense of realism? In the past, the greatest emphasis has been on static modes of simulation, such as photographs, sketches, or slides (Kaplan, 1993; Kaplan *et al.*, 1974). Several studies support the suggestion that descriptive and evaluative responses as well as preferences are comparable between simulations and on-site presentations (Stamps, 1990; Craik, 1981). However, evidence or support concerning physiological and behavioural responses to environment is less lucid. Compared to mere static modes of simulations Virtual Environments (VEs) provide a more dynamic alternative with higher ecological validity (de Kort *et al.*, 2003).

The sense of presence, the experience of being there, is also considered to be higher in VEs, something that has impact on behavioural response (de

Kort & Ijsselsteijn, 2006). It has also been concluded that the higher the immersion, i.e. the extent to which the system blocks out sensory input from the outer world, the better restorative potential is to be expected from a mediated natural environment (de Kort *et al.*, 2006).

Sensory modalities

For a realistic experience to occur in a laboratory setting, other modalities than visual input appear to be important. In particular sound and haptics have an effect on place experience, and other cognitive and affective judgements in their own right but are also expected to influence the perception of the visual impact and subsequently the sense of presence (de Kort & Ijsselsteijn, 2006; Slater, 1999). In a recent study it was found that visual context can actually modulate connectivity of the auditory cortex in the brain with other regions of the brain that are implicated in the generation of subjective states (Hunter *et al.*, 2010). This indicates a relationship between objective multimodal sensory input and subjective mental states.

In virtual settings *sound* rendering can further enhance the participant's experience and impact the perceived realism (Nordahl, 2006).

Sound is also one of the fundamental modalities in the human perceptual system. Research on soundscape has shown that natural sounds are perceived as pleasant and technological noise as unpleasant (Nilsson & Berglund, 2006; Brown & Muhar, 2004). Natural sounds have been used in stressful situations such as a surgical procedure, and have demonstrated stress-relieving effect via SAM (Arai *et al.*, 2008). There are also a few other studies of nature sounds as stress reducing components (Alvarsson *et al.*, 2010; Diette *et al.*, 2003).

1.7 Nature and public health – reflections from a transdisciplinary view

The fundamentals for this thesis are the considerations of natural environments as particularly efficient in stress recovery and relief of mental fatigue, and as such part of the complex systems that align human health with nature. These thoughts are to some extent present within the concept of evidence based design and planning (Ulrich *et al.*, 2008), but from the clinical medical perspective the ideas are less prominent.

Complex systems can be explored within a transdisciplinary framework, something that has been dealt with in a former article by the author (Annerstedt, 2010a), and this last part of the introduction partly consists of extracts from the article.

1.7.1 Transdisciplinary research

The considerations of health issues and disorders as affected by social and environmental factors are not self evidently outlined in a traditional scientific view.

The issues we are facing today in questions of health and nature concern can somehow be regarded in a mutual context by applying a transdisciplinary approach. By using transdisciplinarity as a modern research tool some of these topics could be approached beyond the obstacle of incommensurability between different disciplines.

Multidisciplinarity and interdisciplinarity

Researchers have expressed attempts to embrace a more complex knowledge in various terms. The concept of interdisciplinary research was first mentioned in the 1940s (Brozek & Keys, 1944) in the fields of psychology and epidemiology. Interdisciplinary and multidisciplinary research have since come to involve separate input from different disciplines, but without creative attempts to blend these approaches for a more profound understanding of the problem or its potential solutions (Rosenfield, 1992).

The term *multidisciplinarity* refers to several disciplines working alongside with parallel efforts, but without integration. Some scholars have questioned, over the years, the simple application of other disciplines, such as psychology and sociology, to public health and epidemiological research. It appears that this approach is not practical without a serious effort to bring people together to work collaboratively (Lynch, 2006).

In *interdisciplinary* research, there should be a stronger focus on the integration of methodological and/or theoretical components between sometimes unrelated academic disciplines (Tress *et al.*, 2005; Albrecht *et al.*, 1998). The merge of knowledge is supposed to provide a novel theory development. However, collaboration is still restricted to dealing with limited knowledge bases and predetermined problems.

Transdisciplinarity

The term transdisciplinary research (TR) first emerged in the 1970s (Heckhausen, 1972), and today there are several definitions for the term. These definitions share the idea that in TR, compared to inductive or deductive paradigms, the problem context and knowledge production are closely linked and it includes a team approach to science that aims for synergy from the phases of problem defining to solutions. It should also involve the integration of theoretical and methodological perspectives from different disciplines, as well as from non-academic institutions, to develop novel conceptual and empirical analyses of a research problem (Klein, 2008; Tress *et al.*, 2005; Rosenfield, 1992).

For complex health issues, it is hoped that TR can provide “a systematic, comprehensive, theoretical framework for the definition and analysis of the social, economic, political, environmental, and institutional factors which influence human health and well-being” p.1 (Rosenfield, 1992). TR should also include non-scientific sources of knowledge and integrate them throughout the process of research.

1.7.2 Biodiversity and health

The imbalance between finite resources and their exploitation has resulted in severe damage to natural landscapes and the loss of biodiversity. Decreased biodiversity is also a potential threat to human health. The possible consequences of decreased biodiversity and destroyed landscapes are the spread of human diseases, loss of medical models, threats to food production and water quality, diminished supplies of raw materials for drug discovery (Grifo & Rosenthal, 1997), and—not least—restricted areas for recreational use, stress relief, and cognitive development. This last issue is important in light of the growing number of persons that suffer from mental diseases.

1.7.3 Ecosystem services

All human beings are part of ecosystems, and the health and well being of human populations depend on the services these ecosystems provide.

The concept of Ecosystem Services, a construct coined by Paul R. Ehrlich and Anne Ehrlich (Ehrlich & Ehrlich, 1981), tries to capture the processes by which the environment produces resources that we often take for granted (e.g., clean water, timber, habitats for fish, and the pollination of native and agricultural plants). Whether we are in a city or rural area,

ecosystems provide goods and services that are both familiar and fundamental to us.

I suggest that the relationship between health, mental state, and nature may be regarded within the framework of ecosystem services. Then it becomes obvious that a decreased amount of natural landscapes poses a significant threat to human wellbeing and mental health, and that research on these different issues would probably take advantage from a closer collaboration.

1.7.4 The science war

There are constructed hierarchies and barriers between disciplines, which have been described as the “two cultures” or the “science war”(Gould, 2000; Snow, 1959).

These barriers mirror the arguments of science as objective or subjective and demonstrate how semantic constructions can work against knowledge production. In the discipline of medicine, knowledge is considered as neutral and more or less objective truths that are derived from controlled and empirical research. This argument is part of the positivistic heritage and establishes quantitative, empirical methods as the foundations of true science. However, the failure of positivistic methods to provide solutions for many complex research questions underlines the need to find new methods of constructing knowledge. Thus, the construction of knowledge and its outcomes becomes more important than the construction of arguments for or against any discipline.

Another argument against the construction of fundamental differences between the “two cultures” or “two sciences” is derived from neuroscience, where contemporary theories argue that researchers *must* use data from various disciplines to gain a more complete understanding of social reactions, emotions, and human behaviour because brain function and plasticity are under the continuous influence of an individual’s environment (Cotman & Berchtold, 2002; Hu & Bentler, 1999; Rosenzweig & Bennett, 1996).

1.7.5 Reductionism

At least in medicine, the reductionist tradition [comparable to the absence model (Hallqvist & Janlert, 1991)] for the explanation of diseases and methods of intervention has shaped the general mindset and medical education, training, and research. This stance is probably due not only to an

inbuilt reluctance towards innovative ideas or creativity, but also to a tradition in which it is ethically required to be well-informed about details and to work in a structured way to provide advanced and predictable healthcare for patients as well as minimizing the risks of adverse reactions. Although this approach may have been appropriate when surgical and pharmaceutical interventions were first developed, it is not evidently so in the modern context of health and disease. Thus, the medical establishment must realise that traditional ways of thinking are neither always relevant nor ethically defensible when approaching the novel burden of disease.

1.7.6 Incommensurability

Incommensurability can be interpreted as the, per definition, impossibility of making two parallel lines meet. We can apply this metaphor to a scientific paradigm; it is clearly impossible to meet another discipline that develops on another parallel line if there are no cross-roads. Cross-disciplinary thinking is an example of an intersection that may permit some cooperation between the lines, but the disciplines will never truly meet in a constructive way to create novel knowledge. This temporary contact between the sciences can hopefully create a specific outcome, but the methodology and epistemology are not affected in the long-run if there are no true attempts to widen the linear perspectives.

Kuhn and epistemology

Without a common language, the possibility of mutually understandable concepts, or active efforts to redirect the parallel lines into new, intersecting patterns, we cannot expect to raise the current state of knowledge to a higher level. The lack of a shared language can complicate the processes of reaching a consensus on a research question or theory or interpreting research results. If researchers cannot clearly express ideas or phenomena in a complex framework, they cannot properly conceptualise the problem or its outcomes. This problem relates to Kuhn's view of the incommensurability between disciplines (Kuhn, 1970). Kuhn's later view of incommensurability consists of a translation failure between localised clusters of inter-defined terms in different theoretical languages (Sankey, 1993). Hence, the problem seems to relate mostly to semantics.

According to Kuhn, a paradigm consists of predetermined theories with a fixed set of terminology. With the paradigm as a scientific basis, a community of researchers can come together with a mutual logic and language (Hoyningen-Huene *et al.*, 1993). According to Kuhn, two

paradigms are, by definition, incommensurable, and theories from different paradigms cannot be related to each other.

The Kuhnian view of incommensurable paradigms is therefore a major obstacle for this case, considering that we have already established that new knowledge and the integration of varied theories, disciplines and institutions are needed to solve the questions of health and environmental care. This approach excludes linear thinking in exclusive paradigms from research development, and other paths must be explored.

Today's challenges call for methodological innovations and the creation of an understandable language, potentially in a transdisciplinary context.

1.7.7 The know-do-gap

Unfortunately, a *know-do gap* (or science-policy gap) exists in public health because there is a gap between what we know about the causes of morbidity and the policy actions taken to mitigate those causes (Lynch, 2006). Hopefully, a broader approach to knowledge seeking can narrow this gap to make research more practical and relevant for policy. This approach should also nurture and empower decisions on environmental policies.

Due to scientific uncertainty on environmental issues, it has too often been the case that attempts to implement protective environmental policies have reached no decision. Medical research often shapes policy decisions, and a firmer foundation for policy-making might be laid by linking the relatively grounded knowledge (at least as it has been traditionally seen) that health research produces to these large-scale environmental issues.

1.7.8 The dualistic heritage

There is still an emphasis on biomedical research concerned with therapeutic solutions for individuals with particular diseases. This emphasis is partly due to the fact that most medical research is funded by industry (Patsopoulos *et al.*, 2006), which provides financial incentives for research in pharmacological therapeutic solutions. On the other hand, research on complex behavioural interventions of a motivational or preventive character is restricted in terms of funding, academic citing, and consequently policy impact. Furthermore, the interactions between natural landscapes, environmental change and health are not easily captured in any sponsor program, and hence research and eventually policy influence are limited.

The medical establishment is also much shaped by the Cartesian dualistic heritage; therefore, it is considered a severe biological mistake to believe that the body and soul might have any influence on each other. Applying a transdisciplinary method to these questions is one step towards

empowering public health and environmental research with the credibility that is necessary for it to have an impact on policy.

I do not claim to have adopted a fully transdisciplinary approach in this thesis, rather an interdisciplinary frame has been applied. However, the idea of another scientific set point arose along the process of the work, while facing the obstacles inherently integrated within any research of linkages and bonds between objects. By practically integrating knowledge from my medical education in other disciplines I believe that the outcome has been at least two-dimensional. To some extent I have learnt the language of ecology and forestry and I hope that some traces of medical terms and methodology have reached and inspired my co-workers in forestry, psychology, and technology. In this perspective the approach of the studies of the thesis could be regarded as demonstrations of a few of the typical issues one has to deal with in this field. This would also partly justify the relatively widespread themes and maybe lack of profundity into a specific matter. Rather the broad coverage must be seen as an initializing attempt to exploring the linkage between nature and health from a primary medical view-point, but with a wish to embrace also other disciplines in the work. By the use of different methods (literature review, cross-sectional, longitudinal, and experimental design) in the different papers and the varied perspectives (intervention, promotion, and prevention) the common theme of the linkage/association between nature and health is highlighted from different angles. This may indicate what design might be relevant in further research and how to refine it.

I believe that part of a transdisciplinary process is to realize the shortages within one paradigm, something that could be achieved by for example testing varied scientific perspectives on one subject. Even though this consequently affects and restricts the possibility for digging deep into the matter as such, it might open a door for delving at least a ditch in the fairly obscure land of linkages. Perhaps it is possible to read the thesis as a suggestion of how to consider the incommensurability arising between health and environment research and how to potentially deal with them.

Everyone is a genius. But if you judge a fish on its ability to climb a tree, it will live its whole life believing that it is stupid.

- A Einstein

2 Aims of the thesis

The general aim with the thesis was to consider natural environments as relevant resources for improved population health. This was approached from varied viewpoints through the four included studies (I-IV):

- To set a state-of-the-art and evaluate the current evidence for nature-assisted therapy as an efficient treatment for varied states of ill health, by a systematic review (I).
- To evaluate the health promoting character of forest nature by using a broad-perspective survey examining different dimensions of the value of forest nature and outdoor recreational habits (II).
- To evaluate the disease preventive character of nature by using longitudinal population health data in combination with landscape assessments stored in Geographic Information System (GIS) (III).
- To examine physiological and psychological restorative effects of a virtual nature setting with and without exposure to nature sounds, after a virtual stress provocation (IV).
- To consider the relevance of virtual reality as a useful research tool within studies concerned with mechanisms responsible for the connections between nature and health (IV).
- To start scrutinizing the research approach to the subject nature and health from an interactive/transdisciplinary scientific perspective (I-IV)

2.1 State of the art (paper I)

As a starting point for most research a grasp of the state of the art of the subject to be studied is necessary. The research tradition of associations between nature and health is fairly young, and reports on state of the art have been lacking. One of the aims with this thesis was to create a solid ground for further studies within this field, by trying to clarify the state of the art considering nature assisted interventions or therapies, by evaluating existent evidence and analyse the quality of trials.

2.2 Health promotion, disease prevention, nature, and landscape planning (paper II & III)

As follows from the discussion of contemporary health issues, NCDs, and stress related disorders, one approach to health care may be the one of health promotion. This is a consequence of the view of health as interplay between the individual and the environment, and a resource to be gained partly from ability to adapt to circumstances. In this perspective healthy behaviours can be considered essential and relevant to promote.

One aspect of this is where people dwell. What opportunities do individuals of a society have to actually behave healthy, and to what extent do the environment and neighbourhood matter? One purpose of this thesis was to examine potential associations between nature experiences and health promotion, in aspects of reduced levels of stress (II) and prevention of mental health disorders (III).

2.3 Mechanistic approach and a new experimental research tool (paper IV)

The subjects of mechanisms and standardized nature were preliminary dealt with in this thesis by performing a pilot study of stress restoration in a virtual nature setting, where the experiential realism was enhanced by the addition of nature sound in the laboratory (IV). Physiological measures as well as cognitive and emotional responses were analysed and the results were related to former alike studies in real nature settings.

3 Materials and Methods

Paper I is based on a systematic literature review, paper II and III on data from two different surveys – one cross-sectional and one longitudinal, and paper IV on data from an experimental study.

3.1 Systematic review (I)

3.1.1 Definition

This study was based on the definition of nature assisted therapy (NAT) as an intervention with the aim to treat, hasten recovery, and/or rehabilitate patients with a disease or condition of ill health, with the fundamental principle that the therapy involves plants, natural materials, and/or outdoor environment, without any therapeutic involvement of extra-human mammals or other living creatures. The evidence collected and the identification of primary studies were matched with this definition criterion.

3.1.2 Study design

As far as relevant we used the study design recommended by the Cochrane Handbook for Systematic Reviews (Higgins, 2008) and applied those methods and protocols. This implies a design of the search strategy in several steps – literature scans for annotated bibliographies and scrutinizing of prior reviews of related subjects, electronic search in selected databases, and extended search by e.g. reference checking, consultation of experts, and “snow-balling”.

The databases used are listed in paper I as well as the specific keywords and how they were used (single terms, or in combination with additive terms AND/OR, or with wild cards, i.e. any ending possible). It is also clarified whether the search terms were to be found among MeSH terms, abstract, title, topic, or key words.

3.1.3 Inclusion criteria and quality assessment

Apart from the previously mentioned definition of NAT the inclusion criteria for relevant publications were based on population, end-point data, study design, language, and time. This is reported in detail in paper I.

Further on, quality assessment was performed according to the GRADE system (Balshem *et al.*, 2011; Guyatt *et al.*, 2011a; Guyatt *et al.*, 2011b) by both authors.

The selected articles were carefully scrutinized and relevant information was extracted in accordance with a preformed data extraction sheet.

No statistical meta-analysis was performed. The heterogeneous material made such conclusive results and estimations impossible.

3.2 Survey studies (II and III)

3.2.1 Study design

Paper II and III consisted of observational studies from collected survey data. Short characteristics of the studies are listed in table 2.

3.2.2 Health measurements

Visual Analogue Scale (EQ VAS)

In paper II self perceived health was measured by EuroQol (EQ-5D) and the attached Visual Analogue Scale (EQ VAS)(Kind *et al.*, 2005; Brooks, 1996). EQ-5D is a standardized instrument for use as a measure of health outcome (Szende *et al.*, 2007; Kind *et al.*, 2005). Preliminary results have indicated the instrument's feasibility, reliability, and validity (Ravens-Sieberer *et al.*, 2010; Fernandez & Turk, 1992), though the instrument still needs to be further evaluated.

In this study we exploited EQ VAS and used the estimate as an approximation of general health state, expressed as a single number.

	Paper II	Paper III
Population	Southern Sweden (Skåne and Blekinge). Random sample. N=3000	Southern Sweden (Skåne). Stratified random sample. N=24945
Way of distribution	Mailed questionnaire	Mailed questionnaire
Response rate	49 %	54.5 %
Study design	Cross-sectional (2006) study	Longitudinal (1999/2000 and 2005) cohort study
Survey	Broad perspective, concerned with different dimensions of the value of forest nature, and outdoor recreational habits, and health.	Population health
Environmental assessment	Self reported	GIS-stored recreational characters and residential geocodes
Statistical analyses	Multiple Linear Regression analysis	Multivariate Logistic Regression analysis
Health measure	Visual Analogue Scale (VAS), Level of stress (LS)	General Health Questionnaire (GHQ-12)

Table 2. Brief description of the material used in paper II and III

On EQ VAS the respondents rate his or her overall health status on a scale from 0 to 100, with 0 representing the worst and 100 the best imaginable health state. The original version of EQ VAS is a vertical scale, in this study the scale was presented in horizontal direction for practical reasons (see figure 3).

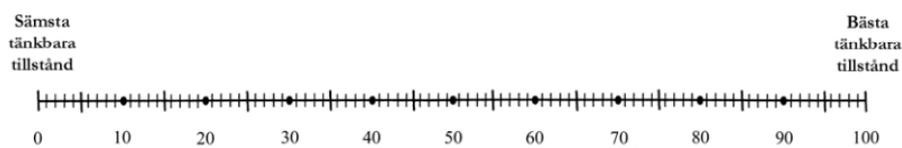


Figure 3. The Visual Analogue Scale (EQ VAS) as it was presented in the survey for paper II. Translated to English “0” says “worst imaginable state” and “100” says “best imaginable state”.

Level of Stress (LS)

In addition we calculated the respondents' level of stress (LS) in accordance with a basic stress test. This test was developed by evaluating the most prominent and clear questions from Stress and Crisis Inventory (SCI-93) (Nyström & Nyström, 1995) and a few other resources (Maslach, 2001; Uvnäs-Moberg, 1997) in order to achieve an easy and feasible instrument with a relevant subset of questions for measuring perceived stress. The initial questions were concerned with headache, ache in the back of the head, annoyance, fatigue, backache, and stress. By factor analysis three distinct variables were distinguished which all pointed to a common factor and that was calculated as LS. Those three variables were concerned with fatigue, annoyance, and stress. The respondents in our study answered how often during a day they experienced stress, fatigue, or annoyance. There were seven response alternatives ranked from never to every day. By principal component analysis based on the correlation matrix a weighed calculation of LS was performed.

General Health Questionnaire (GHQ-12)

In paper III self perceived mental health was measured with the General Health Questionnaire (GHQ-12). The GHQ-12 is a shortened 12-item version of the GHQ-28 (Goldberg & Blackwell, 1970), and is among the most widely used screening instruments for general mental health (Werneke *et al.*, 2000). GHQ-12 focuses on two classes of phenomena – inability to carry out one's normal healthy functions, and emergence of new phenomena of distressing nature (Goldberg & Williams, 1988). Prevalence of poor mental health is defined as reporting problem to three or more of 12 questions in the GHQ-12. Each item (e.g. "Have you, during the past few weeks, felt unhappy and depressed") is rated on a four-point Likert scale: 1) less than usual, 2) no more than usual, 3) rather more than usual, 4) much more than usual. Reporting problem is defined as rating 3 or 4 on the item (scoring 0-0-1-1). According to the validated syntax for GHQ12 (for each question the four response alternatives are divided in two groups, 1-2 = 0 and 3-4 = 1, generating 12 dichotomized variables and these are summarized rendering an interval between 0 and 12) a binary value is calculated for each individual – considered as having good mental health (interval 0-2) or not (interval 3-12).

In a cross-cultural validation study (Goldberg *et al.*, 1997) in 15 centres worldwide GHQ-12 performed well and was robust. In the same study a review of former validation studies (n=9) was presented, reporting high median values for sensitivity and specificity.

Reliability has been reported in several studies with adequate internal consistency (Cronbach's alpha) (Pevalin, 2000; Goldberg *et al.*, 1997; Cronbach, 1951), although the methods for determining its reliability has also been criticized (Hankins, 2008). The effects of age, gender, and education level on the screening performance of GHQ-12 have proven to be non-significant (Goldberg *et al.*, 1997).

3.2.3 Landscape assessment and GIS

In paper II the landscape in focus was forest environments. These were broadly divided into coniferous and deciduous forests and the survey participants denoted themselves what kind of forest they usually visited.

In paper III expertise in landscape architecture assisted with the landscape assessments. The results from these assessments were used in further analyses together with public health data from population health surveys.

The landscape assessments refers to previous studies about *recreational characters* in the landscape which have resulted in eight specific landscape characters (serene, wild, lush, spacious, culture, festive, the common, and festive) considered as restorative and archetypical (Grahn & Stigsdotter, 2010; Grahn *et al.*, 2005). A number of landscape architecture and environmental psychology studies conducted via interviews in different urban parts of Sweden between 1995 and 2005 revealed these eight characteristics of the outdoor environment (from a triangulation approach initially 51 qualities were distilled by factor and cluster analysis). This should correspond to inborn concepts of experienced qualities in nature, comparable to those inborn negative reflexes we have to warn us about threatening elements, such as spiders, snakes, and great heights (Ulrich, 1993b), and thus reflecting basic human needs. When the characters were developed they were also compared with evaluations of what people preferred, and it was found that the characters serene, space, lush, and to some extent culture appeal to many people, especially those who are ill or vulnerable; those who strive to finding a balance within themselves (Grahn *et al.*, 2005). Even though initially developed on a park level the concept has been expanded and the characters are also used on land cover level.

Only five of the eight characters were used in this study, due to lack of relevant land cover data (*serene, wild, lush, culture, and spacious*). Intuitive classification of GIS-data, by expertise in landscape architecture, made land cover data correlations of the characters possible and subsequently storage in GIS (see box 1). This made transparent assessments of the living

environments for the participants possible by geocoding the residents. Characters within a radius of 300 m were considered (see figure 4).

GIS is a spatial analysis system for the organization, storage, transformation, retrieval, analysis, and display of data where location is considered as important (DeMers, 1997; Aronoff, 1989). Any data with geographic coordinates can be stored.

Serene – a place of peace, silence, and care. Sounds of wind, water, birds, and insects. No rubbish, no weeds, no disturbing people.

GIS-criteria: broad leaved forest, mixed forest, pastures, inland marshes, wet mires, other mires, water courses, lakes and ponds.*

Wild – a place of fascination with wild nature. Plants seem self sown. Lichen and moss-grown rocks, old paths.

GIS-criteria: slopes more than 10 degrees. Forest, thickets, bare rock, inland marshes, wet mires, water courses, lakes and ponds. *Each >15 ha if >1 km from the city.***

Lush – a place rich in species. A room offering a variety of wild species, animals, and plants.

GIS-criteria: mixed forests, marshes and mires, beaches, dunes, sand plains, bare rock. All registered “key biotopes”. Pasture land of regional interest. Biodiversity areas, bird biotopes. National parks.

Spacious – a place offering a restful feeling of “entering another world”, a coherent whole, like a beech forest.

GIS-criteria: beaches, dunes, sand plains, bare rock, sparsely vegetated areas, burnt areas, natural grassland, moors, and heath land, forest>25 ha. Slopes>10 degrees. Farmland pointed out in a national plan. Coastal zone preservation.***

Culture – the essence of human culture. A historical place offering fascination with the course of time.

GIS-criteria: Non-urban parks. Farmland pointed out in a national plan. National interests of cultural preservation. Nature reservation areas.

*Excluded areas: noise>30 dB, artillery ranges

**Excluded areas: noise>40 dB, <800 m to wind power aggregate

***Excluded areas: noise>40 dB

Box 1. The five characters applied in paper III and their corresponding GIS-definitions and examples (Skärbäck, 2009).

For the definition of the above mentioned characters data from the European Union programme Coordination of Information on the Environment (CORINE) (Büttner *et al.*, 2000), and regional GIS databases was used. The Swedish CORINE (Marktäckedatabasen (MTD) [Swedish Land Cover Database]) is more detailed than the general European and the

smallest mapped unit is 1-2 ha. The analysis is described in detail in E Skärbäck et al. 2009 (Skärbäck, 2009).



Figure 4. Example pictures of maps showing access to the characters *spacious* and *serene* in the area of Sweden where the study took place.

3.2.4 Statistical analyses

In paper II the data was subdivided in accordance with which kind of forest the participants visited (broadleaved or coniferous) and by gender. Mann-Whitney's tests were used for revealing differences between the groups. Multiple linear regression analyses were used to describe models with LS as dependent variable, in the varied subsets of the data.

In paper III crude odds ratios (OR) and 95% confidence intervals (CI) were calculated in order to analyze associations between different demographic, socioeconomic, and psychosocial variables in 1999, and mental health in 2005 (outcome variable). In addition the association to mental health in 2005 was respectively analyzed for:

- access to one or more recreational character
- access to any specified character (*wild, lush, serene, spacious, or culture*)
- physical activity

Multivariate logistic analyses were performed in order to investigate confounders' (age, country of origin, cohabitant state, mental health 1999, and economic status) effect on any estimated association between recreational characters and the outcome variable.

An interaction variable was constructed from physical activity and access to recreational characters (both in terms of quantity and quality). The effect on the adjusted OR for the outcome variable of this interaction variable was explored by logistic regression analysis. The analyses were restricted to those who didn't move between the two occasions ($n=7549$). Significance of positive departure from additive effect by the interaction variable was calculated by Relative Excess Risk due to Interaction (RERI)(Starr, 2009; Lichtenstein *et al.*, 2008).

Statistical significance level was set to p -value <0.05 and 95% CI.

3.3 Experimental study

3.3.1 Study design

Paper IV presents a randomized, controlled, experimental study performed in two different virtual environments and a control environment without any virtual experience. The study was conducted in accordance with the Declaration of Helsinki and approved by the local committee of ethics. The study participants consisted of 30 healthy males, randomly subdivided into three groups with ten participants in each. After a virtual stress test (common to all groups) the three groups were exposed to three different settings:

- 1) A virtual forest
- 2) The same virtual forest but with addition of nature sound
- 3) An ordinary room without virtual reality.

We used a randomized between-group design.

3.3.2 Virtual reality (VR) technique

VR is a collective denotation of a technique that aims to making the users experience something fictively or “virtually” within an interactive computer-generated environment. It may be a combination of artificial pictures, sound, and sometimes even sense and smell, and the user should be immersed in another environment. The technique can be used for creating design solutions or historical settings, as well as for simulating environments for rehabilitation purposes (Burdea & Coiffet, 2003; Wiederhold & Wiederhold, 2000).

Virtual reality exposure therapy (VRET) has also proven to be an effective, safe, and controlled alternative to other exposure-based therapies

for posttraumatic stress disorder (PTSD)(Rizzo *et al.*, 2009; Parsons & Rizzo, 2008). Different forms of VR therapies have proven successful as psychotherapeutic tools for anxiety disorders and body image disturbances, as distraction during pain, and for neuropsychological assessment (Parsons & Rizzo, 2008; Wiederhold *et al.*, 2008; Wiederhold & Wiederhold, 2000; Rizzo & Wiederhold, 1998).

It has been argued before that the use of virtual environments (VEs) may provide a valuable tool for environmental simulations in research concerned with relationships between natural settings and health (de Kort *et al.*, 2003)

In paper IV the virtual environment was presented with a CAVETM system with three rear-projected walls (4m x 3m), and a floor projection (EON development Inc.). Passive stereoscopy was used to achieve three-dimensional vision. The system also includes an InterSense head tracking system that creates a motion parallax effect to further increase the realism of the VR simulation. For reproducing the nature sound (twittering birds and murmur of water) a surround system was used.

3.3.3 Trier Social Stress Test (TSST), virtual version

For studying particular stress reactions varied tests have been developed. The Trier Social Stress Test (TSST) is a widely and validated used protocol for inducing stress in laboratory settings (Kirschbaum *et al.*, 1993) and has consistently been proven to evoke stress and activation of the HPA-axis and the SAM-system (Kelly *et al.*, 2008; Kelly *et al.*, 2007; Kudielka *et al.*, 2004).

TSST has repeatedly been used to reliably induce social stress with corresponding endocrine and cardiovascular responses. Briefly, the test participant is asked to hold a speech and to do an arithmetic task in front of an audience. The audience, which consists of three actors, doesn't respond emotionally at all to the test participant, making the situation very stressful.

Former tests at the department of design sciences, Lund University, have evaluated TSST in VR and it has been found that the physiological responses to VR-TSST are comparable to responses of real life TSST (Jönsson *et al.*, 2008). The VR-TSST was used in our study (see figure 5).



Figure 5. Example-pictures of the VR-version of TSST. Test-person confronting the committee.

3.3.4 Physiological measurements

For studying physiological stress reactions several validated measures are at hand. Alterations in neuroendocrine secretion associated with stress and HPA-axis reactivity can be assessed by samples of saliva cortisol (Dickerson & Kemeny, 2004). To evaluate sympathetic cardiac control heart rate (HR) and T-wave amplitude (TWA) can be measured (Rau, 2007; Kline *et al.*, 1998), although the reliability of TWA has also been questioned (Furedy & Heslegrave, 1983). High frequency heart rate variability (HF-HRV) can be used for estimating vagal cardiac control (Berntson *et al.*, 2007), and indicating the negative feedback from the parasympathetic nerve system on sympathoexcitatory responses (Thayer & Lane, 2009; Thayer & Sternberg, 2006).

In study III expertise in psychophysiology assisted with the sampling and analysis of mean HR, TWA, and HF-HRV for five minutes in each condition.

HRV is a feasible and non-invasive tool to measure autonomic nerve system activity of the heart by power spectral analysis of the HR time series. By using the Peak Matched Multiple Windows (PM MW) method for analysing HF-HRV the mean square error of the spectrum estimate was optimized, since the spectrum could be expected to include peaks (Hansson, 1999; Hansson & Salomonsson, 1997). The PM MW method has been shown to give reliable results for the HRV spectrum (Hansson & Jönsson, 2006).

In the study saliva cortisol was collected. Cortisol is the key stress hormone of the HPA axis. It interacts with central, sympathetic, and renal mechanisms and plays a potent role in blood pressure regulation. An inverse relationship between cortisol and HRV has been observed (Thayer &

Sternberg, 2006). In this study the cortisol data was log-transformed to approach a normal distribution. For a detailed description of the analytical methods see Kaj Österberg et al. 2009 (Österberg et al., 2009). Electrocardiogram (ECG) and respiration were recorded at 1 kHz.

3.3.5 Psychological measurements

The state scale of the Spielberger state and trait anxiety inventory (STAI) (Spielberger, 1983) was used to estimate the participants' experiences of the TSST. This scale is used to estimate an individual's level of anxiety. The STAI contains four-point Likert items. The instrument is divided into two sections, each having twenty questions. The number on the scale is positively correlated to the anxiety related to in the question. The STAI has proven both validity (Smeets *et al.*, 1997; Peterson & Heilbronner, 1987) and reliability (Spielberger *et al.*, 1995; Rule & Traver, 1983).

The participants also rated their subjective experiences of the VEs.

3.3.6 Statistical analyses

All analyses were performed by expertise in psychophysiology.

Repeated measures ANOVA were used in all analyses for the physiological measures ($p < 0.05$), with experimental CONDITION as repeated factor and GROUP as between group factor. Greenhouse-Geisser adjustments (ϵ) were used to correct for violation of the assumption of sphericity, and were reported together with unadjusted degrees of freedom, adjusted p-values, and η^2 .

To examine specifically the recovery effect for HR, TWA, and HF-HRV, the mean of the two stress conditions were subtracted from the four resting conditions which were used as repeated factors in a similar ANOVA as above. Due to the time lag for cortisol reactivity which peaks after about ten min after TSST, the first recovery or rest condition after TSST were subtracted from the three following conditions. Thus, there were three repeated conditions concerning the recovery effect for cortisol.

4 Results

4.1 State of the art for Nature Assisted Therapy (NAT) (I)

A rather small, but reliable evidence base, supports the effectiveness and appropriateness of NAT as a relevant resource for public health. The initial number of articles identified from the search was 6485. After evaluation of title and/or abstract, 240 potentially eligible papers remained. The final number of included papers, after full analyses of the articles, was 38 (see figure 6).

In general the grade of evidence was modest, and among the six studies of highest evidence grade (according to Cochrane principles) only four proved significantly positive effect of NAT. Among the less scientifically rigid studies health improvements were reported in 26 cases out of 29. The three meta-analyses, included in the review, of wilderness therapy showed modest effect size.

Most of the studies included reported positive outcomes of NAT on schizophrenia, dementia, depression, schizoaffective disorder, substance abuse, and a few other behavioural disturbance disorders. Positive results of NAT were also obtained for capacity to direct attention among breast cancer patients, and for Profile of Mood States (POMS) and heart rate for patients with heart failure.

Although the amount of traditionally considered high quality evidence is not large, the scientific support for NAT is relatively large in comparison with many other complementary or alternative methods (CAM) in health care. CAM is defined as a group of diverse medical and health care systems, practices, and products that are not presently considered to be part of conventional medicine. Rigorous, well-designed clinical trials for many CAM therapies are often lacking (Nahin & Straus, 2001).

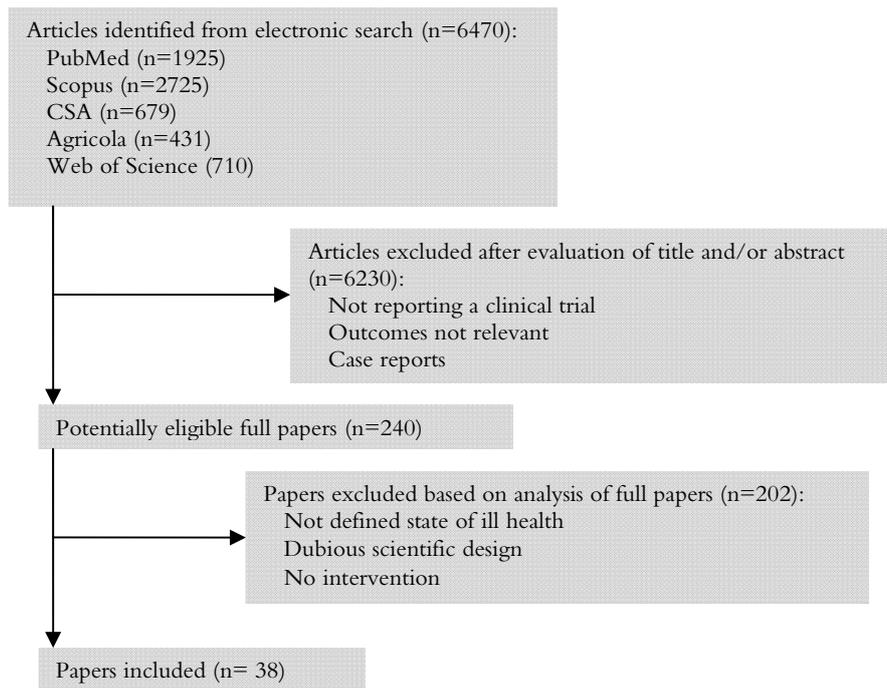


Figure 6. Demonstration of the approximated process of study selection.

4.2 Associations between forest nature and level of stress (LS) (II)

To predict the variation of LS in a southern Swedish population we found a regressive model where length of stay in a broad leaved forest played a significant role for men, and where distance to broad leaved forest played a significant role for women. The models were adjusted for age, household size, education level, employment state, and general health state. The models to predict LS for the visitors to coniferous forest visitors did only include age and general health state, and had no association to forest visits or access to forest (see table 3).

	Coniferous				Broadleaved			
	Men (n=113)		Women(n=105)		Men (n=492)		Women (n=490)	
	β	Adj. R^2	β	Adj. R^2	β	Adj. R^2	β	Adj. R^2
Age	-0.391**	0.135	-0.367**	0.124	-0.310**	0.200	-0.337**	0.112
VAS	-0.340**	0.245	-0.319**	0.219	-0.326**	0.105	-0.314**	0.209
Sick leave	-	-	-	-	-	-	0.111**	0.220
Distance	-	-	-	-	-	-	0.076*	0.230
Unemployed	-	-	-	-	0.075*	0.204	-	-
Length of stay	-	-	-	-	-0.081*	0.209	-	-
Household size	-	-	-	-	0.075*	0.213	-	-
Education level	-	-	-	-	-	-	0.079*	0.226

Table 3. Results from the stepwise regression analysis showing predictors of LS in the groups of coniferous forest visitors and broadleaved forest visitors, men and women respectively.

Note: *indicates significance at the 5% level; ** indicates significance at the 1% level.

β = standardized coefficient

Adj. = adjusted

We also found an association between the purpose of experiencing nature and the type of forest, whereas it was relatively more important to broad leaved forest visitors, compared to coniferous forest visitors, to merely experience the forest nature, rather than having an explicit aim, such as picking berries or mushrooms, walk the dog, or performing physical exercise.

4.3 Synergistic mental health effect of serene or spacious nature and physical activity (III)

As is shown in table 4 the interactive effect of physical activity and access to the recreational characters *serene* or *spacious* respectively significantly reduced the risk for poor mental health in 2005 (OR=0.2 and 0.3 respectively, $p=0.050$ and 0.045) among women. The risk of having poor mental health in 2005 decreased 80 % if having access to *serene* and being physically active, and 70% if access to *spacious* and physically active, compared to not having access to either of these characters and being physically inactive. The

positive departure from additivity of effects was significant for *serene* and physical activity ($p=0.04$, RERI = -0.62 , 95% CI= -1.21 to -0.03). For men the OR was 0.3 for the interaction variable containing *serene*, though the positive departure from additivity was not significant ($p=0.09$, RERI = -0.79 , 95% CI= -0.79 to 0.12).

	Men			Women		
	OR	CI	p	OR	CI	p
Slight financial stress ^a	1.4	1.0-1.9	0.039	1.3	1.1-1.7	0.015
Severe financial stress ^a	2.3	1.6-3.4	<0.001	2.0	1.5-2.7	<0.001
Not cohabiting ^b	1.3	1.0-1.7	0.089	1.0	0.8-1.3	0.67
Born outside Sweden ^c	2.1	1.5-2.9	<0.001	1.1	0.8-1.5	0.63
Age	1.0	0.98-	0.032	1.0	0.98-	<0.001
		1.0			0.99	
Poor mental health 1999 ^d	4.2	3.2-5.5	<0.0001	3.2	2.6-3.9	<0.001
Access to <i>serene</i> 1999	0.9	0.5-1.6	0.77	0.8	(0.5-	0.29
					1.2)	
Access to <i>spacious</i> 1999	1.1	0.7-1.6	0.74	1.1	0.8-1.6	0.54
Access to 1 or more recr values	0.9	0.6-1.2	0.49	0.9	0.7-1.2	0.54
Physical activity						
Little versus (vs) sedentary	0.9	0.7-1.3	0.65	1.1	0.8-1.4	0.47
Regular vs sedentary	0.9	0.6-1.4	0.79	0.9	0.6-1.3	0.54
Advanced vs sedentary	0.9	0.5-1.6	0.77	0.2	0.04-	0.027
					0.83	
<u>Interaction variables:</u>						
Access to <i>serene</i> and physically active ^e	0.3	0.04-	0.25	0.2	0.06-	0.05
		2.4			0.9	
Access to <i>spacious</i> and physically active ^e	1.0	0.4-2.5	0.96	0.3	0.1-0.9	0.045
Access to 1 or more recr values & physically active ^e	0.9	0.6-1.4	0.66	0.8	0.6-1.1	0.21

Table 4. Multiple logistic regression. Adjusted multivariate odds ratios, 95 % confidence intervals and p-tests for risk of poor mental health in 2005. N= 7549 (persons who had moved between the occasions were excluded).

^a vs no financial stress

^b vs cohabiting

^c vs born in Sweden

^d vs good mental health 1999

^e interaction variable. Reference category: no access to the recreational character and physically inactive

Regarding the interaction variable including *spacious* no significant interaction effect was seen for men, and the positive departure from additivity effect was borderline significant for women ($p=0.05$, RERI = -0.57 , 95% CI= -1.13 to -0.01).

Concerning the other three recreational characters as well as amount of characters (in combination with physical activity) no statistically certain

synergistic effects were found. Neither could we discover any significant synergism between nature characters and the other “person”-factors – financial stress and living arrangements.

Considering non-interactive relationships between certain nature characters or amount of characters and mental health we did not prove any significant associations. Regarding physical activity only advanced exercise proved to give significantly reduced risk for poor mental health among women, but not for men, compared to physical inactivity. Other levels of physical activity (little or moderate) did not have any significant impact on the risk.

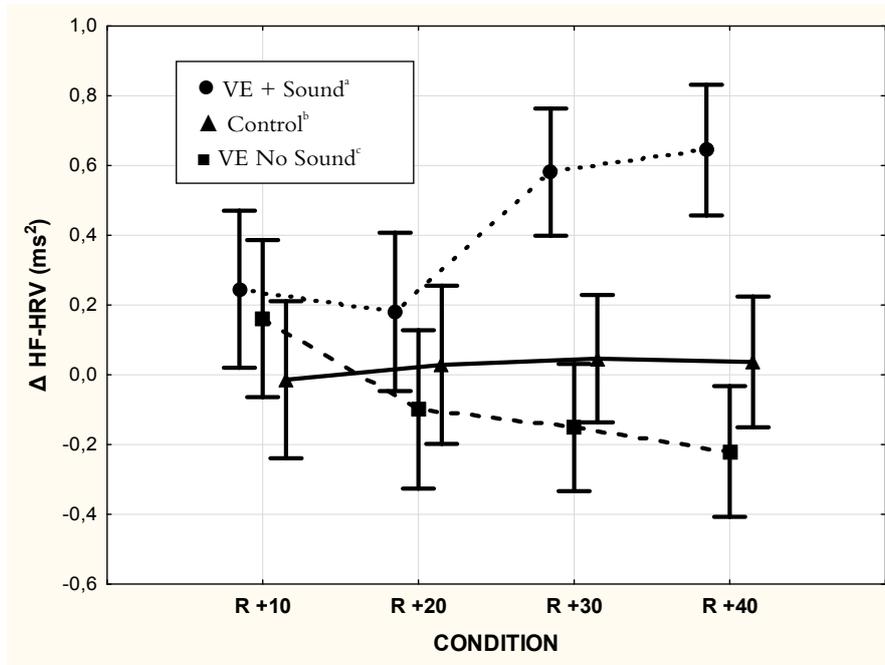
4.4 Activation of the parasympathetic nerve system by stress recovery in a virtual forest with nature sounds

For the group recovering in green virtual nature (see figure 7) with exposure to nature sound the analyses demonstrated a significant group-condition interaction with increased HF-HRV magnitude during recovery. This suggests that this condition may increase parasympathetic activity and hence positively influence recovery from stress.



Figure 7. Example-pictures of the VR-nature the participants were exposed to during recovery. Test-person resting in green VR-environment.

Sympathetic cardiac activity (TWA and HR) and HPA-axis reactivity (saliva cortisol) did not show any significant group-condition interaction for any of the three recovery conditions. This indicates an uncoupled parasympathetic activation in the green VR with nature sound (see figure 8).



^avirtual nature environment and nature sound

^bno virtual nature, no nature sound

^cvirtual nature environment without nature sound

Figure 8. HF-HRV for the three groups during recovery. Values are means (\pm SE), based on the differences between the values for respective subsequent resting condition and the mean values of the two TSST conditions.

Both physiological (cortisol, HR, TWA) (see figure 9-11) and psychological measurements (STAI) showed significant effects of experimental condition, that is expected reactions to stress provocation and subsequent recovery. HR and cortisol increased, and TWA decreased during stress provocation, and returned to basic during recovery. However, we did not find significant support for any particular effect on stress recovery by a silent virtual green environment, or other group effect.

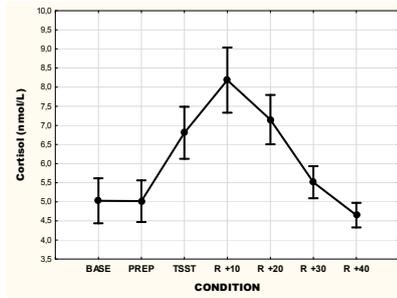


Figure 9. Mean cortisol values as function of experimental condition.

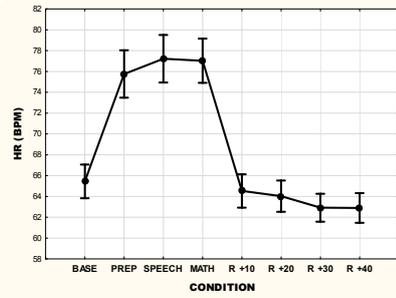


Figure 10. Mean HR as function of condition.

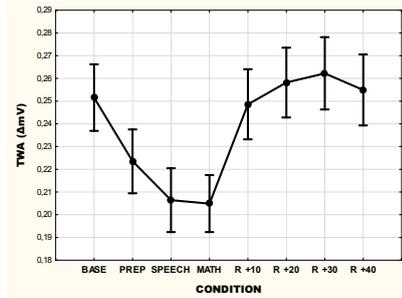


Figure 11. Mean TWA as function of condition.

The participants rated their subjective state anxiety (according to STAI) significantly higher during stress than during baseline. There was no significant difference in state anxiety during exposure to the green environment between the group that also received the auditory stimuli and the group that didn't. Neither were there any different results in the control group.

5 Discussion

A very short and simplified conclusion of the thesis would be that a small evidence base of the efficiency of nature assisted therapy is in line with the findings of certain nature characters as resources for recovery from stress and reducing the risk for mental health problems, and that this may partly be mediated by an active relaxation mechanism within the parasympathetic nerve system.

Concerning the current evidence base for NAT our study provided six high quality studies, whereof four indicated significantly positive results, on different health outcomes.

There is an association between broad leaved forests and level of stress, something that may indicate a health promoting value of certain forest nature.

Combination of longitudinal population health data and GIS-data of landscape characters showed an interaction effect between physical activity and access to *serene* or *spacious* nature characters, preventing development of mental disorder. The effect was most evident for women and *serene* nature.

Green VR proved in a first pilot study to be a relevant tool for examining physiological effects of green recovery. After virtual stress provocation the VR nature in combination with nature sound rendered an active relaxation mechanism, expressed by increased parasympathetic nervous activity, measured by HF HRV.

The research field is well suited for varied forms of interdisciplinary or even transdisciplinary research projects. The variables are dynamic as well as the outcomes, and the studies included in the thesis were all performed by interactive processes between different disciplines. The area covered in the thesis is broad, and every part of it needs to be examined more profoundly, preferably within a continued transdisciplinary approach.

5.1 Current evidence (I)

One of the aims of this thesis was to establish the state of the art for the probably best known application of the association between nature and health, namely *nature assisted therapy*. In a way this sets the agenda for the implication of this research – the implementation of research results for public goods, in this case health, is a major responsibility for most science, and hence it is important to have a starting point wherefrom further research and implementations can develop.

The systematic review (I) did not provide a definite and clear picture of where we stand evidence wise for NAT, but the tendency was positive and a few randomized controlled trials supported the efficiency of the therapy for certain disorders. The research that so far has been performed has often used another study design than what is traditionally regarded as providing the highest evidence. This indicates the need for stronger links between varied research disciplines and society. One may discuss whether the traditional evidence hierarchy is always relevant or adequate, and whether randomized controlled trials should always be the golden standard, even in subjects of broad heterogeneity, dynamic spectrum, and complex interventions. Another perspective is of course to pledge for more traditionally designed studies in the field of NAT and related research issues. The most lucid and coherent outcome seems to be that in an inherently complex research area, dealing with interactions between human behaviour and her natural surroundings and the consequences for health, a critical approach is required. This approach should embrace varied forms of cooperation, and should take into account the obstacles that may arise due to incommensurability between disciplines and meet them by efforts on mutual language and understanding. In any future review of NAT such considerations should be taken into account and it might be recommendable to applying another systematic review design, something that is also acknowledged by Greenhalgh & Peacock (Greenhalgh & Peacock, 2005), for example with the guidelines of MRC on complex interventions as a clearer fundament for the evaluation of included studies.

5.2 Effect of varied natural environments on stress and mental health (II-III)

Another purpose was to explore effects on stress and mental health by access to different kinds of nature. This is partly in line with the above mentioned

call for collaboration between varied research areas, considering the integration of expertise from forestry science, epidemiology, geography, and public health in the studies (II-III). The projects also try and combine theories from environmental psychology with more mechanistic evidence-based medicine. Even though the studies showed associations between LS and access to forest (II), and between lower risk for mental health problems and physical exercise in serene or spacious nature (III), they are however fraught with the inherent limitations of any epidemiological study.

One, maybe provocative, aspect of epidemiological limitations is the risk for violating the hypothesis-driven design. Since practical, ethical, economic, and time considerations all play a role it may happen that research ideas must be modified to what is available, given the resources at hand (Olsen, 2011). This was not the direct case in any of those two studies, but I believe that a reflection on this is important, especially when using collected survey data, or performing register-based research. Other limitations and restrictions, also common for most epidemiological work, were for example selection bias (response rate below 60 % in both studies), and uncertain confounding control.

5.2.1 Health measurements

Varied health measures, with varied advantages and limitations, were applied in the different studies.

LS

Concerning the measure for LS (II) it was a construction developed from other stress measuring scales. The intention was to develop a simple construction with high feasibility, suitable for survey application. However, the precision of the instrument is unclear and it is not a validated construct. Its relative legitimacy was though supported by the close relation to general health state, which was on the other hand measured by a common and validated instrument (EQ VAS).

EQ VAS

In a recent multinational study EQ VAS was evaluated (Ravens-Sieberer *et al.*, 2010). It was found that the feasibility is appropriate, although there is room for further refinement of the presentation and instruction of EQ VAS. The validity calculations (Cohen, 1977) showed convergent validity and association with both physical and psychological well-being. Test-retest reliability was fair to moderate.

GHQ 12

The GHQ 12 consists of a Likert scale and is thus associated with the common limitations of such. The Likert scale was initially developed to measuring attitudes and was then assumed to resemble an interval scale (Likert,1932), and is often used as if it were, although its properties do not respond to the necessary conditions. However, as previously mentioned, GHQ-12 itself seems to present reasonably well in terms of validity, reliability, and feasibility.

5.2.2 Landscape assessments

In study II the so called landscape assessment was simply based on a question in the survey to the participants what kind of forest they usually visited. This is of course a quite subjective measure, and the reliability can be questioned.

In study III the landscape assessment method also demonstrates some particular problems. The theoretical base for relating existing landscape indicators to people's experience of landscape has been found to be rather weak (Tveit *et al.*, 2006) and further evaluations and validations of the concept are necessary. In this case the validations performed have been iterations of the classifications where every version is valued with the experience of the area (southern Sweden) that the members of the project have. No systematic field studies have been achieved, but further studies and projects are planned in order to refine the method. The validation must also be considered as a continuous process.

There is a specific limitation or obstacle related to the data wherefrom the classification of the characters is derived. The land cover data is derived from satellite images, which by computer-aided interpretation is finally integrated in the storage system, Swedish CORINE land cover data. An evaluation of the interpretations rendered a level of correct results in 73% of the cases (Rost, 2005), which is considered an adequate level of specificity, but the distribution is uneven, and this potential source of error must be considered in the interpretation of the results.

From the perspective of self perceived landscape characters by individuals, it was found in a recent study (de Jong *et al.*, 2011) that the sensitivity in self assessment correlated fairly well with GIS definitions, where as the sensibility was lower.

Finally the public health data was derived in 1999/2000 and 2005. Any changes in the participants' living environment during that time span have not been possible to control for since the landscape data for the land cover data base was collected in 2000. However, according to evaluations of

landscape expertise the changes in the environment during the period have not been substantial.

5.2.3 Physiological effects

In order to explore biological mechanisms underlying nature's effect on human health experimental research is required. With the theories from environmental psychology as basis psycho-physiological analyses of an experiment in a virtual reality laboratory indicated an active relaxation response in virtual nature with nature sound exposure (IV). The response seemed to be mediated by the parasympathetic nerve system and cardiovagal activity, as measured by HF-HRV.

The lack of effect on cortisol-response may reflect the inertness of this system. The reaction of cortisol is in general slow and potentially difficult to affect, in a measurable way, by adjustment of recovery environment. The TSST elicits a prompt and high stress related cortisol response; the bodily responses connected to the feeling of relief to quit the stressful task may disguise any slight differences in the eventual recovery response.

Neither did we achieve any other effects on the sympathetic nerve system (HR and TWA). As is discussed in paper IV there are many potential explanations for this. The fascinating aspect is of course that we achieve another kind of result than usual (compared to other empirical studies with exposure to nature, which have shown decrease in sympathetic activity (Hartig *et al.*, 1991b; Ulrich *et al.*, 1991)). Considering that the method we used in this experiment was different than in former studies it is stimulating to find another kind of result, maybe delineating a previously overlooked mechanism. It is also plausible that the study is fraught with measurement errors or artefacts. Another speculation is that the incongruence that is created between a highly realistic visual input without any other relevant sensory input may arise cognitive confusion and a sense of perplexity, which might explain the non recovery effect of virtual nature alone.

This study was a pioneering pilot study, the sample size was small, and many refinements are possible. However, it generates promise for further research with the aim of coming closer to more profound biologic understanding of the health effects to be achieved from nature. This would be another important and essential step in the implication process of nature values in the health sector. It would also be an imperative key in any evidence-based activity concerned with nature and landscape for the sake of quality of life, well being, and health.

5.3 The theories

Considering the results in relation to theories of the connection between nature and health is an ambiguous task, partly due to the fact that the existing theoretical framework has hitherto not achieved non-questionable empirical support (Hartig *et al.*, 2010), or is at least in need of some revision. For example a quite often used argument in favour of the evolutionary theories, is the intercultural agreement in preferences for natural environments (Ulrich, 1993a). However, this argument relies mainly on research concerned with *aesthetical* preferences, something that does not necessarily evoke healthy reactions. However, several empirical studies have actually demonstrated a certain relationship between preferences and restorativeness in a landscape (Tenngart Ivarsson & Hägerhäll, 2008). Another limitation is the historical and ethnic relatedness of the populations in these studies (Lewis, 2005).

The hypotheses of the epidemiological studies of this thesis (II, III) rely partly on the evolutionary hypotheses and the aesthetic affective theory. However, it was only after a rather long time span that any association to stress relief was to be found in the group of broad leaved forest visitors (II), something that is contradictory to the immediate affective response assumed to be the effect of non threatening nature according to the affective aesthetic theory. The second epidemiological study indeed supports the idea of certain nature characters as especially valuable to maintain mental health, although only among physically active individuals.

In the final study an active relaxation process was discovered. This indicates a neuro-hormonal mechanism being responsible for at least part of the relaxing effect of nature, something that has hitherto not been much discussed in theories of nature and health associations. We still cannot say whether the sound exposure itself was crucial or whether the addition of sound made the virtual nature experience more realistic, hence contributing to the effect to occur. In a former study by Alvarsson *et al.* (Alvarsson *et al.*, 2010) the effect of nature sound exposure without VR was studied with similar physiological measures. In this experiment no activation of the parasympathetic nerve system was revealed, but on the other hand a decrease in sympathetic activity. These contradictory results may seem a bit puzzling, but may also give a clue to the actual importance of combined sensory dimensions when exploring relations between natural environments and health, in an experimental setting. Altogether the results may potentially be in line with both ART and the aesthetic affective theory, suggesting an immediate response to nature, in this case a parasympathetic activation.

5.4 Conclusions, reflections, and further research

Apart from the empirical aims and purposes with the thesis my wish was also to start an exploration of the land of complexity and transdisciplinarity in terms of health and environment.

Even though the systematic review was not by definition a true empirical work, the outcome, apart from the systematic study results, gave a hint on the particular problems related to complex interventions. By stressing the difficulties and limitations of a systematic review concerned with multimodal and complex treatments the review demonstrates the potential need for another kind of approach, both in terms of study design and quality measures. Even though this thesis does not provide any definite answers to what approaches should be the most relevant, those results open up for the discussion on what kind of research is possible and whether the current scientific paradigm is the most adequate to deal with questions of mental health and related environmental issues.

I believe that the main contribution of paper I is the introduction of a rigorous systematic design in this research. To my knowledge no systematic review, based on the Cochrane principles, has previously been performed on NAT. Even though the results as such were not completely conclusive the general tendency is positive, and I believe that it may inspire and influence future studies. By pointing at weak points it may speed up further projects aiming for more specific issues, and eventually contribute to a higher awareness of this treatment option among health policies, decision makers, and research funds.

Within the following three studies included in the thesis, at least a multidisciplinary or interdisciplinary approach was adopted. From a medical education background the thesis was produced at the University of Agricultural Sciences, both in collaboration with the Faculty of Forestry and the Faculty of Landscape Planning (Department of Environmental Psychology). The work proceeded in cooperation with the Medicine Faculty (Department of Epidemiology, Department of Laboratory Medicine), Faculty of Engineering (Department of Design), and the Faculty of Social Sciences (Psychological Department). This contributed to a multifaceted basis for the knowledge production, as well as a mutual learning process of varied scientific languages. I do not claim to have constructed a common language to be applied within the field of nature and health, but hopefully a scene has started to be set and a ground for further research might be visualized.

What could be an important outcome from paper II is at least the consideration of health values in forest management. This is of course an issue of augmenting importance in the era of global change and urbanization, where conflicting interests and demands on land use become increasingly intriguing. More than 50 % of the world's population live in cities, and the number continues increasing according to estimates by the United Nations. This consequently puts a pressure on forests and other green spaces in urban and peri-urban landscapes and bringing the health argument into the picture may be one driving force for maintaining green areas. Policies acting to preserve urban green spaces and protecting biodiversity would also contribute to other public health benefits from nature in cities – for example reduction in air pollution and other harmful effects of the climate in cities. Even if the results from paper II are weak in question of causality they may nonetheless serve as input in discussions about environmentally preferable choices also from a public health perspective. This would also stress another important link – the one between research on climate change/urbanization and public health research (Susca *et al.*, 2011; Hägerhäll *et al.*, 2010).

Both paper II and paper III may serve as part of convergence mechanisms, where the specific strength of paper III is of course the longitudinal design indicating the direction of causality. In spite of weaknesses and flaws they both point in the direction that certain qualities or characters of nature play a certain role for public health. Again in the light of competing land interests this may be essential, when green areas and nature need to the most possible extent be adequate for the current requirements. Given a restricted land area we need to provide evidence and arguments for the most efficient design, planning, and composition of nature for the benefit of population health.

Finally paper IV must of course be considered as the pilot study it is, and as previously mentioned it is more or less spawned with potential sources of error and limitations. Still, the results are exciting since they point towards a not previously noted mechanism in the search for the biological foundation for nature's health impact. Would it be true that exposure to nature and its different sensory modalities *activates* the parasympathetic nerve system this is indeed an important research step within the field. This is certainly scientifically inspiring and should initiate many further projects and studies in hopefully a transdisciplinary manner.

In future research on the relationship between health and nature a stronger focus on mechanistic, biological processes ought to be applied. Even though

no neuroscientific studies were included in this project, the subject does ask for attention from this viewpoint. This is even more stressed by arguments from contemporary neuroscience about the necessity of using data from various disciplines when dealing with research on social reactions, emotions, and human behaviour. Since brain functions are influenced by the environment, it should be obvious that a more profound knowledge of the interaction processes between human health and behaviour and natural environments could contribute to a better understanding of brain plasticity, and not the least vice versa.

Connecting again to the theme of links and connections between areas one may consider the executive function *attention* (an essential quality in one of the main theories about nature and health connections (Kaplan & Kaplan, 1989)), as a link between psychology and neuroscience, something that could help in the understanding of human behaviour and how health can be created and developed. This link describes how voluntary control and subjective experience arise from and regulate our behaviour. The development of attentional functions is partly specified by genes, but is also under influence of experiences from surroundings and culture. The structures of executive attention network involve specific brain mechanisms, but the function is to influence the operation of other brain networks (Posner & Rothbart, 2007). Hence the training of attention may render effects on varied human functions, e.g. intelligence (Duncan *et al.*, 2000), temperamental control (Gerardi-Caulton, 2000), regulation of thoughts, emotions, and conflict resolution (Rothbart & Rueda, 2005), all important aspects of human behaviour. Human behaviour is of course a major clue to any question of health, but also an important aspect in terms of how we perceive and treat our environment.

Specialist in sustainable development, G Honadle stresses that policies are aimed at guiding human behaviour (Honadle, 1999), not the least in the case of environmental policies, and that the departure point for natural resource policy should be changing of human behaviour. However, policies have failed in changing routine behaviours of people, despite the fact of the call for evidence based decisions and policies. One reason may be the failure of environmental studies programs to incorporate behavioural science to a sufficient extent, but another possible explanation may be the failure of studies in medicine to integrate aspects of environmental knowledge and to acknowledge the complex fundamentals of health (Annerstedt, 2009). Considering how to change policies from a sociological perspective one might compare the short term decisions aimed for immediate reward (e.g. in liberal market economics) with maladaptive and immature behaviours and

hence the cure for our sick society and environment would be a more sophisticated approach to policies based on more long-term rewards. Since society and policy makers are made up of human beings with human brains the methods and strategies for a healthier outcome, derived from fully developed goal-directed behaviours, ought to be implicit in the system.

Considering human behaviour to be described and understood from evolutionary, biological, psychological, social, cultural perspectives in complex interactions, might give us an insight in the function of human beings, though perhaps not humanity. By putting this insight in the context of our surroundings and environment some advantages might be reached in terms of creating a sustainable and healthy society. The interdependence between healthy people and healthy ecosystems should be more explicitly acknowledged. Recognizing the important health benefits to be derived from natural landscapes ought to be a strong motivator for maintaining our mutual natural resources. This could be accomplished by educated policies influenced by truly transdisciplinary research also incorporating novel findings from “new” sciences (e.g. cognitive and social neuroscience).

What is mostly lacking in the theoretical part of this thesis, in order to call it a transdisciplinary work, is the inclusion and integration of non-scientific resources of knowledge. However, since the subject most certainly touches areas of strong political concern (e.g. public health, environmental issues, and landscape planning) there ought to be several opportunities for involving varied stakeholders in future research. As previously mentioned, such a closer collaboration should also increase the chances for a narrowing of the know-do-gap between science and policy, as well as the chances for fertilization between the traditionally speaking politically influential medical research and the less influential, but quite as important, environmental research, where the off-spring would be policies and decisions which keep both public health and natural environment in clear mind.

“The average, healthy, well-adjusted adult gets up at seven-thirty in the morning feeling just plain terrible” Jean Kerr (1922-2003)

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- Iris Murdoch (1919-1999)

