

# When the going gets tough, will nature get you going?

*The effect of water, natural and urban landscapes  
on cognitive control*

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# Abstract

**Title:** When the going gets tough, will nature get you going? The effect of water, natural and urban landscapes on cognitive control

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**Supervisors:** Tim Brennen (main supervisor) and Anders Martin Fjell (co-supervisor)

According to attention restoration theory (ART), nature provides soft fascination that attracts indirect attention. This allows direct attention, referred to as cognitive control, to rest and be restored. The theory has empirical support, but the field has not come far in untangling the effects of different restorative elements in nature and the effect on cognitive control in particular. The main objective in this study is as follows (1): *What are the effects on cognitive control of viewing photos of natural landscapes with water, natural landscapes without water and urban landscapes?* The secondary objective in this study is as follows (2): *To what degree are the tested landscapes preferred and how does this relate to the effect on cognitive control?* The study is a controlled, randomized experiment carried out by the author as an independent research project with 90 participants doing the ANT (pretest) followed by viewing photosets of natural landscapes with water, natural landscapes without water or urban landscapes, and then the ANT as the posttest followed by a questionnaire with questions, among others, of preference. By utilizing preference research in the design of a study of restorative effects, the study contributes to untangling different potentially restorative elements in natural landscapes in a new way. The study challenges the dominant dichotomy by showing that with a fairer comparison between urban and nature than has been done earlier, with balanced weather, photo quality, contrast, brightness and the amount of sunlight between the photo series of natural and urban environments, there are no significant differences between the groups in terms of the effect on cognitive control. Hence, the study does not support ART. The study confirms previous findings of higher preference for natural landscapes but showed no clear relationship between this preference and cognitive control.



# Acknowledgements

*“First comes thought; than organization of that thought, into ideas and plans; then transformation of those plans into reality. The beginning, as you will observe, is in your imagination”.*

(Hill, 2004, p. 81)

And so it was. However, without my supervisors Tim Brennen and Anders Martin Fjell believing in the idea, without my friends eagerly discussing with me, without family, friends, and strangers sharing their photos with me, and without the participants volunteering for the experiment, I could not have turned my idea into a study.

I thank you all for contributing to making the development from idea to gathering of the data and finally, to written material, into a great journey. A special thanks to Osloforsk for granting me a scholarship.

Vivi Agnete Larsen, Oslo, April 2011.

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# 1 Introduction

It has long been held that nature helps aid the physical and psychological health of urban dwellers, a belief described by Olmsted (1970), among others. Extensive resources are spent on conservation of natural areas close to cities, and people are willing to pay large amounts of money for a view of the ocean (Lange & Schaeffer, 2001). Will these views help you think, and if so, how? When you need to clear your head, what view is likely to help the most?

Attention restoration theory (ART) (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995) predicts that nature has a positive effect on one subcomponent of attention in particular: directed attention, which in this thesis will be referred to as cognitive control. ART predicts nature will restore cognitive control, while urban environments, according to the theory, will deplete this resource. ART has been supported by research (Berg, Koole, & Wulp, 2002; Berman, Jonides, & Kaplan, 2008; Berto, 2005; Hartig, Böök, Garvill, Olsson, & Garling, 1996; Hartig, Mang, & Evans, 1991; Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2009); however, the field has not come far in testing specifically cognitive control regarding natural versus urban environments or in untangling the different potential restorative elements of nature. In this thesis, the landscapes that are tested are specified and carefully chosen according to the literature on landscape preferences, thus building on a solid and related field of research in a way that has not been done before. In addition, the study gives a more fair comparison of nature and urban landscapes than previous research.

First, the theory and research in the field of restorative environments and landscape preferences will be discussed. Given the extent of this thesis, the focus will be on controlled, randomized experiments involving healthy adults. In this thesis, restorative environments refer to environments that lead to a positive effect on the capacity being measured, either comparing different groups on the posttest or comparing a change from the pretest to the posttest. A thorough review of the theories and research will give the background for looking at the chosen objectives for this thesis. Then, the method and results of the experiment will be presented. The findings will be discussed relating to the objectives, theories, previous research, limitations, and further research.

## 2 Background

### 2.1 Can landscapes be restorative for cognitive control?

Two main theories concern restorative environments, Ulrich's theory (1983) and ART (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). They both build on the theory of evolution and propose that humans function best in natural environments because those are the ones humans are best adapted to. While ART focus on how nature will improve directed attention, Ulrich proposes that nature will have a restorative effect on arousal level and emotions.

#### 2.1.1 Attention restoration theory

ART propose that directed attention is a limited resource that gets depleted in modern life and that nature provides soft fascination that activates our involuntary attention so that directed attention can rest and be restored (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995; S. Kaplan & Berman, 2010), as illustrated in Figure 1. Involuntary attention is a more automated stimuli-driven process, and hence less time- and resource demanding, where attention is captivated by interesting or important stimuli.

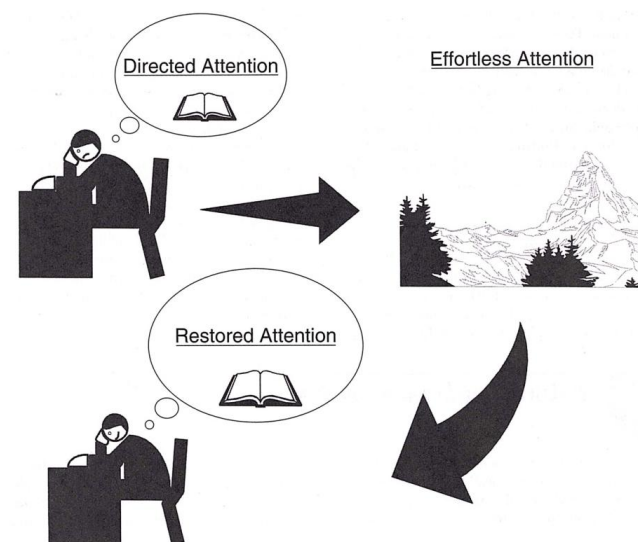


Figure 1. The restorative effect of natural environments as depicted in ART. The concept effortless attention is used interchangeably with involuntary attention. Adapted from *Environmental Psychology* by P. A. Bell, T. C. Green, J. D. Fisher, & A. Baum, 2001, Orlando, FL: Harcourt Press.

According to ART, the most important aspect to attract involuntary attention is *fascination*, and the best provider of this is nature. Nature has an endless list of fascinations. Not all fascinations that exist in nature are restorative. The best are soft fascinations such as clouds, sunsets and leaves flickering in the sunlight. These soft fascinations require little effort to capture and hold our attention. ART asserts three properties or features of restorative settings in addition to fascination: A sense of *extent* is seen as prolonging the effect of fascination. To be a restorative environment, it also has to give the person a feeling of *being away*. Psychologically, and not necessarily geographically, the person has to be distanced from unwanted distractions and routines that impose demands of directed attention. In addition, there must be a correspondence between what the person wants to do, must do and can do in the environment; this is referred to as *compatibility* (S. Kaplan, 1995). Urban landscapes, however, according to the theory, capture attention in a dramatic way and require directed attention to overcome the stimulation, and thus urban landscapes are less restorative.

### **Attention restoration theory and cognitive control**

What is the definition of directed attention in ART? ART builds on James's proposal of two divisions of attention (James, 1892) that has since been thoroughly supported (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Fan, McCandliss, Sommer, Raz, & Posner, 2002). This separation involves the component of directed attention (James: involuntary attention), in which attention is directed by processes of cognitive control, and is inhibitory in nature. Berman et al. (2008), with Stephan Kaplan as co-author, described directed attention as "in addition to top-down control, directed attention involves resolving conflict, when one needs to suppress distracting stimulation" (Berman, et al., 2008, p. 1207). In addition, they stated that their use of direct attention is synonymous with Fan et al.'s use of the concept executive control, which is defined as "conflict resolution among responses" (Fan, et al., 2002, p. 340), and that directed attention can best be measured in the executive control component of Fan et al.'s (2002) Attention Network Test (ANT). Since the ANT also is a widely used and validated test (MacLeod et al., 2010), it will be used in the present study to measure directed attention. Briefly, the ANT separates the three attention components of orienting, alerting, and executive control, shown in research to correlate and be separable from each other (MacLeod, et al., 2010). Fan et al.'s use of executive control and Kaplan's (1995) use of directed attention are closely related to cognitive control, which often is operationalized as implementation of top-down control for task-relevant processes

(MacDonald, Cohen, Stenger, & Carter, 2000). In their most recent work, Kaplan and Berman (2010) used the term cognitive control synonymously with directed attention. In this thesis, directed attention will be referred to as cognitive control, defined as conflict resolution among responses, and operationalized as the capacity being measured with the executive control component of the ANT. However, to avoid confusion with the broader concept of executive functions, this component of the ANT will be called the conflict component instead of the executive component in this thesis.

### **2.1.2 Ulrich's theory**

Ulrich (1983; Ulrich et al., 1991) focused on how exposure to natural environments can provide for psychophysical stress recovery after a challenge or threat. He proposed that if the viewer is stressed and has excessive arousal, an attractive natural scene could elicit feelings of mild to moderate interest, pleasantness and calmness, as well as lower arousal level and holding interest and blocking stressful thoughts. Ulrich (1983) focused more on improving an individual's emotional state than cognition but emphasized how emotions are closely related to thought, neurophysiologic activity and action. To be restoring, according to Ulrich the visual stimuli must include the following qualities: moderate depth, moderate complexity, the presence of a focal point and the presence of content such as vegetation or water. The theory has been given much support through research findings: it has been found that nature gives more positive feelings (Berg, et al., 2002; Hartig, Evans, Jamner, Davis, & Garling, 2003; Hartig, et al., 1991; Ulrich, 1979; Ulrich, et al., 1991; White et al., 2010) and reduces physiological activation (Hartig, et al., 2003; Laumann, Gärling, & Stormark, 2003; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998; Ulrich, et al., 1991).

### **2.1.3 Discussion of the theories**

Similar to other theories related to evolution, both Ulrich's (1983) theory and ART are close to the pitfalls of circular arguments. The answer to the question of why natural landscapes are more restorative than urban is, according to both theories, because we are best adapted to them. But why, according to ART, for example, do leaves flickering in the sunlight provide soft fascination for humans? Is it because leaves are natural? If the theories went beyond this, looking at in what way our perception is adapted to seeing these leaves, this would give

another level of explanation. Welcomed approaches to this are made by, among others, Hagerhall et al. (2008) in the study of fractals.

The reference in ART as to why nature is restoring is because it has stimuli qualities that allow direct attention to rest. In addition to not specifying *why* the stimuli type of nature would allow directed attention to rest, ART neither specify what resting this type of attention involves nor what this hypothesis builds on. Resting of any of the executive functions is not a traditional way of viewing these capabilities. The authors of ART refer to the famous article by Bargh and Chartrand for this argument (Bargh & Chartrand, 1999), and indeed, it does discuss the adaptiveness of automated processes; however, it does not seem to specify allowing other capabilities to rest.

The two theories differ in their focus on what functions nature restore: ART looks into how nature will improve directed attention, while Ulrich claims nature will improve mood and that sympathetic arousal will decline. Hartig and Evans suggested a synthesis of the theories (Hartig, 1993). More recent research shows a tight interaction between emotions, attention and arousal; partly regulated by the anterior cingulate cortex (Critchley, 2005). No research has shown that some of these processes are restored after a certain timeframe or with certain landscapes while others do not, and although the theories have different focuses, the theories do not claim to exclude each other. They do not predict differently in relation to the effects of different environments on cognitive control; hence, the present study does not aim to compare them in such a way, however, ART has a specific prediction regarding cognitive control while Ulrich (1983) have no predictions or focus on cognition. Therefore, ART will be emphasized in this thesis. Furthermore, the present study will test ART's specific prediction regarding that exposure to nature will lead to improved cognitive control. What can we learn from previous research testing ART?

#### **2.1.4 Research testing attention restoration theory**

Several research studies claim to support ART by having found that exposure to natural environments improves different aspects of cognition (Berg, et al., 2002; Berman, et al., 2008; Berto, 2005; Hartig, et al., 1996; Hartig, et al., 2003; Hartig, et al., 1991; Mayer, et al., 2009). The theory is typically tested with between-subjects designs, exposing the participants to urban and natural environments by means of direct exposure like walks or by means of

photos or video. Then cognition is measured by various tests. Some experiments also apply pretests, providing a baseline for the measured capacity.

In the earliest years, it seems that as though the focus was on mainly testing working memory when comparing effects of exposure to natural and urban environments: Hartig et al. (Hartig, et al., 1991) used a proofreading task, while Berg et al. (2002) used the d2 cancellation task requiring participants to search through lines of the letters p and d with no, one or two apostrophes, and the participants were to check all d's with two apostrophes. Both tasks mainly taxed working memory. In addition, Hartig et al., in 1996 and 2003, as well as Mayer et al. (2009) used the search and memory task (SMT), requiring participants to search through lines of letters for targets given in the beginning of each line. In order to respond quickly, the targets had to be kept in short-term memory, thus this task also mainly taxes working memory. The five aforementioned studies found significantly better performance on the tests for the nature groups compared to the urban groups after seeing the stimuli, but a weakness in these studies is the lack of a pretest. Even though d2 and SMT also require efficient visual search, and to a certain degree inhibition, because responding to letters that are similar to the target has to be inhibited, this is not the main purpose of the test. It seems as if the earliest work in the field focused on mostly on tests taxing working memory, and not cognitive control specifically. This is quite interesting considering that ART clearly states which attention aspects the theory predicts will be improved. These functions, however, are of course closely interrelated, all being a part of executive functions. There are quite some overlapping definitions relating to the subcomponents of executive functions. Several different independent but interrelated subdivisions of executive attention have been proposed – among them, a division of shifting, updating and inhibiting as proposed in the widely cited review by Miyake et al. (2000), and, proposed in another widely referred paper by Smith and Jonides (1999), attention and inhibition, task management, planning, monitoring and coding. However, inhibition, corresponding to cognitive control, is one of the partly independent sub processes in both (Miyake, et al., 2000; Smith & Jonides, 1999). Hence, although the subcomponents are partly interrelated, it still seems fruitful to try and individually test the different subcomponents of executive functions.

An interesting study compared nature photos and urban photos by testing attention orienting, using Posner's attention-orienting task (Laumann, et al., 2003). The participants were to respond as fast as possible to an asterisk that occurred either in a validly cued location or in an

invalidly cued location. The cues were either an endogenous cue, a central arrow pointing to the left or right or an exogenous cue, in the left or right visual field. The authors hypothesized that seeing a series of photos of natural landscapes before doing the attention-orienting task would facilitate the reaction time (RT) in invalid endogenous trials, comparing this with voluntary (direct) attention in ART. The results showed that during the posttest the nature group was no longer faster on valid cues, as both the nature and urban groups had been on the pretest. The effect on the reaction time of being oriented actually deteriorated for the nature group, with a significantly slower RT than the urban group on the posttest in validly exogenous cued trials and the same trend for endogenous cues, while remaining constant for the urban group. The researchers also measured heart rate, which was significantly slower than baseline for the nature group, while it remained at baseline in the urban group. Hence, the study supports Ulrich's hypothesis but not the author's interpretation of ART; however, this interpretation of which components are the most central in ART can be debated, as the attention-orienting task measures the effect of orienting and not inhibiting information.

In recent years, the focus has shifted more toward cognitive control when testing ART's predictions: in addition to SMT, Hartig et al.'s (2003) study included the Necker Cube Pattern Control Test (NCPCT), which mainly tests spatial attention and the ability to hold a perceptual perspective of a cube. According to Kaplan (1995), reversals that occur despite the effort to hold are thought to be due to attentional fatigue. Hartig et al. found that the participants in the nature group performed significantly better on the posttest, but again, there was no pretest. Two later experiments testing the ART used tests specifically designed to test cognitive control: study 2 in Berman et al. (2008) and Berto (2005). These will therefore be described in further detail;

### **Research testing nature's effect on cognitive control**

Berto (2005) used photosets previously judged on their perceived restorative potential using Hartig et al.'s (1996) Perceived Restorativeness scale. Based on the judgment, two stimuli groups were formed, one containing photos judged to be low on restorative potential and another with photos judged to be high on restorative potential. The result, however, was quite similar to comparing a nature group to a urban group: all the photos high on perceived restorative potential were natural scenes of lakes, rivers, sea and hills, and none of the photos low on perceived restorative potential were nature scenes; they were city streets, industrial

zones and housing (Berto, 2005). In the discussion of the results, the groups will be referred to as nature versus urban for simplicity; however, the difference in the stimuli groups from Berman et al.'s study should be noted, and the implications of this will be discussed later.

The participants in Berto's study performed the Sustained Attention to Response test (SART), then saw either the urban/non-restorative photo series or the nature/restorative, and then did SART again, in this way, applying a repeated measures design. Berto (2005) chose SART because she considered it to fit closely with ART's definition of directed attention, as the test implies concepts such as inhibition of stimuli, production of response and depletion of inhibitory capacity. Participants saw 24 different digit combinations, one at a time, where 10% were the target (digit 3). The participants were to press the spacebar whenever the target appeared, and to withhold the response when other digits appeared. The results showed that participants who had seen the restorative photos had improved performance on SART from the pretest to the posttest, while those who had seen the urban photos did not have a significant improvement, and comparing posttests, the nature group was significantly faster (Berto, 2005). Thus, the study supports the hypothesis that nature improves cognitive control, but a weakness of the study is that a potential interaction between the groups and the test was not discussed; so it is not known whether nature landscapes led to significantly more improvement from pretest to posttest than urban landscapes. In addition, the photos in this study are not to be regarded as fair comparisons between urban and nature photos as the photos were preselected for restorative value.

Berman et al. (2008) compared performance on the ANT after seeing photos of either urban or natural environments. They applied a repeated measures design with ANT as pretest and posttest. If not otherwise stated, the reference to Berman et al.'s study in 2008 is referring to study 2; in study 1, they did not set out to test cognitive control in specific. The ANT is specifically developed to separate the three attentional functions alerting, orienting and executive control, and Berman et al. claimed that the control component of the ANT are perfect for testing ART predictions. In the ANT, five arrows appear on the screen, and the respondent is always to answer which way the middle one points. The flanking arrows point either the same way (congruent condition) or opposite ways (incongruent condition), varying conflict; this is the *conflict* measure in the ANT. In addition, the respondent is sometimes *alerted* by stars before the arrows, and these stars sometimes *orient* attention to the location where the arrows will appear (e.g., flashing over the fixation cross). By calculating the



differences between the incongruent versus congruent condition (conflict effect), the unalerted versus alerted (alerting effect), and the unoriented versus oriented condition (orienting effect), the three different attention network scores appear; conflict effect, alerting effect and orienting effect. See Figure 2 for more details about the conditions.

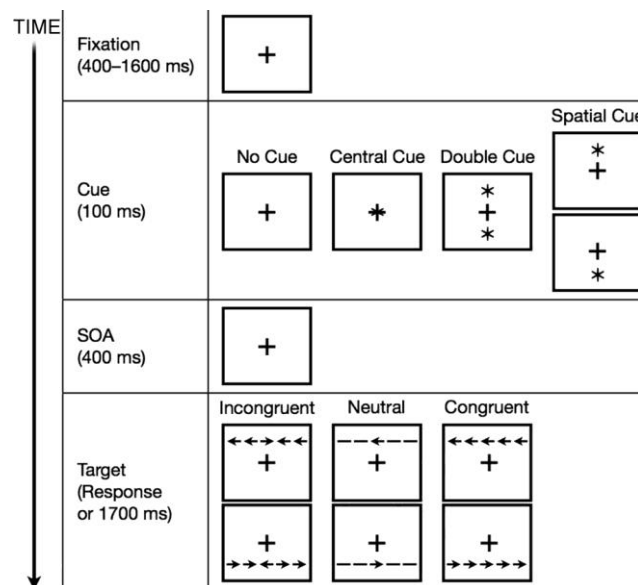


Figure 2. The ANT experimental procedure. The sequence of events in one trial is conveyed in the left column, and all possible stimuli associated with each event are presented in the right column. All four cue types (second row) are equally probable in the task, as are all the three flanker conditions (bottom row). Targets appear above and below fixation (equal probability). Adapted from “Appraising the ANT: Psychometric and Theoretical Considerations of the Attention Network Test,” by MacLeod et al., (2010), *Neuropsychology*, 5, p. 638.

The researchers found that the participants in the nature condition had a significantly greater improvement in conflict scores on the ANT than the participants in the urban condition, namely an interaction effect between group (nature, urban) and test (pretest, posttest). The greater improvement Berman et al. (2008) found in the nature condition relative to the urban condition was only for the conflict scores: no reliable differences were found for alerting or orienting. The authors argued that these results support the notion in ART that nature selectively improves directed attention, as “if interactions with nature had improved all portions of the ANT, alternative explanations, such as increases in motivation or effort induced by interactions with nature, may have been tenable” (Berman, et al., 2008, pp. 1210-1211). These results can also explain why Laumann et al. (2003) did not find that nature improved orienting capabilities. However, in light of the results of a big meta-review of the ANT test by MacLeod et al. (2010) that shows that the three networks are most likely not

independent, as well as the conflict component being more reliable both in the RT and the error rate, and hence more often reported with significant results than orienting and alerting, the reason for significant improvement only on the conflict component in Berman et al.'s (2008) study might be just as much an artifact of the test as support of ART. However, the results still show that nature gives stronger improvement in cognitive control measured with the ANT than urban landscapes in their laboratory setting, and hence also supports the hypothesis of nature improving cognitive control.

A limitation of Berman et al.'s study is the choice of photos, which did not give a fair comparison of natural and urban landscapes. In the set of 40 urban photos (see examples in Figure 3, the whole series can be downloaded from <http://www-personal.umich.edu/~berman/RestorationPictures/>), 25 were visibly old, scanned paper copies from another decade (Figure 3, example a) with bad quality and smaller than 400 kb, which makes the photos clearly grainy when filling the screen, whereas in the natural condition, only six photos were smaller than 1000 kb and none were as low as 400 kb. The nature photos were also clearly newer photos taken with a better camera. Furthermore, seven of the photos in the urban series were taken at night in the dark (all nature photos were from daytime), partly with bad weather (example b), and there were also in general less visible sunlight in the urban photos as well as dark foregrounds due to bad image quality and high contrasts (example c). There were also more repetitions of photos from the same place in the urban series than the nature series (three highly recognizable repetitions, while in the nature condition one). In addition, one of the urban photos had an obvious fault in exposure (example d) and was out of focus. However, some of the urban photos in study 2 in Berman et al. (2008) contained quite a large degree of vegetation, as discussed later, which according to theory could heighten the restorative effect. In addition, some of the natural photos had grey water and some dead vegetation, which is negative for preference.

All together, the photos chosen in Berman et al.'s study are to be considered most in favor of natural landscapes, and there is a possibility that these differences between the photosets in Berman et al.'s (2008) study may have produced confounding variables that gave an advantage to nature.



(a)



(b)



(c)



(d)

Figure 3. Photos showing examples of (a) bad quality scans from a different decade, (b) night/bad weather, (c) bad quality scans with dark foreground and (d) unfocused photo with faulty exposure.

### Which timeframe is optimal for restoring cognitive control?

If we look at studies that have found significant restorative effects of nature vs. urban in measurements other than just cognitive, we find significant effects on physiological measurements such as blood pressure, heart rate and spontaneous skin conductance after stimuli times ranging from 10 min (Parsons, et al., 1998; Ulrich, et al., 1991) to 20 min (Laumann, et al., 2003) and 50 min (Hartig, et al., 2003). Note that both studies with 10 min used video, which can be considered a stronger stimulus as it includes audio. The two studies finding no significant effect of natural environments used stimuli times of 20 min (Laumann, et al., 2003) and 12 min in study 1 in Hartig et al. (1996).

Comparing only studies using cognitive tests that found significant effects, we find stimuli times varying between approximately 3 min and 40 min (Berg, et al., 2002; Berto, 2005; Hartig, et al., 1996; Hartig, et al., 1991; Mayer, et al., 2009). One study using a cognitive test did not find a significant effect: again, Laumann et al.'s (Laumann, et al., 2003) study with an exposure time of 20 min. If we look at the three studies having a pre- and posttest, and significantly more improvement in the nature condition than in the urban condition, we see that the stimuli time here varied from 10 min (Berman, et al., 2008) to 60 min (Berman, et al., 2008; Hartig, et al., 2003). Since in the present study photos will be used to compare the environments, the studies that used photos are the closest references, leaving us with Berman et al. (2008) with 10 min as the closest reference.

What about exposure time for each individual photo? Previous studies using photos varied between 6 sec, in study (3) in Berto (2005), and 15 sec, study (1) in Berto (2005) and in Laumann et al. (2003). Again, no clear trends related to a significant effect of the photos were found; for example, using the same exposure time for each photo, Berto (2005) found effects, but Laumann et al. (2003) did not. To sum up, previous studies do not show clear effects of different exposure times, neither for each photo nor for the total length of the photo series.

### **2.1.5 Natural landscapes have been shown to be restorative of cognitive control**

Previous research testing ART, and cognitive control in specific have showed a greater improvement after seeing natural environments than after seeing urban environments, but the comparison of these environments are not considered fair, due to preselection of restorative/nonrestorative photos (Berto, 2005) and bad representatives of urban environments (Berman, et al., 2008). A clear pattern regarding the most ideal exposure time are not found in previous research. So far, research investigating the dichotomy between nature and urban landscapes has been discussed. Are there any landscapes likely to have even more positive effect on cognitive control than the natural landscape Berman et al. (2008) tested? And what is it in the natural landscapes that are restorative?

## 2.2 Which natural landscapes are likely to be the most restorative?

Attention restoration theory mentions some attributes of natural landscape that must be fulfilled for it to be restoring, but these are concepts about how the viewer experiences the landscape and are at another level than those that Ulrich mentioned; Ulrich mentioned qualities that can be directly observed, e.g., water. Kaplan and Kaplan mentioned how not all natural landscapes are restorative but did not specify what they are. The field of restorative landscapes has not come very far in untangling these elements. Where can we look to find information about which natural landscapes are likely the most restoring? It is natural to look into the closely linked and more widely researched field of landscape preferences.

### 2.2.1 Link between preference and restoration

Two concepts link the field of landscape preferences and restoration: tranquility and perceived restoration. Preference for a landscape is typically measured by self-reporting, answering questions like “*How much do you like this landscape*” (e.g., on a scale from 1 to 10), while tranquility ratings are closely related to Kaplan’s concept of being away, which typically asks to what degree you think this environment would “*encourage relaxation, peace of mind and escape from the strains of living*” (Herzog, 1992, p. 117). It is closely related to the concept of restorative potential, which is the viewer’s own perception of how restorative the landscape might be. Like tranquility, the concept also taps ART’s components but to a greater extent: all of the five, rather than only the ones mostly related to calmness. Several studies have shown that the element of tranquility has a large impact on preference (Herzog, 1985, 1992; Herzog & Barnes, 1999). Several authors have proposed that the most preferred landscapes are also the most restorative (Berg, et al., 2002; Han, 2010; Hartig, et al., 1996; Ulrich, 1981). Three studies (Berg, et al., 2002; Berman, et al., 2008; V. A. Larsen, 2005) have combined questions of preference with tests of restoration, and Berg et al. and Larsen found that the most preferred type of landscape was the most restorative. However, Berman et al. (2008) found that although nature photos were liked more and gave more restoration, no significant relationship was found between preference ratings and the backwards digit span task or the ANT. As we have seen, natural landscapes are more preferred than urban landscapes (Berg, et al., 2002; Purcell, Lamb, Peron, & Falchero, 1994; Ulrich, et al., 1991) and more restorative (Berg, et al., 2002; Berman, et al., 2008; Berto, 2005; Hartig, et al.,

1996; Hartig, et al., 2003; Hartig, et al., 1991; Mayer, et al., 2009; Parsons, et al., 1998; Ulrich, 1979; Ulrich, et al., 1991). Several studies have shown that perceived restoration correlates with preferences (Han, 2010; Herzog, Colleen, Maguire, & Nebel, 2003; Purcell, Peron, & Berto, 2001), and other studies have shown that perceived restoration correlates with actual restoration (Berto, 2005).

There is no agreement about whether restorative landscapes might be preferred because they symbolize recovery potential (Berg, et al., 2002; Purcell, et al., 2001; Staats, Kievet, & Hartig, 2003) or whether it is the positive aesthetic experience that is restorative in itself (Nasar & Li, 2004). However, since the two are most likely part of the same dynamic process, discussing any direction in this link might not be the most fruitful. For this thesis, the most interesting is that it seems likely that the most preferred landscapes are the most restorative, and we can then use preference theories and studies to look for the potentially most restoring types of natural landscapes. Utilizing this in a restoration study is a rather new approach.

### **2.2.2 Theories of landscape preferences**

Similar to theories of restoration, the majority of theories of landscape preferences build on biology and evolutionary adaption. According to Appleton's (1975) prospect-refuge theory, there are three symbols of importance in landscapes: hazards, prospect and refuge. In addition, we like landscapes where we can see but not be seen; where we have a good *prospect* of seeing prey, predators and potential *hazards*, but at the same time we have a *refuge* if necessary. These landscapes are similar to the landscapes our species have had the strongest evolutionary adaption to: the savannah (Bell, Greene, Fisher, & Baum, 2001).

Kaplan also has a theory about landscape preferences (1995). To a larger degree than ART, Kaplan's theory describes different elements in the landscape. According to the theory, we prefer landscapes where we can use our qualities the most: landscapes that are interesting, that call on our ability to understand and to process information, with four critical elements: *coherence* – how well the landscape is organized and seems to “hang together,” *legibility* – to what extent the observer can understand and categorize the elements in the landscape, *complexity* – the number and variety of elements in a scene and *mystery* – to what extent the landscape contains hidden information that makes the observer curious. Ulrich specified in much detail what landscape properties that influence landscape preferences in a positive way; the complexity should be moderate to high with structural properties that establish a focus

point and some elements that give order or a pattern in the landscape; as well as a moderate to high depth, and a ground surface texture that is homogenous and even, a deflected vista and no appraised threat. He also stated that the presence of a water feature would heighten preference for any landscape.

### **2.2.3 Research on landscape preferences**

Stamps (Stamps, 1996) compared 28 of the studies that have tested the four elements in Kaplan's theory. Stamps found no consistent relationship between the four elements and preference; positive, inverse and no relationships occurred. This does not necessarily mean that the elements cannot be regarded as preference attributes; the studies tested different types of landscapes, and perhaps the significance of the attributes varies according to the type of landscape. However, Stamps' results show that Kaplan's four attributes are not stable predictors for preference for landscapes in general.

A number of experiments have shown that naturalness is a very important predictor of preference (Purcell, et al., 1994; Real, Arce, & Sabucedo, 2000; Strumse, 1996; E. H. Zube, Pitt, D. G., & Anderson, 1975). Regarding how this can be explained by the theories, Ulrich mentioned elements of vegetation and water, which are highly natural elements. In addition, ART pinpoints the importance of naturalness, more so than Kaplan's theory of preferences (Kaplan, 1995) – however, it might be seen as a ground stone in this theory, as they state that preferred landscapes are the ones we are best adapted to.

Fourteen studies of landscape preferences contained photos of water and landscapes without water (Arriaza, Canas-Ortega, Canas-Madueno, & Ruiz-Aviles, 2004; Berg, et al., 2002; Bulut & Yilmaz, 2009; Di, Yang, Liu, Wu, & Ma, 2010; Hammitt, Patterson, & Noe, 1994; Han, 2007, 2010; Herzog & Barnes, 1999; Herzog & Bosley, 1992; Kaltenborn & Bjerke, 2002; Purcell, et al., 1994; White, et al., 2010; Yang & Brown, 1992; E. H. Zube, Sell, & Taylor, 1982), and in all 13, all the most preferred photos contained water. The only study that did not find a significant difference between preference for landscapes with and without water was Berg et al.'s (2002), possibly because the stimuli were videos along the same path but in the one containing water the water was not really very visible (Berg, et al., 2002).

Emphasizing the importance of water, a study by Dramstad et al. (2005) showed that there is high preference for landscapes with water even when the water is not visible in the landscape, e.g., a river covered in vegetation. White et al.'s (2010) study is one of the only studies that set

out to investigate the preference for water specifically. White et al. separated their photos by proportions of built elements and natural and aquatic environments and found that the most preferred photos contained mostly water and some green vegetation, followed by scenes with only water and then other aquatic environments. In general, and supporting White et al.'s hypothesis, images of water in natural and built environments were the most preferred.

Furthermore, addressing the link between preference and restoration, landscapes with water have gotten high ratings on tranquility (Herzog, 1985; Herzog & Barnes, 1999; Herzog & Bosley, 1992), and were rated by participants as having greater potential for restoration than other natural environments (Herzog & Barnes, 1999; Herzog & Bosley, 1992).

Summing up research on landscape preferences, the element that is the most predictable for positive preference ratings is water. How can the preference for water be explained?

According to Pitt (1989), the importance of water for preference can be explained by water being our most important basic need. Looking closely at prospect-refuge theory, water is represented in all three symbols in the theory: a large water body can give a good prospect, but it can also be a hazard retarding human beings in their escape. At the same time, water is very often framed by vegetation, and that together with the undulating shoreline gives ample opportunity for refuge (Pitt, 1989). Regarding Kaplan's theory, water adds complexity to all landscapes, by being a form in itself, and leading to geomorphic and biologic processes that form the rest of the landscape. Water also often represents mystery (Pitt, 1989). In the savannah landscapes, irregularly shaped water bodies serve as the focal point, which again is important in landscape preferences (Pitt, 1989). Ulrich mentions specifically in his theory how the element water will lead to heightened preference and restoration. Related to his other concepts, landscapes with water are often richer in depth cues than other landscapes, because geologic and vegetative material protrudes through the surface at varying distances from the viewer and establishes notions of near and far (Pitt, 1989).

#### **2.2.4 Water is a highly preferred and a potentially restorative element**

Studies of landscape preferences show that water is one of the most pivotal elements for preference ratings, and also highly positive for both tranquility and restorative potential. It is also the most stable: compared to other preferred elements, the content of water is positive for the preference in a range of different types of landscapes. In addition, water is the preferred



element that is the easiest to control; the other elements are, for example, mystery and coherence, which are hard to evaluate objectively. Previous research shows that it is likely that the most preferred landscapes are the most restoring.

## **2.3 What do we know about water and restoration?**

Only a few studies to this date have looked into the restorative effect of landscapes with water in particular. Ulrich et al. (1991) tested affect states, heart period, muscle tension, skin conductance and pulse transit time after films of natural environments with and without water as well as urban environments. They found significant effects favoring nature compared to urban but no significant difference between natural environments with and without water. However, the condition with water was described as “dominated by trees and a fast moving stream; waves and ripples on stream surface” (Ulrich, et al., 1991, p. 211). These results might mean that water does not have particular restorative potentials, but it might also be that water was not very visible in the stimuli as the scenes were dominated by trees. Berg et al. (2002) tested preference and restoration of waterscapes but found no significant difference between natural landscapes with and without water. The researchers claimed, however, that this was due to very low visibility of the water in their stimuli. In addition, the water visible was dark brown, hence clearly polluted. Ulrich (1981) found that natural landscape dominated by water experienced a more positive change in self-reported feelings of attention, sadness and fear compared to natural landscapes without water. He also found that the sight of water gave lower alpha activity than natural landscapes without water and urban landscapes. Some of the effects of natural landscapes with water on emotions and alpha levels were significantly more positive than for urban, while not so many of the comparisons between urban and natural landscapes without water reached significance. This points to an advantage of water over only green landscapes, however, the researchers report no significant difference in the effects of natural landscapes with water versus no water.

Larsen (2005) found that natural landscapes with and without water gave positive and significant changes in the self-reported feelings of attention, heartbeat, breathing frequency and fear, but there was no significant difference between the groups in this change, only a trend suggesting water had a stronger effect. White et al. (2010) measured both preference and emotional state, and found the photos with water were the most preferred, and that adding aquatic elements to natural and built scenes led to a significantly more positive emotional

state. However, wholly aquatic scenes received lower preference and emotions than aquatic scenes with some green elements.

White et al. (2010) proposed that the element water has been overlooked in many studies of nature's restorative effect. The studies often include water in the natural conditions that are compared to urban conditions, without investigating or discussing the effect of this presence (White, et al., 2010). White et al. inform us that in Berman et al. (2008), 78% of the nature scenes contained water, while none of the urban ones did. Further, several of the water scenes contained as much as 60% water. A similar point occurred for Berto (2005): 76% of the photos in the restorative group contained water, while only 8% of the unrestorative scenes did. Not mentioned in White et al.'s paper, water was also dominant in the nature condition in Laumann et al.'s (2003) experiment, a video of the waterside of an island on the west coast of Norway. Were these researchers actually testing the restorative effects of water more than testing the restorative effects of nature? One study is particularly interesting when it comes to this point. Karmanov and Hamel (2008) set out to give a fairer comparison between natural and urban environments than previous research, choosing a natural landscape that is partly a nature reserve and partly an agrarian landscape and comparing that landscape to an urban landscape with modern semidetached houses, excellent architectural quality and lots of water, with canals of different lengths and widths. The researchers found that there was no overall difference in positive effect on emotional state between the natural and urban scenery. The natural condition also contained rivers and other water features, but the authors claimed that water was a much more dominant element in the urban scenery. Referring to the aforementioned research by Ulrich (1981) and Berg et al. (2002), the researchers report that the presence of water in their urban condition might have been partly, but not entirely responsible for the restorative effects in the urban environment.

Since most previous research investigating the difference between natural and urban environments actually seems to have tested natural waterscapes against urban, one of the aims of the present study is to separate the effects of natural landscapes and water, by having one photoset of natural landscapes with water and one without. To sum up the research cited above, there is reason to believe that landscapes with water are highly restorative, although it's restorative potential compared to natural landscapes without water remains unclear, as previous studies apart from Larsen (2005) have not balanced the two landscapes in other means, and have not fully made use of landscape preferences to maximize the restorative

potential in the landscapes with water. In addition, none studies have compared natural landscapes with and without water with respect to effect on cognitive control in particular. Wanting to heighten the restorative potential of the waterscapes as much as possible, which type of landscapes should we choose?

### **2.3.1 Which landscapes with water are likely to be the most restoring?**

No studies to our knowledge have so far had this as their objective, but some studies of preference have water in one or more of their tested categories and analyzed in a way that gives some information about which qualities in waterscapes are most important for preference, and hence also perhaps for restoration. Researchers have found that coherence (Herzog, 1985) and tranquility (Herzog & Barnes, 1999; Herzog & Bosley, 1992) are positive for the preference for waterscapes, and positive for tranquility ratings of waterscapes are that the water bodies are large (Herzog & Barnes, 1999; Herzog & Bosley, 1992). Further, large water scenes are more liked if the surfaces are calm (Herzog & Barnes, 1999), and if the landscape have a large degree of focus and openness (Herzog & Bosley, 1992). According to Yang and Brown (1992), water with reflections is the most preferred scene among scenes with still water. Purcell et al. (1994) and Yang and Brown (1992) found that water in natural settings was more preferred than water in other types of settings. Studies have shown that in water scenes, flooding (Litton, Sørensen, & Beaty, 1974), foam on the surface (Herzog, 1985; Wilson, Robertson, Daly, & Walton, 1995), algae (Calvin, John, & Curtin, 1972), water plants (not easily recognized as plants) (Wilson, et al., 1995) and swamps (Herzog, 1985; R. Kaplan, 1984) are disliked.

To get information for our purpose, about which water landscapes would be the most likely to be restoring, it would be ideal if the studies would control the variables (e.g., openness, focal points) that might affect the results and analyze according to these variables. However, because none of the experiments tested the attractiveness of water as their main objective, most of the information regarding water scenes was not analyzed according to this (except for Herzog and Barnes's experiment in 1999). This might have affected the results, for example, if the water category "lakes" in Kaltenborn and Bjerke's (2002) experiment was the only open landscape, then the openness might have been why the landscape was preferred, not the element water. The categories not containing water seems to be very varied in all the

experiments, however. In addition, Han et al. (2010) controlled for complexity and openness and found that water features had more impact on preference than openness and complexity did. The scenes with water were the most liked in this study, but were judged to have a higher degree of complexity than of openness.

To sum up, attributes such as tranquility and preference seem to be strongly interconnected when it comes to waterscapes. Thus, it seems likely that landscapes with large water bodies, a high degree of openness, coherence and naturalness, with clean water and calm surface with reflections would maximize the preference and restorative potential of landscapes with water. These types of landscapes will therefore be chosen for this study.

## **2.4 Aims and objectives in the present study**

Previous research has indeed showed that natural landscapes can be more restorative on different cognitive functions than urban landscapes (Berg, et al., 2002; Berman, et al., 2008; Berto, 2005; Hartig, et al., 1996; Hartig, et al., 2003; Hartig, et al., 1991; Mayer, et al., 2009). However, the previous approaches had several shortcomings; (a) unfair choice of photos to represent the urban condition, with bad quality, bad weather, some night photos, less visible sunlight, high contrast, dark foreground, repetitions, faulty exposure, out of focus and older compared to the photos in natural condition, making these possible confounding variables; (b) very few attempts have been made to untangle the potential restorative elements of natural landscapes, and especially interesting, the highly preferred element of water has often dominated the restorative, natural photos; thus, the presence of water might have been confounded with the term natural landscapes; (c) the few attempts of testing the restorative effect of water have seldom controlled other elements in the landscapes; and (d) when the restorative effects of landscapes were studied, research findings in the related field of landscape preference were not utilized.

The present study tests ART predictions in a novel way by taking advantage of research in the related field of landscape preferences. As previously mentioned, the effect on cognitive control was operationalized as the change from the pretest to the posttest in the conflict effect in the ANT. One of the aims of this experiment was to give a fairer comparison between urban and natural environments with regard to the effect on cognitive control than has been done before, thus addressing shortcoming (a). Another aim is to contribute to untangling the potential restorative effects of different elements in natural landscapes, addressing

shortcoming (b) and (c). Since it is likely that the preferred elements are the most restorative, and water is the most stable, easy measurable highly preferred element, we differentiated the effects of this from other natural landscapes without the presence of water. These aims were achieved by the following:

- Three groups were compared: urban landscapes, natural landscapes with water and natural landscapes without water. This allowed ART to be tested and to untangle the effects of water from other elements in natural landscapes on cognitive control.
- The photos in the natural and urban conditions were balanced with respect to quality, time of day, weather, amount of visible sunlight, contrast, focus and brightness.
- The two types of nature photos were balanced in terms of degree of openness, brightness, focus points, number of elements, textures and composition, so that to the largest possible extent what separated the two natural landscapes was the content of water.

In addition, by including the highly preferred element water in the highly preferred category of natural landscapes, as well as choosing the most preferred type of scenes among water scenes, both preference and restorative effect was potentially maximized in this category, addressing shortcoming (d). To validate this maximizing of preference (as it does not build on a selection study) and to test the relationship between restoration and preference, questions about preference, tranquility and restorative potential were included. Due to the main interest of combining two highly preferred elements (naturalness and water) and to restrictions in the project, a fourth group with urban landscapes with water was not included. Preference for the landscape was operationalized as self-reporting of how much the participants liked the landscapes they saw on a scale ranging from 1 to 5. Questions of tranquility and perceived restorative potential were also asked.

The landscapes were represented by photos as several studies have shown that photos are powerful stimuli in experiments concerning restorative potential (Berman, et al., 2008; Hartig, et al., 1996; Herzog, Black, Fountaine, & Knotts, 1997; Staats, et al., 2003; Ulrich, 1979). Using photos makes it easier to control the experimental situation than real experiences but also makes it easier to implement the findings in indoor environments with the need for restoration of cognitive control – for example, wall art in working environments. However, research has also showed that especially for waterscapes the effects on emotions and preference are stronger after direct exposure than through videos or slides (Huang, 2009).

Taking this into consideration, the participants were asked to imagine that they were at the place shown in the photos.

As we have seen, there is no clear pattern regarding the effect of different exposure times in previous studies. However, due to higher similarity between stimuli types, longer stimuli times than the most typical in previous research were chosen. We sought to prolong the total exposure time as much as possible without the participants getting bored. Regarding the length of each photo, it was considered important that the participants saw the photo long enough to complete the instructed exercise of looking closely at each photo and to imagine themselves being in the landscape. After a pilot study including questions about the experience of the exposure time of each photo and in total, an exposure time of 20 sec for each photo and a total length of 12 min were selected for the present study.

The design described above allowed us to test the following objectives in the present study:

- ***Main objective: What are the effects on cognitive control of viewing photos of natural landscapes with water, natural landscapes without water and urban landscapes?***

Considering the predictions of ART and, despite of its shortcomings, previous research, the hypothesis regarding this was as follows:

- *Hypothesis 1: Viewing natural landscapes with and without water will have a more positive effect on cognitive control than viewing urban landscapes.* Considering the aim of differentiating the effect of natural landscapes with and without water, no hypothesis was made concerning this; with the balancing of photos, the two sets become very similar, and it is such a new approach that predictions are hard to make.

The secondary objective in this study was the following:

- *Secondary objective: To what degree are the tested landscapes preferred and how does this relate to the effect on cognitive control?* Considering preference studies, the first hypothesis related to this is as follows:
- *Hypothesis 2a: Both types of natural landscapes will be more preferred than urban landscapes.* No hypothesis is given for the difference in preference between the two natural landscapes; for the same reasons as no specific prediction of the difference in the restorative effects of these environments are given. Regarding the hypothesized link between preference and restoration in the literature, it is predicted that:
- *Hypothesis 2b: Preference for the landscapes will be positively related to the effect on cognitive control.*

## 3 Method

### 3.1 Participants

Ninety-three students were tested; 3 were excluded from further analysis because they misunderstood the instructions, and hence 90 were included in the analysis. The participants were students recruited from lectures and halls in the Department of Psychology and other faculties at the University of Oslo. The mean age was 22.4 years, and 72% were female. Only participants who spoke norwegian fluently and had no previous knowledge of the project were included. The participants were given one universal gift card worth 100 NOK.

### 3.2 Procedure

The experiment was conducted as a controlled experiment with randomized allocation to one of three stimuli groups: (1) natural landscape with water (referred to as water), (2) natural landscapes without water (referred to as green), and (3) urban landscapes (referred to as urban). The testing was carried out in the Cognitive Laboratories at the Department of Psychology, University of Oslo by the author as an independent project. The facilities include a welcome room, and the participants were tested separately in one of two identical test rooms with all identical equipment. Participants were seated approximately 60 cm from a 19-inch computer screen. After arriving, the participants signed an informed consent form and switched off the sound and vibration on their mobile phones, and then the chairs, screen, and response box were adjusted. An overview of the procedure is given in Figure 4. The participants first performed the ANT (pretest), which lasted approximately 20 min, and then viewed one of the three photo sets. The participants performed the ANT (posttest) again and filled out a questionnaire about their preference for the landscapes they had seen, their relation to different types of landscapes, demographics, previous studies, activities before the testing, and dominant hand (see Appendix (A) for the full questionnaire). The participants were told to not talk about the study and wrote their e-mail addresses on a list to receive information about the study's purpose and results later. The participants were given the gift card and dismissed. The whole experimental procedure (except the questionnaire) and responses were collected using E-prime software (Psychology Software Tools, Pittsburgh, PA). The author was the experimenter and blind to the conditions throughout the testing, and the conditions were randomized by E-prime. The participants received personal and identical instructions

from the protocol from the experimenter before each part of the experiment see Appendix (B) for the protocol. In the photo series, each photo lasted 20 sec, and in total, the stimuli exposure was 12 min. Before viewing the photos, the participants were prepared for a slower pace and instructed to look at the photos and imagine being in the environment shown. The experiment lasted approximately 1 hour and 20 min in total.

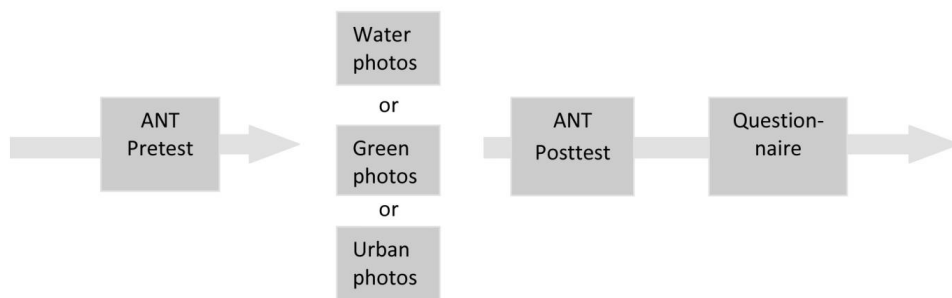


Figure 4. Procedure in the present experiment.

### 3.3 Measures

#### 3.3.1 Attention Network Test

The full adult version of the ANT was used as a measure of cognitive control. The version can be downloaded from Jin Fan's website: <http://sacklerinstitute.org/users/jin.fan/>. Only the instructions were changed; a Norwegian translation used and validated in two studies by Westlye et al. (Westlye, Grydeland, Walhovd, & Fjell, 2011; Westlye, Walhovd, Bjornerud, Due-Tonnessen, & Fjell, 2009). In all other means, the version is identical to the one used by Berman et al. (2008). For details about the conditions in ANT, please see background section. The version used consists of a practice trial with 20 trials followed by two experimental trials each consisting of 96 trials, so there are 288 trials in total. The participants chose the length of the break between trials themselves. The experimenter instructed the test via protocol and stayed in the room during the practice trial to ensure the participants' comprehension. Participants were instructed to focus on both speed and accuracy. Completing the ANT took approximately 20 min. For the posttest, the same version was used, but the practice trials were reduced from 20 to three. The responses were obtained on Psychology Software Tools Serial Response Boxes (Psychology Software Tools, Pittsburgh, PA).



### 3.3.2 Questionnaire

Regarding the preference questions, both questions of general preference as well as tranquility and restorative potential were asked. Of the possible elements, questions about tranquility and perceived restorative potential focused on the concept of relaxing and being away, and effort was put into not having multiple questions in one. Hence, the questions given were, “To what degree do you think these landscapes are good places to relax?” (referred to as “relax”) and “To what degree do you think these landscapes are good places to get away from everyday stress and demands?” (referred to as “being away”). In addition, and referring to the hypothesis on the more visual qualities of the places per se, a question that addressed this idea was also added: “To what degree do you think these landscapes are comfortable to look at?” (referred to as “comfortable”). Of course, this also relates to the concept of relaxing. The questionnaire also included questions about demographics, dominant hand, activities before testing and experiences of the length of stimuli and related task. Since the participants were recruited from the university through all hours of the day Monday to Friday, it was hypothesized that all participants were in need of some restoration of cognitive control, and hence, no fatiguing task was given up front. To separate the visual preference for the photos from the potential confounding variable, questions of to what degree the participant liked staying in five different outdoor environments were asked (referred to as outdoor questions); How much (on a scale of 1 to 5, ranging from *not at all* to *very much*) do you enjoy spending time in (city, ocean, lakes and forest)? For the whole questionnaire, please see the Appendix (A).

## 3.4 Stimuli material

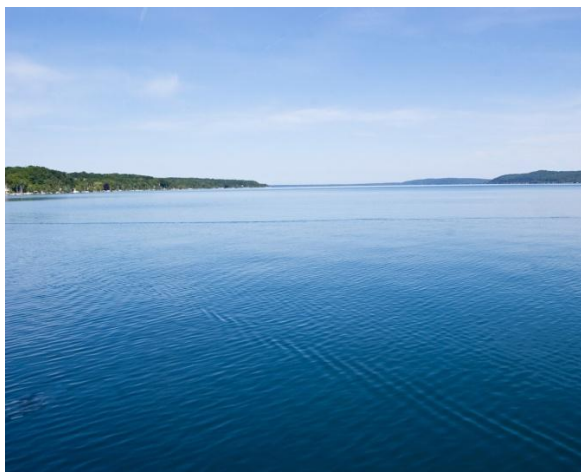
One thousand four hundred sixty-three photos were collected from family, friends and other researchers. However, not enough photos met the stringent criteria described below. More photos were collected via the search engines Picasa and Flickr, and only photos with no copyright but instead with the less stringent criterion of “creative commons” were used. In total, 2,631 photos were collected. Out of these, 108 photos were selected, 36 for each condition. All the photos were of real landscapes, and only minor manipulations were done, for example, removing power poles in the distance on natural photos, and removing people or green vegetation in the distance in urban photos (photos with this up close were not chosen). For all three categories, only photos taken in clear weather were used, and the brightness,

color and photo quality were balanced across the three groups. All editing of the photos were done using Adobe Photoshop CS5.

### **Natural landscapes – balanced groups**

Referring to landscape preference studies, to maximize the restorative potential and preferences in the water scenes, landscapes with large water bodies, a high degree of openness and naturalness with clean water were chosen. All signs of potential pollution were avoided. Water bodies with a calm surface and reflections were specially searched for, but to ensure variation, with some from lakes and some of the ocean, not all photos had a calm surface.

The photos of natural landscapes with and without water were carefully balanced in pairs to have the same degree of the following variables: openness, brightness, focus points, number of elements, textures and composition; allowing to as closely as possible with real photographs to test the content of water per se and not potential confounding variables that normally would vary in landscapes with and without water. See figure 5 for examples of the matching, and the Appendix (C) for the whole sets. The aforementioned factors were matched for each pair, while amount of clouds were matched in the samples as a whole. To minimize the risk of favoring one of the groups when matching, the photos were placed in one water pool and one green pool, and starting with water, a match was looked for one photo from that pool, then one from green, etc. The majority of the photos were not matchable.



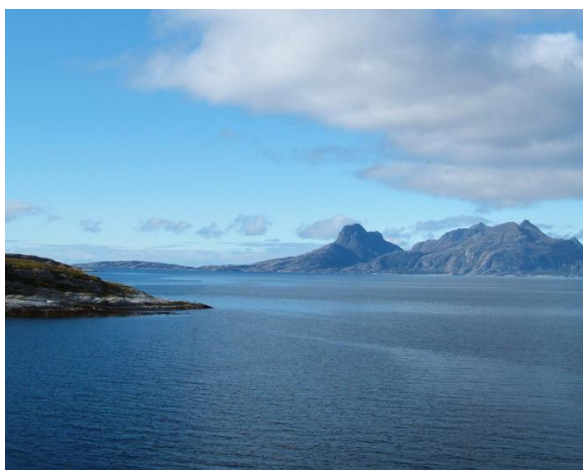


Figure 5. Example of pairing of the photo series of natural landscapes with water (left column) and natural landscapes without water (right column). The full photo lists in pairs are provided in Appendix (C).



## Urban landscapes

When choosing urban photos, highly preferred elements like green vegetation, people, amount of sky and tourist attractions were kept to a minimum. At the same time, the amount of traffic jams, etc. was varied, for the set to give a fair representation of an everyday city landscape. All urban photos had the same nice, clear weather, same photo quality, amount of sunlight, time of day, exposure, brightness and contrast as the natural photos. Photos from Norway were avoided to minimize the effect of known places. See Figure 6 for examples of urban photos, and full list in Appendix (D). The order of the photos in the series was randomized, and then kept identical for all participants.

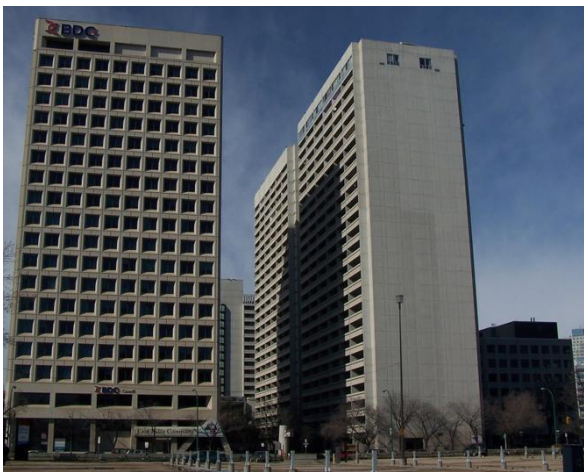




Figure 6. Examples of photos in the urban condition.

## 3.5 Statistics

### 3.5.1 Treatment of data

For preference questions, a mean score was calculated, and for the outdoor questions, the questions concerning cities were reversed and included in a mean outdoor score that represented liking to stay in natural environments.

Concerning the ANT data, due to the skewed nature of the RT distributions, the median RT was used when the trials were aggregated for each subject. The conditions were calculated as averaged median scores across participants. The measures for accuracy (percent of trials with correct response) were calculated in the same way, but the mean was used as the central tendency. The calculation of the attention network scores followed the same manner as other studies using the full version of the ANT, as shown in Figure 7:

Conflict effect RT	= RT incongruent flankers - RT congruent flankers
Alerting effect RT	= RT double cue - RT no cue
Orienting effect RT	= RT spatial cue - RT center cue

Conflict effect accuracy	= accuracy incongruent flankers - accuracy congruent flankers
Alerting effect accuracy	= accuracy double cue - accuracy no cue
Orienting effect accuracy	= accuracy spatial cue - accuracy center cue

Figure 7. Calculation of attention network scores.

Data were pruned from the ANT by developing principles for valid trials, concentrating on the conflict component. This was natural as this component have been shown to be the most reliable part of the ANT (MacLeod, et al., 2010) and because it is the most central measure for this thesis. The ANT consists of 288 trials. Because error trials are believed to belong to a separate RT distribution (Rabbitt, 1966), only correct trials were included in the RT analysis. Thus, due to posterror slowing, trials after errors were excluded. Next, the first three pretest and posttest trials were removed. To remove outliers, all RTs that deviated more than 3 standard deviations from the mean RT for each subject were also removed (this excluded a mean of 3.68 trials per person). These exclusions together removed on average 39.9 trials per person.

Persons deviating more than 3 standard deviations from the mean in accuracy would be quite likely to have a large degree of random responses in their correct trials, as well as their scores becoming less reliable because their many error responses resulted in removal of nearly half their responses in pruning of the error and posterror trials. Two persons were excluded with this criteria, with a mean accuracy of 71% (incongruent condition: 34%, congruent condition: 96%) and 79% (incongruent condition: 51%, congruent condition 94%). This exclusion resulted in enforcement of the pattern already seen in the data.

### **3.5.2 Analysis of data**

All analysis were carried out using PASW Statistics 18. To analyze the data according to the main objective, “What are the effects on cognitive control of viewing photos of natural landscapes with water, natural landscapes without water and urban landscapes?”, separate two-way analyses of variance (ANOVAs) with the independent variables group (water, green, urban) and test scores conflict effect (pre, post) were carried out on the RT and accuracy data. Although the main focus was on the conflict effect score, analyses were also carried out on the other network scores in order to make comparisons to Berman et al.’s (2008) findings. Regarding the preference data, the Kolmogorov–Smirnov Z test showed that the distribution from the Likert scales was significantly different from a normal distribution, and hence, nonparametric tests were used for the preference data. Related to the secondary objective, “To what degree are the tested landscapes preferred and how does this relate to effect on cognitive control?”, the Kruskal–Wallis statistic was calculated to determine whether any of the distributions in preference varied significantly within and between groups. This was tested for

all preference questions separately, and for a calculated total mean of the preference questions. Further, to analyze differences in preference between potential pairs of conditions, separate independent Mann–Whitney U-tests were performed. Furthermore, in order to see whether the different preference questions correlated with the change in scores from the pretest to the posttest on the ANT, a change score for conflict effect (pretest minus posttest) was calculated; Pearson two-tailed correlations were performed comparing this change variable and preference variables. To see whether demographics or which outdoor environments the participants normally liked to be in and whether liking of the design of the study affected the change in the attention network scores, Pearson two-tailed correlations were performed using these variables.

## 4 Results

### 4.1 Summary of data

#### 4.1.1 Attention Network Test

The scores on the ANT were compared to other studies using the same version of the ANT. Overall, the RT's in the pretest ( $M=445$ ,  $SD=48$ ) and the posttest ( $M=435$ ,  $SD=43$ ) were much faster than in Westlye et al.'s (2011) study -in which the participants were older (mean age 48.5). In addition, the RT's were a little bit faster than in Fan et al.'s study from 2002 (mean age 30.1). This is in agreement with the age-effect on RT (Westlye, et al., 2011). In short, the RT and accuracy for the different groups, and the conflict effect ( $M=96$ ,  $SD=27$ ) as well as the other attention network scores were comparable to similar studies, suggesting that the attention network scores in this study are valid. The results also showed the Gratton effect (also called the conflict-adaption effect) (Gratton, Coles, & Donchin, 1992), in which implementation of cognitive control can be seen not only in the present trial, but also as an interaction between a previous trial type and this trial. The group scores had small numerical differences on the pretest as shown in Table 1, but a one-way ANOVA showed that they were not statistically different.

Table 1

*Mean (SD) Conflict Effect in Milliseconds for the Reaction Time, and in percent for Accuracy.*

	Conflict effect RT			Conflict effect accuracy		
	Pretest	Posttest	Change	Pretest	Posttest	Change
Water	96.35 (21)	88.50 (26)	<b>7.85 (16)</b>	-0,13 (0,10)	-0,11 (0,07)	-0,02 (0,07)
Green	91.28 (25)	85.29 (17)	6.0 (16)	-0,14 (0,13)	-0,12 (0,11)	-0,01 (0,07)
Urban	100.43 (34)	87.24 (28)	<b>13.19 (22)</b>	-0,12 (0,10)	-0,11 (0,09)	-0,01 (0,04)

*Note.* Bold print indicates significant change, see analysis section. The change scores do not add up with the pretest and posttest scores in the table since the change score was calculated from scores with more decimals than shown in the table.



### 4.1.2 Preference scale

Reliability analysis suggested that the four questions about preference measured one latent variable, Cronbach's  $\alpha = .924$ . Table 2 shows numerically how the participants who viewed the photos of water liked those landscapes a little bit more than those who viewed green landscapes, and both natural landscapes were generally more liked than the urban landscapes. Note that the scores for the urban landscapes all were below the middle (3) in the scales, which ranged from 1 (*did not like at all*) to 5 (*liked very much*), while all the scores for natural landscapes were above 4. In addition, the standard deviation (*SD*) for the urban group was on average higher than for the natural groups. The descriptives indicate a potential ceiling effect for the natural groups in the preference scale.

Table 2

*Mean Score (SD) on the Preference Questions by Group*

	General preference	Comfortable	Relax	Being away	Total
Water	4.33 (0.758)	4.37 (0.615)	4.33 (0.884)	4.47 (0.776)	4.38 (0.524)
Green	4.28 (0.751)	4.41 (0.628)	4.14 (0.915)	4.55 (0.736)	4.34 (0.588)
Urban	2.76 (0.786)	2.55 (0.948)	1.69 (0.712)	1.86 (1.125)	2.22 (0.734)

### 4.1.3 Outdoor questions and design questions

Although the outdoor questions were not constructed as a scale, Cronbach's  $\alpha$  was performed to check correlations between the questions. Cronbach's  $\alpha$  was quite low (0.580), and the urban question in particular was different from the rest. After this item was removed, Cronbach's  $\alpha$  was .615, indicating that the questions still measured different concepts. On average and independent of group, the participants liked best to stay by the ocean ( $M = 4.5$ ,  $SD = 0.72$ ), followed by staying in the mountains ( $M = 3.9$ ,  $SD = 1.11$ ), in the city ( $M = 3.9$ ,  $SD = 0.84$ ) and by a lake ( $M = 3.8$ ,  $SD = 0.80$ ), and least, but still liked above middle: the forest ( $M = 3.8$ ,  $SD = 1.11$ ). An average variable of liking to stay in natural environments were calculated by reversing the question of liking to stay in the city, and then calculating the mean of all the five questions. This showed that all participants on average liked to stay in natural environments; ( $M = 3.6$ ,  $SD = 0.58$ ). The people in the three groups had comparable liking of natural landscapes.

Descriptives of the questions concerning the design of the study showed that on average, people replied that they paid quite close attention to the photos ( $M = 4.4$ ,  $SD = 0.67$ ), and also remembered to imagine being there ( $M = 3.7$ ,  $SD = 0.85$ ). The exposure time for each photo and total length of photoset was in general liked above the middle value of the scale (for each photo,  $M = 3.6$ ,  $SD = 0.90$ ; for total length,  $M = 3.2$ ,  $SD = 0.89$ ).

## 4.2 Analysis

The analysis section examines the objectives in the study.

### 4.2.1 Objective (1) What are the effects on cognitive control of viewing photos of natural landscapes with water, natural landscapes without water and urban landscapes?

Separate two-way ANOVAs with the independent variables group (water, green, urban) and test scores conflict effect (pre, post) were carried out on the RT and accuracy data. On the RT, the main effect of the variable test conflict effect was significant,  $F(1, 85) = 21.545$ ,  $p < .001$ , and the main effect of the variable group was not significant,  $F(2, 85) = 0.420$ . The interaction was not significant either,  $F(2, 85) = 1.227$ . Also for accuracy, the main effect of test conflict effect was significant,  $F(1, 85) = 4.986$ ,  $p = .028$ , and the main effect of group was not significant,  $F(2, 85) = 0.160$ . The interaction between group and the test variable conflict effect accuracy was not significant either,  $F(2, 85) = 0.479$ . An independent samples  $t$  test was used to compare each potential pair of groups (e.g., water vs. urban) to the calculated change score (pretest minus posttest) in RT and accuracy with all three network scores separately. This test yielded no significant effects.

For comparison with Berman et al.'s (2008) results, separate two-way ANOVAs with the independent variables group (water, green, urban) and test scores alerting and orienting effect (pre, post) were also carried out. For the alerting effect on RT, the main effect of test was significant,  $F(1, 85) = 5.073$ ,  $p = .027$ , and the main effect of group was not significant,  $F(2, 85) = 0.311$ . The interaction between group and the test variable alerting effect RT was not significant either,  $F(2, 85) = 1.450$ . For the alerting effect on accuracy, and for orienting on both RT and accuracy, there were no significant results for the main effects of test, group or interaction.

Even though the effect of the variable group was not significant, comparisons between the pre- and posttest within each group were performed using dependent  $t$  tests to see if the main effect of test found with ANOVA was significant for all groups. Two of these comparisons yielded significant differences, for water,  $t(29) = 2.7, p = .011$  and for urban,  $t(28) = 3.2, p = .003$ . The comparisons between the pretest and posttest for green on this measure were close to significant,  $t(28) = 2.0, p = .055$ . The same tests for the alerting and orienting effect on RT as well as all attention network scores on accuracy between the pretest and posttest yielded no significant results.

Across groups, there were no significant relationships between the change in the ANT scores and questions about paying attention, imagining, length of each photo and total length. However, some significant relationships appeared when looking at correlations between the ANT scores and these questions within group; for water, there was a positive relationship between reporting to like the total length of stimuli and change in the conflict effect RT ( $r = .401, p = .028$ ). For green, there was a positive relationship between reporting to pay attention and the conflict effect RT ( $r = .409, p = .028$ ), and for urban, there was an inverse relationship between the conflict effect RT and reporting imagining ( $r = -.469, p = .010$ ), as well as with reporting to pay attention ( $r = -.398, p = .033$ ).

The most significant correlations between liking different outdoor places and preference for the landscape were for those who saw water. For water, liking to be by the ocean was positively related to general preference ( $r = .435, p = .004$ ), comfortable ( $r = .513, p = .004$ ) and relaxing ( $r = .470, p = .009$ ). In addition, liking to stay in the woods and in the mountains was positive for preference for water. For urban, there was a positive relationship between liking to stay in the city and relaxing ( $r = .412, p = .026$ ).

#### **4.2.2 Objective (2) To what degree are the tested landscapes preferred and how does this relate to the effect on cognitive control?**

##### **Hypothesis (2a) To what degree are the tested landscapes preferred?**

When the Kruskal–Wallis statistic was calculated to determine whether any of the distributions varied statistically significantly according to the nominal characteristics of the sample, a statistically significant difference was found between groups for all separate

preference questions, general preference (to what degree do you like these landscapes?) ( $C2 = 41.717, p < .001$ ), comfortable (to what degree do you think these landscapes are comfortable to view?) ( $C2 = 45.557, p < .001$ ), relax (to what degree do you think these landscapes are good places to relax?) ( $C2 = 54.832, p < .001$ ), being away (to what degree do you think these landscapes are good places to get away from the stress and demands of everyday life?) ( $C2 = 53.288, p < .001$ ), as well as for total preference (mean of the four preference questions) ( $C2 = 54.585, p < .001$ ).

As shown in Table 3, a separate independent Mann–Whitney U-test was performed to analyze differences between the potential pairs in preference, and showed that those who saw urban landscapes liked those less than the extent the participants in the natural group liked the natural landscapes.

Table 3

*U-statistic (p) from Mann–Whitney U-test Comparing the Groups on the Preference Scale*

	General preference	Comfortable	Relaxing	Being away	Total mean
Water vs. green	413.50 (.719)	415.50 (.741)	377.50 (.344)	414.00 (.707)	430.50 (.945)
Green vs. urban	<b>81.00 (&lt; .001)</b>	<b>63.50 (&lt; .001)</b>	<b>28.00 (&lt; .001)</b>	<b>32.50 (&lt; .001)</b>	<b>18.00 (&lt; .001)</b>
Water vs. urban	<b>78.50 (&lt; .001)</b>	<b>70.50 (&lt; .001)</b>	<b>20.00 (&lt; .001)</b>	<b>42.00 (&lt; .001)</b>	<b>9.00 (&lt; .001)</b>

*Note.* Boldface indicates a significant difference.

## **Hypothesis (2b) How did the preference for the landscapes relate to effect on cognitive control?**

Pearson two-tailed correlations were performed to see whether the different preference questions correlated with the measures of attention. For this analysis, only attention scores previously found to be affected by the stimuli was chosen: the change (pretest-posttest) in the conflict effect on RT and accuracy, and change in the alerting effect on the RT. Change in the conflict effect RT was inversely related to general preference ( $r = -.295, p = .005$ ), comfortable ( $r = -.293, p = .006$ ), relaxing ( $r = -.176, p > .05$ ), being away ( $r = -.275, p = .009$ ) and to the mean of the preference questions:  $r = -.279, p = .008$ . No correlations were found among preference and the other attention network scores. The relationships were made clearer when divided by group; see table 4.

Table 4

*Pearson two-tailed correlations ( $r$ ) between Change Score (RT and accuracy) in Conflict Effect and Preference Questions*

		General preference	Comfortable	Relaxing	Being away	Total mean
Water	Change RT	-.020	.136	.141	-.145	.038
	Change accuracy	.069	.046	.347	.329	.307
Green	Change RT	-.300	-.137	-.107	-.056	-.191
	Change accuracy	-.117	-.306	.055	.018	-.092
Urban	Change RT	-.404*	-.516**	-.270	-.395*	-.492**
	Change accuracy	-.249	-.256	-.506**	-.234	-.362

*Note.* \*\*. Correlation is significant at the .001 level (two-tailed). \*. Correlation is significant at the .005 level (two-tailed).

For change in alerting and orienting, the only significant correlations were also for urban: relax was found to correlate positively with the change in alerting effect measured in the RT ( $r = .371, p = .048$ ). For the variable of liking to stay in natural environments (calculated by reversing the question of liking to stay in the city, and then calculating the mean of all the five outdoor questions), the only significant correlation between this and changes in attention network scores were for change in attention effect RT, for urban ( $r = -.503, p = .005$ ).

## 5 Discussion

The main finding in this study, related to the main objective and hypothesis (1), is that none of the types of landscapes led to a statistically more positive effect on cognitive control from the pretest to the posttest than the other landscapes. Thus, it does not support hypothesis (1), ART or previous findings. Interestingly, a significant positive change in cognitive control was found for water and urban but not for green. However, due to the lack of interaction effect between the type of landscapes and cognitive control, this change from the pretest to the posttest should be interpreted with caution. The study also shows that, related to the secondary objective and hypothesis (2a), those who saw natural landscapes with and without water preferred these significantly more than those seeing urban landscapes, and related to hypothesis (2b), for those who saw urban photos, there was a significant inverse relationship between preference for the type of landscape seen and change in cognitive control from the pretest to the posttest. The findings in the study will first be discussed separately related to the objectives, and then the findings will be discussed in general.

### 5.1 Discussion of findings

#### **5.1.1 Natural landscapes with water did not give more positive change in cognitive control than natural landscapes without water**

Previous studies have claimed to find that natural landscapes lead to restoration of cognitive control, without the ambition of separating the effect of water. This is the first study to try this for cognitive control. There was no interaction between the group (water, green, urban) and test (pretest, posttest) variables; hence, the change in cognitive control measured by the ANT did not depend on which environment the participant had seen. Of the two types of natural landscapes, only natural landscapes with water gave a significant change in the conflict effect from the pretest to the posttest, while there was no significant difference for the group that saw natural landscapes without water. This might suggest that landscapes with water had a stronger effect on restoration of cognitive control than natural landscapes without water, and that it is safer to say that natural landscapes with water lead to restoration of cognitive control, rather than natural landscapes in general. However, due to the lack of significant group x test interaction, this can only be suggested as a trend. This trend, however, would be supported by preference research. There was no specific hypothesis about the difference in restorative

potential between the two natural landscapes, but the results are in line with Ulrich's study from 1991 that also found no significant difference in the restorative effect of natural landscapes with and without water.

The photos of landscapes with water in this study were not more restoring (measured in positive effect on cognitive control) than natural landscapes without water, but this does not mean that natural landscapes with water *in general* are not more restoring than natural landscapes without water; if the typical landscapes with water are more open, have more depth cues, more focus elements, etc. than a typical landscape without water as, for example, claimed by Ulrich (1983), then the results of this study cannot be generalized to typical landscapes (if such exists). What the results from this study *do* show is that the content of the element water in a natural landscape, other elements kept equal, does not in itself make a difference for cognitive control.

### **5.1.2 Natural landscapes did not give more positive change in cognitive control than urban landscapes**

There was no significant difference in the effect on cognitive control from either type of natural landscapes compared to urban landscapes. This finding challenges the predictions from ART as well as departs from previous research by Berman et al. (2008) and Berto (2005), and do not support hypothesis (1) in the present study. As this lack of interaction between landscape type and cognitive control is the main finding of this study, discussion of this finding will be emphasized, related to potential explanations and relationships with previous research and theory. The potential explanations for the findings are found in the aspects in which this study departs from previous studies, which are related to the choice and length of the stimuli.

#### **Fair comparison of urban photos**

As mentioned, this study gave a more equitable test of urban landscapes than previous studies, especially the closest comparable, Berman et al. (2008). In the present study, great care was taken to ensure the same nice, clear weather in urban photos, same photo quality, decade, amount of sunlight, time of day, exposure, brightness and contrast as in natural photos, while in the photoset used in the Berman et al. (2008) study, the photos in the urban condition were of worse quality, too high contrast, dark foreground, less visible sunlight, from a different

decade, some with bad weather and several night photos as well as one with obvious exposure fault and several clearly repetitions of the same place. The present study has allowed a more clear-cut comparison between natural and urban environments, and the results could support the hypothesis that the potential confounding variables in Berman et al.'s (2008) study produced an advantage for nature. However, it is important to mention that in this thesis, the focus is on Berman et al.'s (2008) study because of the similarities in measures, and that because the photo sets from other studies have not been made public, we do not know whether this hypothesis holds for other research showing different restorative effects of natural versus urban environments.

However, the second most comparable study, Berto (2005), also supports this hypothesis. As mentioned before, Berto's study can be compared to studies investigating the difference between nature and urban photos because the selection study of restorative versus nonrestorative photos resulted in only nature photos among the restorative photos and only urban photos among the nonrestorative photos. This makes it also very likely that the selection of photos, as in Berman et al.'s study, did not give a fair comparison between urban and nature. However, this was not the authors' aim.

Taking a closer look at Berto's (2005) results, out of the four scores she found only nature had a significant more positive improvement in three scores in experiment 1 and two in experiment 3. In addition, in both experiments she did not find significant improvement in nature in the number of incorrect responses; actually, in experiment 1, urban improved significantly in this aspect while the restorative group numerically (and not significantly) actually deteriorated. In experiment 3, urban also had greater improvement than the restorative group on this measure, yet again, not significant. This measure is especially interesting in terms of cognitive control because it involves not pressing the spacebar when the target is present; so it can be seen as a typical measure of inhibition, and the most comparable subcomponent in the SART to the conflict component in the ANT. As mentioned, a limitation of this study is that it did not discuss whether there were any significant interactions between the group and test variables. In addition, Berto did not discuss the surprising results in IR mentioned above. What Berto did discuss, however, is the failure of experiment 3 to replicate the significant improvement in RT in experiment 1 for nature while the effect in the urban group, which was significant improvement, was replicated. The author related this finding to a lowered arousal for the nature group in experiment 3 that slowed



down RT. However, the author presented no hypothesis for why the arousal was lowered more in experiment 3 with a mean exposure time of only approximately 6 sec versus 15 sec in experiment 1. Is it likely that an exposure time of only 2.5 min would lower arousal more than one of 6.25 min (experiment 1)?

The study of Karmanov (2008) show that some urban environments can have restorative effects on emotions, and thereby supports the departure from the urban-nature dichotomy, however it has two important difference from the present study in that the present study it was not tried to make the urban environments pleasant as in Karmanov, as well as very different measurements.

All in all, previous research show that the lack of interaction between type of landscape and cognitive control in the present study could be due to the fair comparison between urban and nature.

### **Exposure time**

In addition to choice of photos, a difference in the present study from previous research is the stimuli time. As mentioned, to be able to separate the two quite similar natural landscapes, the stimuli time was longer in the present study than in many other studies, including Berman et al. (2008). Considering the studies supporting Ulrich's (1983) theory about how nature reduces arousal, together with Yerkes-Dodsons inverted u-curve, could it be that the threshold for an optimal arousal reduction is different for restoration measured in reaction time tasks than for example restoration measured in emotional state? Given nature's especially calming attributes, could it be that in the present study, arousal level was lowered below optimal for ANT in the nature group, while in urban group, with less calming characteristics, arousal was lowered to a more optimal level?

No studies have tested the relation between arousal level and ANT performance in specific, but studies have shown that cognitive conflict is especially handicapped in states of awakening and drowsiness (Matchock & Mordkoff, 2007), and the conflict score in the ANT specifically has been shown to be more sensitive than the rest for a number of different aspects, including the time of day (Matchock & Mordkoff, 2009). Further more, Anterior Cingulate Cortex have been found to have a direct involvement in regulating arousal in effortful cognitive processing (Critchley, 2005) and cognitive conflict and error

processing in specific are found to increase arousal (Kobayashi, Yoshino, Takahashi, & Nomura, 2007). However, these studies do not address whether this change in activity contributes to cognitive functioning.

For selective attention we know more specific effects; researchers have shown that there is an interaction with arousal (Tracy et al., 2000), in which arousal stimulates stimulus filtering and suppresses peripheral stimuli, so that the participants in the aroused condition had lower accuracy on tasks with peripheral stimuli than the participants in the non-aroused condition. The authors relate this to Yerkes-Dodson's inverted U-curve. Even though none of the stimuli in the ANT can be said to be peripheral, their results show a close connection between one type of attention closely related to cognitive control and arousal. This might also explain the lack of improvement in the orienting effect after nature photos are viewed found by both Laumann et al. (2003), Berman et al. (2008) and the present study; with lowered arousal, the focus are broad and the gain of attention oriented to the right location will then be less than when in a condition with high arousal and narrow focus.

So then it is possible that due to the calming qualities of nature, together with a long stimuli time, arousal was lowered beyond the optimal level in the nature group, while for the urban group, with fewer calming characteristics, arousal was lowered to a more optimal level. In support of this explanation is the fact that Laumann et al. (2003) did not find significant results either – also with stimuli of 20 min. There are other studies that have used this time or a longer time, but they used direct exposure to nature, which have included walking. This, of course, has its own interaction with the arousal level.

With a choice of water scenes that have previously been rated as the most tranquil, the hypothesis that the choice of exposure time and variability did not make full use of the restorative potential could be especially true for water. In addition, a positive relationship between change in cognition and liking of stimuli length was found only for the water group; those who liked the stimuli length were more restored. Perhaps this was because the liking length was related to finding it easy to pay attention to the photos without mind-wandering. Berto (2005) found that when participants chose their stimuli times themselves, they most often chose shorter stimuli time and got the same restorative value as in another identical experiment. Berto (2005) suggested that restorative value was strengthened by the ability to control the exposure time, but one can also look at it as each person has his or her own

timeframe or rate that he or she prefers because it gives the optimal balance for processing time and variation. Perhaps the exposure time in the present research fitted only a minimum of the participants, meaning only parts of the restorative value of the nature photos were used. The smaller change from the pretest to the posttest compared to Berman et al.'s (2008) study in the natural group could support this explanation.

### **Variation within photo series**

Another difference from other research is the variation within the photo series. Since large open water scenes were selected to increase the preference in this study, and because the photos without water also consisted mainly of open landscapes due to the balancing of these series, the two natural series had less variation than the urban photos. Perhaps this can lead to loss of attention to the photos and increased mind-wandering, which is related to low alertness (Braboszcz & Delorme, 2011). On the other hand, there are large individual variations in the number and rate of stimuli input that are optimal for keeping focus, among others depending on personality aspects (R. J. Larsen & Buss, 2002). In addition, urban photos were liked less. It seems likely that a strong preference for the landscape, as was the case for natural landscapes, is less connected to boredom and mind-wandering than not liking the landscape, as was the case for urban landscapes.

### **Relation to predictions in Attention Restoration Theory**

According to ART, soft fascinations that require little effort to hold our attention are the key to the restorative benefit of nature. Could it be that the restorative effect of the nature photos were lowered because of less variation and rather long stimuli time for each photo, in this way making it less of a soft fascination provider than in other studies, not as capable of holding the attention and therefore resulting either in increased mental effort to hold attention or mind wandering? The positive relationship between cognitive restoration and liking of stimuli length for the water group supports this hypothesis, as well as how the natural photos numerically got the lowest scores on whether the participants paid attention to the photos. In addition, the inverse relationship between restoration and paying attention to and imagining one to be in the place for the urban group makes sense in light of Kaplan's theory; if urban landscapes are depleting directed attention because demanding it, it will do even more so if you try to pay close attention to it and imagine yourself there.

However, and as we will see, caution must be taken in interpreting these correlations. More importantly, given that nature is such a natural way of providing soft fascination, nature should be restorative regardless of stimuli length and variation.

At least in the most recent work, ART predicts cognitive control to be improved by nature, and Berman et al. (2008), predicted improvement only the control component and not alerting and orienting. However, in a meta-analysis conducted in 2010, MacLeod et al. showed how correlational and variance analyses implicated that the networks were not independent. Furthermore, as previously mentioned, the researchers found alerting and orienting to have weak split-half reliability, whereas for conflict, it was a little higher. Although reliability cannot be used alone as a determinant for the statistical power of the test, the authors also reported that of the 39 studies they looked at, in between subject designs, 37% of the studies found significant alerting effects, 30% found significant orienting effects and 77% found significant conflict effects. Given the interconnectedness of all executive functions, and within this test, is it likely that exposure to natural environments would improve only cognitive control? According to Kaplan, it is because of the soft fascination provided, but if this is so positive for directed attention, is it not likely that soft fascination also will be positive for some of the other executive functions? A comparison of the results from tasks similar to the ANT makes it more likely that Berman et al.'s results were an artifact of their design; Laumann et al. (2003) found no significant difference with the attention-orienting task, Berman et al. (2008) found significant results only for conflict effect, Berto et al. found no significant effects in the measure closest related to cognitive control, and the present study found no significant differences between groups for any of the network scores.

Related to one of ARTs proposed components of restorative landscapes; fascination; it should be mentioned that even though the photos were not from Norway, the urban photos are easier recognized by location than the nature photos. Together with less variation in the nature series, this could have made the urban photos more fascinating; however, people fond of nature can also try to recognize these landscapes, and if the urban photos were that fascinating, this should have been reflected in the preference data.

### **Lack of precision in attention restoration theory**

As mentioned in the background section, ART has especially two limitations when it comes to explaining why nature would be restoring: why it captures voluntary attention and whether

resting of directed attention actually is a phenomenon that leads to replenishment of the resource. When it comes to resting of attention, an interesting question regarding this is, is resting directed attention enough to restore it?

In experiment 2 in 2005, Berto added a third stimulus type in addition to restorative and nonrestorative environments to the study design: photos of geometrical patterns. Berto et al. found that even though the geometrical patterns should be effortless to view just like the restorative ones (consisting of natural environments), the group that had seen these performed worse on SART than the restorative group. This finding led the researcher to propose that all four of Kaplan's criteria are needed for environments to be restoring (fascination, extent, being away, compatibility), hence; that the stimuli not requiring direct attention was not enough. A limitation of the study, however, is that she did not measure in any way or express reasons for whether the geometrical patterns actually were effortless to view; thus, as far as we know, they might have been just the opposite.

In literature, the closest we come to ART's concept of resting cognitive control is in improving cognitive control by various means. The focus has been on training cognition by using cognitive exercises on computer, most recently for cognitive control specifically (Siegle, Ghinassi, & Thase, 2007). In addition, research has shown that mindfulness training can also improve cognitive control (Y. Y. Tang et al., 2007) to a similar degree as nature did in Berman et al. (2008). In a recent article, Tang and Posner (2009) compared these and other studies and argued for a division between attention training, as in the computer-based training referred to above, and attention state training, where instead of changing specific networks, the focus is more on achieving a state leading to more efficient self-regulation. The authors claimed that the effects of mindfulness training and exposure to nature can be put in the last category. However, considering research showing how meditation and mindfulness training do indeed alter neural networks in the brain (Lutz, Dunne, & Davidson, 2007) and how also other different new or altered activities have their markers that can now be identified in magnetic resonance (MR) imaging (Draganski et al., 2004; Engvig et al., 2010), it seems more likely that this mindfulness training gives improved performance that lasts beyond the training session, and thus, has more similarity to computer aided training than exposure to nature. So, it is likely that exposure to nature is left alone in the category of attention state training, and the concept is thus not as supported by similar strands of research as Tang and Posner (2009) claimed. Furthermore, the effect of meditation on cognitive control is not

claimed to be because of resting it, and it seems as if ART is the only theory with this concept when it comes to cognitive control.

We have seen that the ART prediction that natural environments are restorative specifically on cognitive control has been supported in research, but due to the shortcomings of those studies and the results from the present study that show quite different results when testing a more fair comparison of urban to nature, perhaps the predictions in ART of what type of natural images will have a positive effect on cognitive control, or, compared to what type of urban photos have to be refined – the present study indicates that it is not the visual qualities of typical urban and natural environments per se that makes the difference for cognitive control.

### **Test-retest effects**

Since there were no interactions between the type of landscapes and cognitive control, the change from the pretest to the posttest for two of the groups could be due to test-retest variability. A pretest might change the way participants perform on the posttest, for example, by drawing attention to the behaviors addressed, learning effects, or fatigue (Bordens & Abbott, 2005).

Considering test-retest effects specifically for ANT, Fan et al. (2002) found the test-retest variability of the RT in the orienting scores to be .61, alerting .52, and conflict .77 (all correlations were significant). The sample (40) is comparable to the present study. However, Fan et al. did not discuss the time lapse between the two sessions. In a meta-analysis, MacLeod et al. (2010) calculated split-half reliabilities for each dataset (a total of 15 datasets), extrapolated the test-retest variability using the Spearman-Brown prophecy formula, and found the test-retest variability for alerting .38, orienting .55, and conflict .81. Interpretation of this extrapolation must be treated with caution, however; since, for example, the ANT has been shown to vary with the time of day, it is more relevant for the present study to be compared with studies where there was a certain interval between tests. Anyway, the test-retest reliability of the ANT shows that the change found in the present study *could* be due to test-retest variability. On the other hand, why would a test-retest effect yield for only two of the experimental groups (water and urban)? Given the randomization in the study, a test-retest effect should affect all three groups (Bordens & Abbott, 2005). However, even though not reaching significance, the effect from the pretest to the posttest was also a positive trend for

the green group, close to significance. In addition, the change from the pretest to the posttest was not significantly related to the group, so the differences in change between the groups were not statistically significant. One point limiting the likelihood of learning effects improving performance on the ANT in the present study for all three groups, are the results of Berman et al. where the performance in urban group actually numerically deteriorated from the pretest to the posttest. To sum up, given the design of the experiment it is hard to tell whether the difference in the  $t$  test from the pretest to the posttest had to do with the type of stimuli or with test-retest effects.

With a more time-consuming design, one could separate these effects. By including a group that had no pretest, this would introduce some control of test-retest effects. Also, the Solomon-four groups design, which is specifically developed for avoiding difficulties associated with pre-posttest designs (Bordens & Abbott, 2005) could also be applied. In addition to pretest-treatment-posttest (the present study), and treatment-posttest, it would include groups performing only pretest-posttest, and only posttest. This would allow for further control of test-retest effects as well as interaction effects between treatment and posttest. A major drawback of this model, however, is that it is quite time- and resource-consuming; in the present study, this model would involve having eight groups instead of three.

Many studies in the field have used only posttest (Berg, et al., 2002; Hartig, et al., 1996; Hartig, et al., 2003; Hartig, et al., 1991; Mayer, et al., 2009), probably, at least partly, to avoid the test-retest effect. However, a new confounding variable is introduced in the lack of baseline because then individual variations in performance cannot be controlled. A repeated measures design allows controlling for individual variations, but without a control group, other confounding variables of test-retest designs are introduced.

To sum up, there are several possible explanations for the main finding in this study: that natural landscapes did not have a significant more positive change in cognitive control from the pretest to the posttest than urban landscapes. Part of the explanation might be related to less variation in nature series compared to the urban series, and part to the exposure time, but most likely, the lack of interaction between the landscape and cognitive control is due to the new and fair comparison between nature and urban performed in the present study.

### **5.1.3 Natural landscapes were more preferred than urban landscapes**

That natural landscapes were the most preferred confirms previous findings (Purcell, et al., 1994; Real, et al., 2000; Strumse, 1996; E. H. Zube, Pitt, D. G., & Anderson, 1975) and theories (S. Kaplan, 1995; Ulrich, 1983), as well as hypothesis (2a) in this study, and because this is the most researched area of this study, this finding supports generalization of the results to a larger population. Regarding the difference between water and green, there was a numerical difference in preference between water and green but no statistical difference. As other studies have found that natural landscapes with water are liked more than natural landscapes without water, this finding might seem contrary to previous research, but given the stringent balancing of the two groups, it might also mean that we have succeeded in testing the content of water and not the degree of openness or other landscape variables. This made the categories very similar and they are both preferred categories to start with. Due to the lack of previous research, there was no hypothesis in the present study regarding this objective.

### **5.1.4 Preference for the landscapes was not positively related to effect on cognitive control**

The natural landscapes were liked significantly more than the urban landscapes but did not have a significantly more positive effect on cognitive control. Furthermore, the change in conflict effect (pre-posttest) was significantly inversely related to the preference for an urban landscape, and no significant relationships between the other groups and the change in cognitive control were found. The lack of significant correlations between the change in cognitive control and preference data for the natural groups could, again, be due to less variation in the data than for the urban group.

However, the results did not show a clear relationship between the change in cognitive control and preference; thus, hypothesis (2b) in the present study was not confirmed. This finding could mean that given a fairer comparison of photos, the link between restoration and preference is not as strong as previously claimed in the literature. However, as mentioned, caution related to the ceiling effects for natural groups in preference data must be taken in interpreting these data.



## 5.2 General discussion

Explanations of nature's restorative effect have so far built on evolutionary theories and therefore should generalize to all humans. Could it be, however, that individual differences in interpretation and associations of the photos also are quite determining for restoration? In the present study, to avoid the effect of known places, none of the urban photos were from Norway, while almost all the natural photos could have been (even though they were not) from Norway. In addition, avoiding the ugliest parts of urban environments such as the heaviest industrial zones could have made the participants associate the urban photos less with daily hassles than in previous research, as for example, most of the urban photos in Berman et al. seem to be from Ann Arbor where the study was conducted. This hypothesis is made more unlikely since preference for urban environments in the present study was above the middle, so the photos cannot have been that strongly associated with non everyday activities such as holidays. However, this serves as an example of how preference and perhaps restoration can be influenced by interpretations and associations to the presented stimuli. For example, Karmanov (Karmanov & Hamel, 2008) found that adding cultural and historical information about the environments gave an increase on perceived interestingness (25%) and perceived attractiveness (14%), and the effect of interpretations and associations to the environmental stimuli could deserve some more focus.

Could it be that culture affected the results in another way; that the participants in this study for some reason were more urban compared to the other studies? This is made more unlikely by the participants' answers to the outdoor questions, which shows that the average participant in the study preferred to stay in nature more than in urban surroundings. We do not know, however, whether the people in other studies would answer that they liked nature even more, but the preference scale shows that the people in this study did not depart from other populations in regard to a preference for the urban versus natural landscapes the participants saw. Is it likely that the participants would depart on restorative effects and not preference?

In relation to how the present results seem to deteriorate from previous research, it must be noted that due to the file-drawer phenomenon, the published works in an area only represents the actual findings to varying degrees, as "failure" to obtain significant results are less likely both to be submitted for publication and published (Bordens & Abbott, 2005). Due to probability pyramiding, the effect of the file-drawer phenomenon can get quite serious, as

repeated attempts with using better controls might lead to finding significant findings in the long run both due to actual effects both also due to probability pyramiding. Hence, the likelihood of finding a difference where there is none will be greater than the alpha-level would suggest. For the present study the implications are that the findings of no interaction between environment and restorative effect might not be such new results as the present published literature suggests.

### **5.3 Limitations of this study**

In this study, as many other studies, there might be limited opportunities to generalize due to the participants being students, which are a rather young population and not equally representative of all socioeconomic backgrounds. Even though attention is to be considered a basic attribute without great problems of generalization, as mentioned, the interaction with the type of environment might not be as general and basic as the dominant theories propose. The replication of preference ratings for urban and nature landscapes, however, suggests that the participants are comparable to other studies. In addition, students are very often used in this type of research, and were used in Berto et al.'s (2005) and Berman et al.'s (2008) studies.

As previously mentioned, a limitation to the present study is the lack of control group with no stimuli in between ANT measures that would allow controlling for test-retest effects. Given the limitations on the type of project, this was not applied.

The results from this study concerning cognitive control are limited to the effect on the applied measure in this study; namely, conflict effect on the ANT. There are several other possible ways to measure cognitive control. The results from the questionnaire are all limited by being self-reported.

The preference ratings in this study were conducted as a validation of the maximizing of preference in the natural categories, and not as an independent measure. To measure the difference in preference for the three types of landscapes in the present study, the participants would ideally be exposed to all three environments. Further, the preference scale was constructed by the author and not validated, but reached a fairly high level of internal consistency. Another limiting factor was the potential ceiling effect for the natural categories. Furthermore, since the participants filled out the preference questions after three interventions (ANT, photos and ANT), there might be an interaction between this and the questions, for

example expectations of what have been measured. Finally, the answers to the preference questions do not represent the preference for one landscape compared to another one; the respondents only saw one type of landscape each, and did not get a choice as to which of several types they liked best. However, this method is often used in landscape preference research. The aforementioned factors limit the interpretation of the preference data, however, the validity are supported by showing high similarity to previous research. Furthermore, the most important aim with the preference data were validation of the choice of photos, which is considered achieved.

## **5.4 Contributions and further research**

As mentioned, improvement of cognitive control has been found in studies of attention training, mindfulness and integrated body-mind training (Y.-Y. Tang & Posner, 2009). However, all of these are internal exercises that require former training, and the potential for environments to restore these capacities without formal training is therefore worth investigating. If replicated, this study offers some new findings that should be used to modify the applied use of restoration studies. Thus far, this field has focused on how nature views are good for health, but perhaps the dichotomy between this and urban environments should be reduced. The present study shows that a view to nature is not necessarily more positive for cognitive control than urban, and for example Karmanov (2008) showed that also urban environments can be restoring.

It also would be interesting to investigate the effects in the present study with a test even more specialized on cognitive control, for example the Eriksen Flanker task (Eriksen & Eriksen, 1974). With all the condition centering on varying conflict (and none on orienting/alerting), the results regarding cognitive conflict in specific might be clearer. This would also allow analyzing according to the Gratton effect as previously mentioned, which states, in short, that the effect of conflict on behavior is most apparent in the interaction between the previous and present trial. The Gratton effect was apparent in the present data, but the ANT does not have enough trials to compare this effect between groups. There is also reason to combine several measurements of cognition in the same experiment, to test whether the effects of environments really are so specific to cognitive control/directed attention as ART proposes. For example, adding a typical working memory task would allow this.

Using the same photos but varying the stimuli length would untangle the effects of less variation in natural photos from the effect of long stimuli time. It would also be relevant to try to untangle the other elements in these landscapes, for example, traffic, amount of sky, amount of sunlight, time of day, etc., hence controlling the potential confounding variables to a higher degree. To this date, there has been surprisingly little discussion about these types of elements, especially in restoration studies. In addition, considering that the results from studies on nature's restorative effect seem to be ambiguous, other potentially confounding variables also need to be investigated. One example is how nature's restorative effect might vary with personality aspects; for instance, the preference for different types of nature paintings (varying in terms of complexity and tension), have been shown to depend on personality aspects (Zuckerman, Ulrich, & McLaughlin, 1993).

## 6 Conclusion

This study confirms hypothesis (2a) and previous findings of higher preference for natural landscapes versus urban landscapes. However, the study departs from hypothesis (1) and previous research by finding no significant difference in the effect of urban versus natural environments on cognitive control measured with the ANT, possibly due to a fair comparison between them. In this way, the dominant dichotomy between nature and urban landscapes when it comes to restorative effect is challenged, and a more nuanced picture is painted of the relationship between different environments and restoration, at least for cognitive control. The results do not give support to ART's predictions regarding the effect on cognitive control of natural versus urban environments. The present study also shows that the most preferred landscapes are not necessarily the most restorative, thus departs from hypothesis (2b). Future research exploring the effects of different stimuli lengths and inclusion of elements in the photos, as well as different combinations of measurements of cognition would shed further light on the relationship between natural landscapes, urban landscapes and restoration.

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# Appendix

## Appendix (A) Questionnaire

*DEL 4*

*Tusen takk for innsatsen så langt i eksperimentet! Du har nå kommet til siste del. Vennligst fyll ut dette skjemaet før du forlater rommet.*

*Deltaker nummer: \_\_\_\_\_*

### Landskapene på bildene

Vennligst tenk på stedene på bildene, og svar på følgende spørsmål ved å ringe rundt det som passer best:

- Hvor godt likte du disse landskapene?

1 ----- 2 ----- 3 ----- 4 ----- 5  
Ikke i veldig godt  
det hele  
tatt

- I hvor stor grad synes du disse landskapene er behagelige å se på?

1 ----- 2 ----- 3 ----- 4 ----- 5  
ikke i veldig stor  
det hele grad  
tatt

- I hvor stor grad synes du disse landskapene er gode steder for å slappe av?

1 ----- 2 ----- 3 ----- 4 ----- 5  
ikke i veldig stor  
det hele grad  
tatt

- 1 ---- 2 ---- 3 ---- 4 ---- 5  
ikke i veldig stor  
det hele grad  
tatt

- 1 ---- 2 ---- 3 ---- 4 ---- 5  
ikke i hele tiden  
det hele  
tatt

- 1 ---- 2 ---- 3 ---- 4 ---- 5  
ikke i                      hele tiden  
det hele  
tatt

- 1 ---- 2 ---- 3 ---- 4 ---- 5  
ikke i veldig stor  
det hele grad  
tatt

- 1 ---- 2 ---- 3 ---- 4 ---- 5  
ikke i veldig stor  
det hele grad  
tatt

- Kjønn; vennligst ring rundt:  
Kvinne Mann

- Er du høyre- eller venstrehendt?

Høyre Venstre

- Alder

\_\_\_\_ år

- Hvor godt liker du å være:

a: I byen

1 ----- 2 ----- 3 ----- 4 ----- 5  
Ikke i veldig godt  
det hele  
tatt

b: Ved havet

1 ----- 2 ----- 3 ----- 4 ----- 5  
Ikke i veldig godt  
det hele  
tatt

c: Ved innsjø

1 ----- 2 ----- 3 ----- 4 ----- 5  
Ikke i veldig godt  
det hele  
tatt

d: På fjellet

1 ----- 2 ----- 3 ----- 4 ----- 5  
Ikke i veldig godt  
det hele  
tatt

e: I skogen

1 ----- 2 ----- 3 ----- 4 ----- 5  
Ikke i veldig godt  
det hele  
tatt

- Lag en liste over hva du har studert hittil i livet, med hvor mange år på hvert studie (eks: årstudium foto 1 år, årsenhet psykologi 1 år).

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- Hva gjorde du den siste timen før eksperimentet?

1. \_\_\_ forelesning
2. \_\_\_ reise (t-bane etc)
3. \_\_\_ lesesal/datasal
4. \_\_\_ sosialt (kafe etc)
5. \_\_\_ trening
7. \_\_\_ shopping
6. \_\_\_ annet, spesifiser: \_\_\_\_\_

- Hadde du noen slags problemer underveis i eksperimentet, følte deg uvel, feil med utstyret eller liknende?

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## Appendix (B) Instructions

The participants were given instructions in between each part of the experiment. The instructions were shown on the screen and were read by the experimenter.

### Før pretest:

*”Velkommen til dette eksperimentet! Det er delt opp i fire deler: DEL 1, 2, 3 og 4. Som du kanskje har sett er DEL 1, 2 og 3 på pc'en her. DEL 4 er utfylling av skjema som ligger på bordet. Trykk MELLOMROM/SPACE for å starte DEL 1.”*

### Pretest

**\*\*Instruksjoner og test sekvens tilhørende Attention Network Test, som kan lastes ned her:**  
<http://sacklerinstitute.org/users/jin.fan/>. I tillegg til instruksjonene viste eksperimentator en figur over betingelsene.

### Stimuli

*”Velkommen til DEL 2. I denne delen er tempoet roligere. I denne delen av eksperimentet vil du få se en samling bilder. Dette vil vare ca 12 min. Se på bildene og forestill deg at du er på stedene de viser. Det er ingen oppgave knyttet til bildene. Bildene går videre av seg selv, du trenger ikke trykke på noe i denne delen. Trykk en tast når du er klar for å se bildene..”*

### **\*\*Bildeserie**

*”Du er nå ferdig med DEL 2. Takk for innsatsen så langt!”*

### Posttest

*”Velkommen til DEL 3. I denne delen av eksperimentet er tempoet høyere igjen. Du skal nå gjøre oppgaven med pilene igjen. Den er helt lik som forrige gang, bortsett fra at øvingsoppgaven er mye kortere. Den er der for at du skal komme inn i oppgaven igjen.”*

**\*\*Instruksjoner og test sekvens tilhørende Attention Network test.**

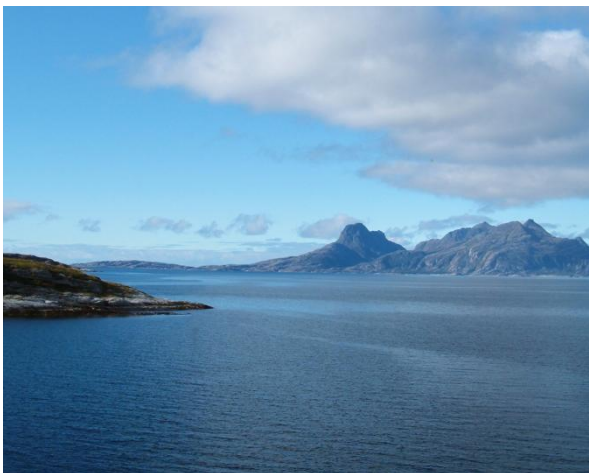
*”Nå er du ferdig med hele DEL 3.*

*Takk for innsatsen så langt!*

*Du skal nå fylle ut DEL 4, som ligger på bordet.”*

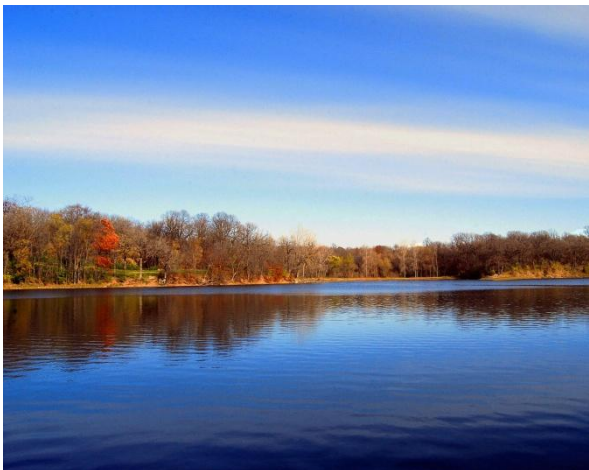
## Appendix (C) Set of photos, natural landscapes

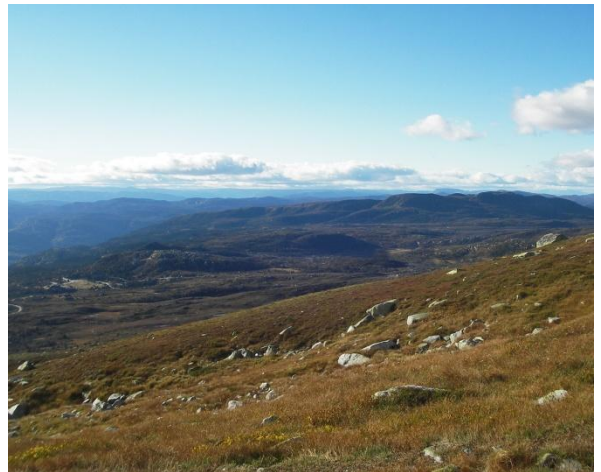
List of photos of natural photos with water (left column) and natural photos without water (right column) shown in the experiment. Note that the photos are organized by matching pairs from the selection process of the photos, and the depicted order are not corresponding to order given to the participants, which was a fixed, random order.



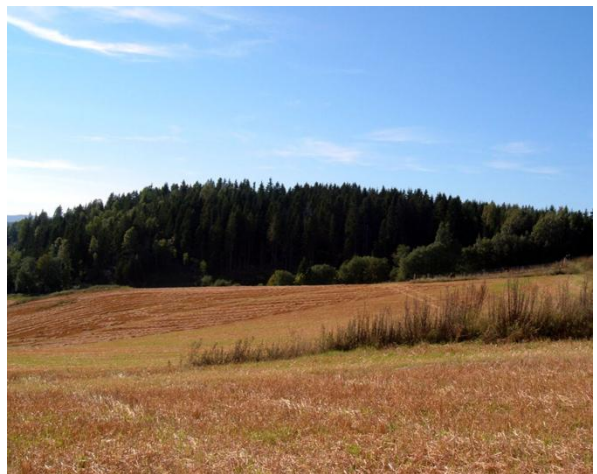
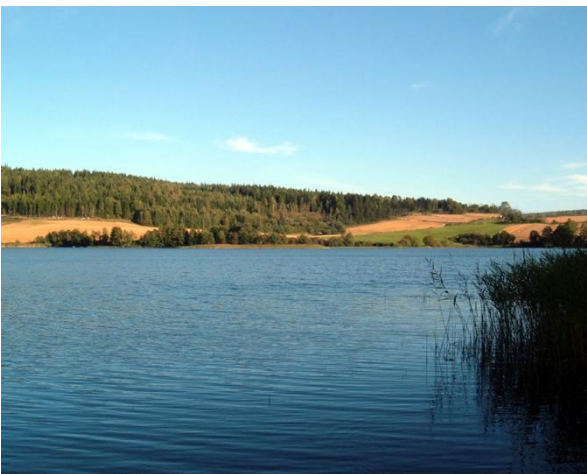






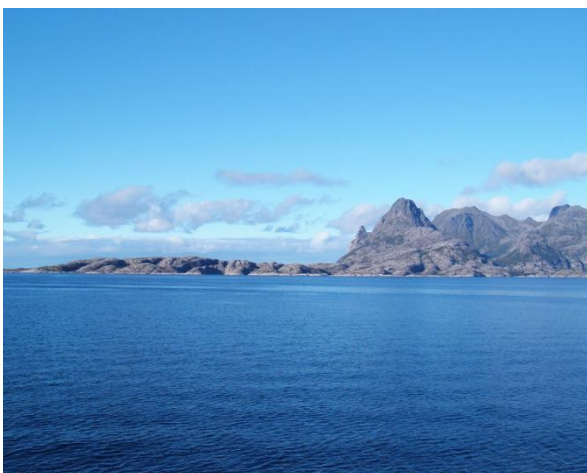




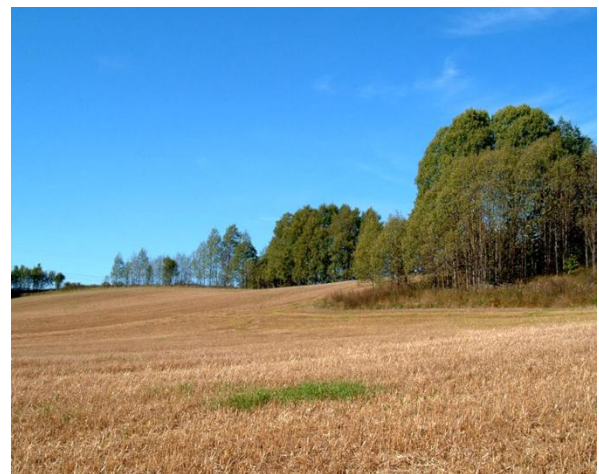


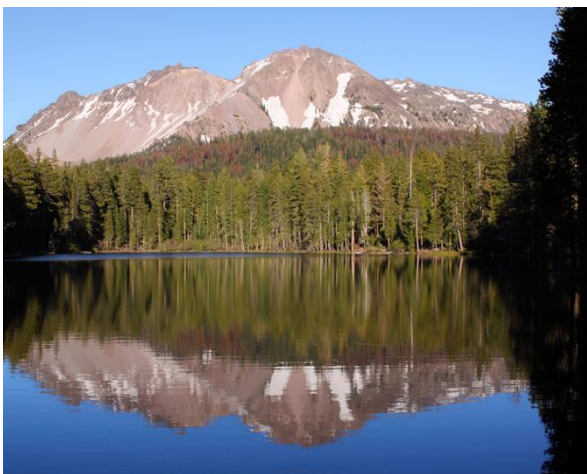
























## Appendix (D) Set of photos, urban photos

List of urban photos shown in the experiment. Note that the order is not corresponding to order given to the participants, which was a fixed random order.

