The impact of sound in health promoting environments

Patrik Grahn & Matilda van den Bosch

Institutionen för arbetsvetenskap, ekonomi och miljöpsykologi, SLU Alnarp

Essential qualities in a recreational outdoor setting

During the million programme - the ambitious housing programme in Sweden in the 1960s and 1970s - urban areas grew significantly. This was because housing areas in general were built outside the old city limits. In the 1980s, a backlash grew strong against this type of city planning, which meant increasing distances between people living in monotonous, dreary outskirts to livelier city centres. Criticism covered many aspects, such as a waste of good farmland; that people became addicted to cars; that the cities became more socially segregated; and that this way of planning and building was not at all about creating real, vital cities. One way of turning back and creating "real cities" again was to densify, saving cities from "urban sprawl" (Grahn, 2012).

However, to build in areas that had earlier been saved, e.g. urban parks, created much criticism as well, not at least from people living close to these areas. In addition, to have less access to urban parks together with increasing stress and more sedentary everyday situations could have negative impact on people's mental health (Grahn & Stigsdotter, 2003). The question came to a head: what kind of recreational areas do people need? Which qualities are more needed than others? Several research projects started in the late 1970s and early 1980s, in order to find out which qualities people really do need in urban parks. A summary of the research that had been carried out was conducted,

and all the qualities that had been identified as of special importance were listed in an extensive questionnaire survey (Grahn & Sorte, 1985). The result was treated factor analytically, and a number of characteristics stood out clearly. Similar studies were conducted later, in Sweden, in the UK, USA, Germany, and other countries. Usually, eight characteristics emerge (Grahn & Stigsdotter, 2010; Adevi & Grahn, 2012).

In their most distinct forms, these eight characteristics can be described as follows (Grahn & Stigsdotter, 2010; Grahn et al 2010):

1. Serene: Peace, silence and signs of care, safe and secure. Sounds of wind, water, birds and insects. No rubbish, no weeds, no other people or just a few.

2. Nature: Fascination with wild nature. Plants seem self-sown. Lichen- and moss-grown rocks, old paths. Something created not by humans, but by the power of something mightier.

3. Rich in Species: An outdoor area offering a variety of species of animals and plants.

4. Space: An outdoor area offering a restful feeling of "entering another world". A coherent whole, like a beech forest.

5. Prospect: A green, open place with room for vistas, and a place that invites you to stay.

6. Refuge: A sanctuary, an enclosed, safe, secret and secluded place, where you can relax and be yourself and also experiment and play.

7. Social: A meeting place for festivity and pleasure. A social arena or meeting place.

8. Culture: A place offering fascination through evidence of people's values, beliefs, efforts and toils, and perhaps with the passage of time.

All these characteristics seem to include more than one sense; sight, hearing and some characteristic could also include other senses (Hedfors & Grahn, 1998).

A health-promoting everyday environment

From above mentioned studies we got some knowledge about which qualities in urban parks and natural areas people seek to find because they are perceived as recreational. We assumed that e.g. architects and other planners in a near future could use this knowledge in planning and design. However, to develop tools for planners and architects, we had to know more about the characteristics (Grahn et al 2005): Which green areas correspond to people's expectations on e.g. the characteristic Space? In addition, we wanted to know more about recreational and health promoting effects.

We focused on the county of Scania. With available data from regional GIS-databases from the County Administrative Board, we could hypothetically stipulate the presence or not for five of the eight characteristics: Serene, Nature, Rich in Species, Space and Culture (Björk et al 2008). Data regarding these five characteristics were put in a large dataset, comprising an extensive public health survey (n=27 963 persons in Scania). Associations between access to different characteristics and health were analysed using ordinary epidemiological statistical methods. Could it be, that access or not to these presumed restorative characteristics in everyday life could affect people's health? Results showed that the number of recreational values near people's residence were strongly associated with satisfaction of their own neighbourhood, and moreover their amount of physical activity. There was an evident positive correlation between the number of recreational values present within 300 metres distance from the residence and time spent on moderate physical activities every week ($p < 0.001$). The effect on satisfaction was especially marked among tenants: presence of recreational values was associated with low or normal BMI in this group (Björk et al 2008). One characteristic seemed more than others to be associated with different aspects of well-being – Serene.

The hypothetical "objective" ratings of the various characteristics proved to work quite well, but we wanted to make them more sharp and distinct. Hence, we included people's assessments of their neighbourhood with the "objective" criteria, and finally could merge these assessments to make a Scania Green Score (SGS) (de Jong et al 2011). This balanced SGS showed to have a positive influence on people's health. Again, Serene showed to be the most important characteristic (Annerstedt et al 2012; de Jong et al 2012).

Several studies show that the characteristic Serene in urban parks and natural areas might be a specific factor, affecting people's mental health in a positive way. It could be that above all access to Serene in everyday life would render more people a positive development in public health. This is important information in an urbanizing society where any nature at hand should contain as much value as possible. The results may influence urban planning as well as health policies. Since the characteristic Serene could be of such great importance, it is of great value to further understand it.

A salutogenic rehabilitation garden

Stress-induced sicknesses have become a huge global problem. According to the World Health Organization (WHO), mental health disorders and heart diseases – both of which are clearly affected by stress – are expected to be the two major contributors to sicknesses in all parts of the world, with mental health disorders calculated for all age groups and both sexes, by the year 2020 (WHO, 2008). In Sweden, mental health disorders are already the main cause of long-term sicknesses. The amount, especially in the younger age-groups 20-35, is still growing (Försäkringskassan, 2013). Rehabilitation is often prolonged, and return to work rate is low. It is recognized that individuals with stress-related mental sicknesses are in great need of rest and mental recovery (Perski 2004). There is increasing scientific evidence that nature can be a positive resource for relieving symptoms of stress and improving mental recovery (Nilsson, et al 2011). Since at least the 1930s, there also exist therapies, e.g. in the US, based on gardening (Stigsdotter et al 2011).

In order to scientifically establish rehabilitation based on activities and rest in nature, a Nature Based Rehabilitation (NBR) program was developed at the Swedish University of Agricultural Sciences, Alnarp campus. It consists of a specially designed garden, a selected treatment team and a special developed activity program for stress-related mental sickness (Stigsdotter & Grahn, 2003; Grahn et al 2010). The garden has been constructed and laid out on the basis of a theory, that people who suffer from stress-related mental sickness can best regain health in a natural setting (Grahn, 1999). The theory argues that people affected by stress-related mental sickness get a changed understanding of their activities as well as their surrounding environment, and how they

can work in and manage that change in their lives: their "Scope of meaning" and "Scope of action" (Grahn, 1991; Grahn et al 2010). Their function in everyday life has become seriously weak, and they need a lot of support from the environment. The theory asserts that people in the beginning of a process of rehabilitation from this illness has a great need of support, especially from natural environments (Grahn, 1991; Grahn et al 2010). Gradually, as they get better, the large and immediate need of support will diminish and will also change in character. Now, a need of support from people starts growing. This theory is summarized in a diagram (Fig. 1).

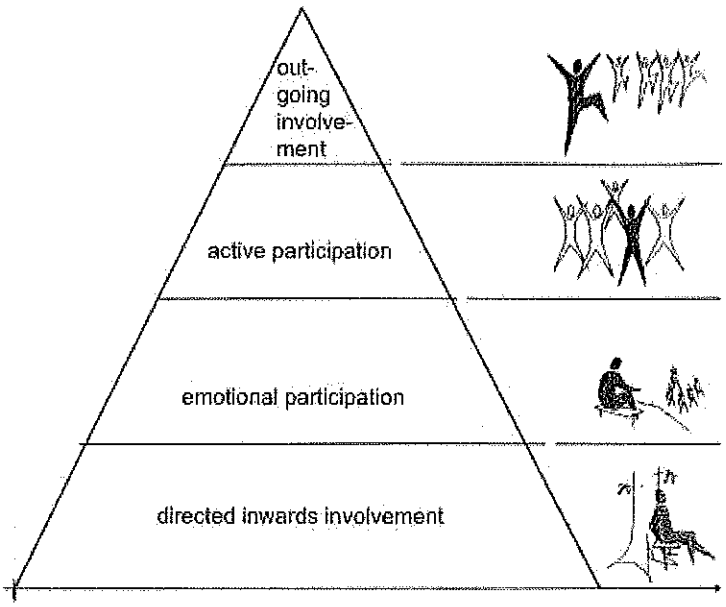

Figure 1.
"The pyramid of supporting environments summarizing the "Scope of meaning/scope of action" theory."

When the Alnarp Rehabilitation Garden was laid out, the design mainly followed the above theory (Stigsdotter & Grahn, 2003). The garden had to be functioning in all phases of treatment; so according to the theory it consists of a range of different types of nature and garden environments. These garden rooms are designed to include the eight characteristics. Garden rooms which are designed to be used in the beginning of rehabilitation, include Serene, Refuge and Nature. Earlier research shows that these characteristics are of utmost value for those who are most vulnerable (Grahn & Stigsdotter, 2010). Other garden rooms include characteristics of value later in the rehabilitation program, like

Culture and Social (Grahn et al 2010). Moreover, the environment (social) consists of a small group of people (patients or participants) in the same situation as well as by a team who are experts in managing a rehabilitation garden (landscape engineer and landscape architect) and experts on human health (occupational therapist, physical therapist, and psychotherapist). The rehabilitation garden started in 2002.

Since then, several projects and dissertations have been made during the years (e.g. Stigsdotter, 2005; Tenngart Ivarsson, 2011 and Adevi, 2012). In essence, the program seems to work well, both when it comes to improving health and reducing health care consumption (Palsdottir et al 2013; Währborg et al 2014), as well as in terms of how the garden as a whole is perceived and used (Tenngart Ivarsson & Grahn, 2010; Grahn & Stigsdotter, 2010; Adevi 2012).

It has not been easy to establish how the different characteristics are perceived. It is clear that many senses are involved. As for "Rich in species"; in addition to vision, hearing is used (birdsong, insects) and olfactory perception (fungi, flowers). For the characteristic "Space", many senses must be used to assess the size and coherence: using vision, hearing, locomotion, and a spatiotemporal perception together, can lead you to judge this quality.

The scope of meaning/scope of action theory we are now developing in Alnarp (Grahn et al, 2010) suggests that the surrounding environment and its characteristics communicate with the visitor on many levels: that an environment presents so called affordances of different intrinsic and perceived worth. These values can sometimes be of huge importance to their Self. An affordance of an environment offers the visitors possibilities for different kinds of activities (including rest) and experiences. These possibilities are considered as properties of person-environment interaction: not merely properties of the physical environment.

New research shows that especially at the beginning of the rehabilitation, Serene is important. All separate components of the characteristic are thus of importance: the absence of traffic sounds and noise; the presence of natural sounds such as birdsong and the sound of the wind in the leaves; and perhaps most important - the absence of people (Pálsdóttir et al 2014).

So, to be able to hear the sounds of serenity - calming sounds from nature - there must be absence of noise from traffic, and even absence of people. Why? Affordances from a rehabilitating environment is about sensitive

communication between a person and his surrounding world – what does the environment tell him, about how to react and behave. Johan Ottosson wrote an introspective study about his rehabilitation after a traffic accident. He had to use the natural environment outside the hospital to feel that he could have a chance to rehabilitate.

> *He preferred to be alone when out in the wild. The feeling of communion, calm and harmony was too subtle, too delicate to compete with the company of other people. For him, the experience of being "alone with nature" was different from when he shared the experience with others. (...)*
>
> *When he had company, nature assumed a different and more passive role, and the landscape was transformed into a backdrop.*

(Ottosson, 2001, page 170).

Experimental investigation of relation between sound, environment, and human physiological reactions

Background

From the above it has been shown that sounds are important for creating health promoting environments. This has been studied in epidemiological studies, and further been demonstrated in a rehabilitating garden. It has been found that the acoustic environment can be interpreted in varied ways and thus give rise to varied emotional or psychological reactions. However, it has not been clear what the bio-physiological reactions are behind those variations in psychological reactions. By understanding the physiological processes that mediate the associations between health and sound, a wider implication of the relationship might be expected. In addition, it may contribute to a better comprehension of how to optimally continue the research and exploration of the complex relationship between natural environments and human health in general.

The impact of nature experience on human health is often attributed to nature's inherent stress reducing effects (Lottrup et al. 2013, Grahn and Stigsdotter 2003). Stress, and especially chronic stress, has a well-known detrimental effect on health, directly or indirectly contributing to the epidemic of non-communicable diseases (NCDs), such as diabetes, cardiovascular and mental disorders(McEwen 1993, McEwen 2012).

Several studies have been performed using images of nature to investigate the impact on stress reactions. This has revealed a certain positive effect by visual exposure to nature(Balling and Falk 1982, Staats et al. 2003).

Purpose, method, and material

In order to explore the specific impact of natural sounds and the interaction between visual and auditory exposure we planned and accomplished an experimental pilot-study in the virtual reality (VR) laboratory of Lund University.

Compared to static simulations (e.g. photos), virtual environments (VEs) provide a more dynamic alternative with greater ecological validity, that is, approximating the real-life situation (de Kort et al. 2003).

The VE in the study was presented using a CAVE™ system with three rear-projected walls (4 m × 3 m) and a floor projection (EON Development Inc.). Passive stereoscopy was used to achieve three-dimensional vision. The system also included an InterSense head tracking system that creates a motion parallax effect to further increase the sense of realism.

The test participants (n=30) were first exposed to a VR stress test, where after they were randomised to recover in three different conditions (10 persons in each condition).

The stress test was based on one of the most validated and reliable stress provoking tests that exist for research purposes – the Trier Social Stress Test (TSST). It has consistently been proven to activate the hypothalamus–pituitary–adrenal (HPA) axis and the sympatho–adrenal–medullary (SAM) system (Kudielka et al. 2004, Kelly et al. 2008), along with the corresponding endocrine and cardiovascular responses.

In this study we used a recently developed virtual form of TSST to induce

acute stress (Jönsson et al. 2010, Jönsson et al. 2008), which has demonstrated resembling reactions as the ordinary TSST.

Autonomic and endocrine stress reactivity was assessed by heart rate, T-wave amplitude (TWA), heart rate variability (HRV) parameters, and saliva cortisol, together with subjective ratings of stress (Annerstedt et al 2013). Heart rate (HR), TWA, and HRV were recorded with electrocardiogram (ECG) and a strain gauge for breathing registration. Both HE and TWA are markers of the sympathetic nervous system and increase with stress. HRV is a parasympathetic marker and decreases with stress (Dickerson and Kemeny 2004, Kline et al. 1998, Berntson 1997).

Saliva cortisol was collected in sampling tubes with cotton swabs. Cortisol is an indicator of sympathetic activity, and increases with stress. Baseline testing and subsequent testing throughout and after the experiment were carried out.

Subjective stress was assessed with the Spielberger state and trait inventory (STAI-S) (Spielberger et al. 1983).

The stress provoking part of the study, the TSST, was identical for all test participants and lasted about 15 minutes. After the stress test we changed the VE around the participant and they recovered in the new environment for about 40 minutes. The stress recovery took place in three different settings; i) VR-nature without any sound, ii) VR-nature and sounds of nature, and iii) an ordinary indoor control condition. After the recovery session was completed a few post-experiment tests were run and the purpose of the study was explained to the participant.

The virtual natural environment consisted of trees in a forest, surrounding a path leading to a stream of water, reminiscent of a natural setting in Scandinavia (see Fig. 2).

Figure 2.
Photo of the virtual reality nature used in the recovery phase of the study

Regarding the sounds of nature we decided to use sounds of birdsong and water, since this has previously been related to feelings of relaxation and positive reactions (Brown and Muhar 2004, Nilsson and Berglund 2006). Such natural sounds have been used in stressful situations like surgical procedures, and have demonstrated stress-relieving effect via the autonomic nervous system (Alvarsson et al. 2010, Diette et al. 2003). The sounds were also in concordance with the virtual green environment we used.

Statistical analysis

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

Results

No significant differences (independent samples Mann Whitney test) were found for the participants at baseline in terms of former experiences, or perception of stress and general health.

All the physiological measurements as well as the STAI-S ratings demonstrated that the stress induction was successful.

During the stress recovery phase there was a GROUP effect for the HRV-parameter, but nor for cortisol, TWA, or HR, which demonstrated a main effect of CONDITION only. The analysis of HRV showed that group recovering in VR-nature + sound responded with increased HRV-magnitude during recovery. The groups recovering in VR-nature without sound and the control group responded with decreased HRV of about the same magnitude (see Figure 2)

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 did not.

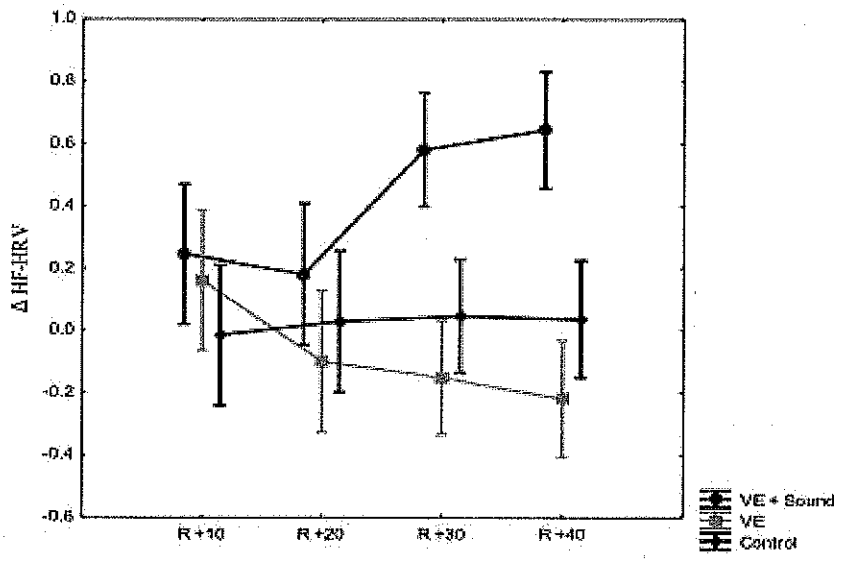

Figure 2.
Different changes in HRV depending on condition. R= Recovery, where numbers indicate time after stress provocation, e.g. +10 is 10 minute after ended stress test

Discussion

We found that stress recovery can be facilitated by the addition of sounds of nature to a virtual green environment in a laboratory setting. Concerning recovery, HRV increased (indicating parasympathetic, stress relieving activity) for the group that after TSST were exposed to a virtual forest with congruent nature sounds. The control group showed about the same HRV magnitude as during TSST, and neither did we detect any significant effect on stress recovery in the silent green environment.

Thus, our hypothesis was partly confirmed. Stress recovery seemed to be facilitated for the group that recovered in the setting with both visual and auditory nature stimuli as indicated by increasing parasympathetic activity. However, in contrast to our intention the silent forest may have created a component of uncertainty or un-pleasantness. That is, the very quiet and silent VE was not Serene, safe and secure – on the contrary. Some of the participants, who recovered in the silent forest, mentioned that they had experienced some kind of anticipation fear, expecting something threatening or dangerous to appear from the surrounding VR nature. The incongruent situation of a high visual realism with no other modality exposure might produce an almost surrealistic experience that may be perceived as some-what frightening.

The lack of effect on cortisol response may reflect the inertness of this system. The reaction of cortisol is generally slow and difficult to affect in any measurable way by adjustment of the recovery environment.

Besides from the small sample size this study has several other limitations. An additional control group with only auditory recovery would have increased the interpretational value, and should be explored through further developed study protocols in response to this initial pilot study. Although inclusion of only men helps standardising the results it also restricts generalizability.

To summarize, the findings of this pilot study give preliminary but positive support for the potential of nature VE in research. There seems to be a significant interactive effect between sound modality and visual input in the virtual nature setting, contributing to increased parasympathetic activity and more efficient recovery after virtually-induced stress. Consequently, this

discovery of an activation mechanism operative in the case of stress recovery suggests novel interpretations of how health effects in nature are achieved. The findings offer prospects for a new research strategy in the field of interactions between humans and nature. By standardising natural settings, applying different modalities, and using varied measurement techniques and variables within the laboratory, a more fundamental understanding of the mechanisms and pathways for this interaction may be achieved, with an eventual importance for creating healthy environments.

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