**The moderation of neuroticism on the relationship between nature exposure and working memory**

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**Abstract**

This study aimed to investigate the effects of different times of nature exposure on working memory and if neuroticism would moderate this relationship. It is already known that nature has positive effects on well-being. For instance, it may improve one’s immune system and decrease anxiety and rumination. With the growing urbanization and other factors such as long work hours that lead people to visit greenery less, it is promising to see if nature exposure improves people’s cognitive function. It has been proposed by the Attention Restoration Theory (ART) by Kaplan that directed attention resources may be replenished by natural stimuli, as they do not require much cognitive control. The Stress Reduction Theory by Ulrich on the other hand, suggests that nature reduces stress levels and in turn replenishes cognitive function. As persons scoring high on neuroticism tend to experience stress and negative emotion more easily, it could be so that nature exposure has fewer positive effects for this population. The results showed that nature had a positive effect on working memory scores, unless of the duration of the exposure. This finding suggests that short exposure to nature already replenishes higher-order attention functions. Neither neuroticism led to significant differences. Also, weather circumstances did not lead to different outcomes. These findings can correspond with the ART, suggesting that natural stimuli do not demand much cognitive control, and in turn, replenish directed attention resources. However, from colleagues, it has been known that nature had a positive effect on positive affect. So, the SRT could also be suitable through a possible mechanism of affect. Future studies are needed to confirm a causal relationship and a suitable theoretical background.

**The moderation of neuroticism on the relationship between nature exposure and working memory**

In a world where urbanization is only developing more rapidly, where people sit behind their computers for hours straight and a pandemic leads us to be home more often, spending time outside is valuable. Being in nature can have positive effects on human well-being (Jimenez et al., 2021). Exposing oneself to nature can, for instance, alleviate high blood pressure levels, improve positive affect, lower symptoms of anxiety and rumination, and improve immune function (Wen et al., 2019; Holt et al., 2019; Ohly et al., 2016; Song et al., 2016; Li et al., 2007). A study by Stiggdotter et al. (2010) researched a Danish population where they investigated the association between proximity to greenery and overall quality of life. They found that people who lived closer to greenery (<1 km) had higher levels of quality of life. This suggests that the proximity to natural environments may lead to more exposure to those environments. It has been shown that exposure to nature relative to urban environments has significant positive effects on affect states and attention (Berman et al., 2008). Bratman et al. (2015) compared urban with nature walks and found that nature walks reduced anxiety, rumination, and negative affect while maintaining levels of positive affect in participants with no current diagnosis of a psychological disorder (Bratman et al., 2015).

The beneficial effect of nature in comparison to urban environments has thus been shown (Bratman et al., 2015; Berman et al., 2008). One promising component nature exposure has a beneficial effect on, is cognition restoration (Schertz & Berman, 2019). Positive correlations have been found between green environments around schools and the cognitive development of children (Dadvand et al., 2015). Walking in nature has shown to have positive effects on cognitive performance, specifically executive cognitive functions that require high directed attentional control (Stenfors et al., 2019). Green views at home are positively associated with self-control behaviors in young girls (Taylor et al., 2002). Next to this, adults who live in greener randomly assigned public housing buildings, show higher attentional functions (Kuo & Sullivan, 2001). The study of Berman et al. (2008) showed compared walking that walking in nature significantly improves directed attention measured by the Digit Span Task. Exposure to nature in comparison to urban environments also has a positive effect on verbal working memory scores (Bratman et al., 2015). Nature exposure has further been positively associated with cognitive flexibility and concentration (Berman et al., 2008, 2012; Hartig et al., 2003).

The positive effects of nature exposure have been repeatedly associated with cognitive restorationas well as diminished perceived stress experiences (Hartig et al., 2014; Berman et al., 2008). The cognitive mechanism behind these effects can be explained by the Attention Restoration Theory (ART) (Kaplan, 1995). According to the Attention Restoration Theory, nature experiences such as sunsets and greenery help to replenish cognitive function and especially functions of attentional control (Kaplan, 1995). Attention can be subdivided into involuntary attention which exists through bottom-up processes that capture salient stimuli and directed attention that uses cognitive control processes (Stenfors et al., 2019). The key rationale of the ART is that natural stimuli do not demand much cognitive control, and thus directed attention (Kaplan, 1995). Because nature stimuli are processed through involuntary attention, thus through bottom-up processes, directed attention reserves can be restored (Jiminez et al., 2021).

Directed attention processes serve a large role in working memory (Oberauer et al., 2007). According to Baddeley (2010), working memory serves as temporal storage that can hold information and manipulation processes. This manipulation of information of incoming and recalled information is useful for cognitive complex tasks like reasoning, learning, and comprehension (Baddeley, 1992). According to the multicomponent model, working memory consists of four components: the phonological loop, the episodic buffer, the visuospatial sketchpad, and the central executive (Chai et al., 2018). The central executive contains the attentional control system and has an overarching role in manipulating, recalling, and processing information (Chai et al., 2018). According to Cowan (2008), the limited capacity of working memory depends greatly on directed attention. Directed attention plays a big role in activating, updating, retrieving, and maintaining information in the working memory system (Oberauer et al., 2007).

Another view that can support the positive effects of nature on cognition is founded on the reduction of stress. The Stress Reduction Theory (SRT) by Ulrich (1983) suggests that interaction with nature can help restore and reduce the negative effects of stress, and so improve well-being (Wells & Evans, 2003; Hartig et al., 2014). It has been theorized that this stress reduction works via a connection between cognitive systems and affective arousal (Ulrich, 1983). In other words, natural environments can reduce negative affect and stress and improve positive affect which results in higher levels of directed attention (Ulrich, 1983). According to this, people who experience higher levels of stress or anxiety will also benefit more from the effect of nature (Jimenez et al., 2021).

Personality can influence how vulnerable someone is to experience stress and/or anxiety and therefore, could be an important component to differentiate between individuals. Neuroticism is defined as a personality trait that is associated with a vulnerability to experience more negative emotions, like stress, and is a risk factor for multiple psychiatric disorders, such as anxiety, mood, and eating disorders (Clark et al., 1994). Moreover, persons who score high on neuroticism tend to have a lower tolerance to stress and are very emotionally responsive (Lahey, 2009). It has been shown that persons scoring high on neuroticism and trait anxiety are more likely to interpret ambiguous information negatively than people who score low on those facets (Salemink & van den Hout, 2010). This tendency to interpret ambiguous stimuli as negative can also be described as a *negative interpretation bias* (Vinograd et al., 2020). High neuroticism is also associated with poorer cognitive performance (Saylik et al., 2018). Persons scoring high on neuroticism tend to perform worse on working memory tasks that demand shifting and/or inhibition properties of working memory (Saylik et al., 2018). Based on the Attention Control Theory, worry-related arousal rises in persons scoring high on neuroticism when a task becomes complex, which makes it difficult to cope with the task-related activities because they also must deal with the worry-related mental activities (Eyesenck et al., 2007; Eyesecnk & Derakshan, 2011).

Hence, a solution to diminish the stress and/or restore cognitive function could be of meaningful relevance for all (working and studying) individuals who deal with cognitive tasks daily. Packed work schedules and stressful situations and tasks during which we must perform at our best constantly screams for a healthy buffer. Especially in times of Covid-19, unpredictable work schedules can be straining. Also, according to the Dutch Ministry of Health, 17% of Dutch employees experience burnout symptoms (Ministerie van Volksgezondheid, n.d). Concerning busy lives and limited time off, it would be interesting to see if even short exposure to nature could lead to benefits. An outdoor break of 10 minutes has already more benefits than an indoor 10-minute break (Largo-Whight et al., 2017). On the other hand, Li et al. (2018) found that, concerning daily exposure to greenery, a higher exposure resulted in a better mood. For working memory scores, a higher exposure may result in better effects as well.

This study is the first to investigate the moderating effect of neuroticism on nature exposure and working memory, concerning exposure duration. Participants will do a long or short duration nature walk. It is hypothesized that both nature exposure times will positively influence the performance on the working memory task with a higher score for the persons scoring low on neuroticism.

**Method**

**Participants**

The participants studied in this research were students at Utrecht University (*N=*47). The participant’s ages ranged from 20 to 28 years old (*X=* 22.07, *SD*= 2.04). Furthermore, the sample consisted of 33 females and 13 males, 71.7% and 28.3% respectively. 89.1% of the participants were Dutch, 6.5% were Colombian, 2.2% came from Poland and 2.2% were British or Northern Irish. They were recruited through a digital platform of the university as well as posters that were hung up on walls in several buildings. The participants were randomly assigned to either the long or the short walk, with a long, long, short design (1-1-2). This resulted in a division in which 34.8% of the participants were placed in the short-duration group and 65.2% in the long walk category. This division was made because a bigger part of the researchers in the data collection only investigated the longer duration condition.

Exclusion criteria were only age-related, participants had to be between 18 and 35 years old.

**Measures**

***Working memory task***

For this study, a cognitive task that measured working memory was needed. An *n-*back Task was created, consisting of a 2-back, 3-back, and 4-back. The *n-*back Task is widely used in the field of experimental psychology as well as neuroscience (Jaeggi et al., 2010). The task measures different aspects of working memory, such as encoding, monitoring, maintaining, and updating incoming stimuli and matching stimuli that were presented N positions back (Jaeggi et al., 2010). Participants must decide if or if not, they have seen the stimulus N positions ago. Accordingly, selection, interference, and inhibition are also important aspects of the task (Jaeggi et al., 2010). Considering the validity and reliability, the *n-*backTaskis not useful to measure individual differences. However, the task is a valid and reliable measure for inter-group differences (Jaeggi et al., 2010).

***Eysenck Personality Questionnaire***

A shortened and revised version of the NEO-PR was used for this study. This version of the questionnaire was formerly used in the SATSA study (Saudino et al., 1997). The questionnaire consisted of Extraversion as well as Neuroticism items. The reliability in terms of internal consistency for neuroticism according to the SATSA study was *α*= .75 and *α*= .66 for Extraversion (Saudino et al., 2997). Each scale consists of 12 items with a 3-point scale (0= no, 1= maybe, 2= yes). The sum scores were categorized into low and high scores, through a median split. The cut-off score for having a high neuroticism score was 13. The formal cut-off scores were not used, because the sample had a low variability as well as neuroticism scores that were more skewed to the lower side. Therefore, the scores were also split into three equal parts, to see if that influenced the analyses. This was done through equal parts of 33.33% percentage.

***Weather***

The weather was taken in as a moderator to control for the different weather during the data collection. This was done through the daily weather scores of Weeronline, a Dutch weather application. The weather score was collected every day. The scores were categorized into “good” and “bad” and were coded as 0 = bad and 1 = good.

**Procedure**

This study was conducted in a lab on the campus of the University of Utrecht and a park around the campus. The researcher picked up the student from the waiting area and brought them to the laboratory cubicle. It was explained that the participant would do a few tasks, go for a walk and then do another few tasks. First, the personality questionnaire and other questionnaires that are not used in this study were assessed. The participant called the researcher when they were done, and the working memory task (T1) was made ready. The instructions were given during the task, but an instruction form was also on the desk. After the task, the researcher instructed the participant that he/she would go on a walk and kindly asked them to leave their mobile device in the cubicle. A fitness watch was attached to the participant’s wrist as a sign of trust to symbolically make sure that the participant would walk the whole route because we mentioned that we measured their heart rate and used the GPS tracker. There was a small distance between the start of the walk and the laboratory, so it was explained that there would be no conversation for the 5-minute walk towards the start of the stroll. Green and red cones were used to set out the short and long route, and it was instructed what color the participant had to follow. The participant could choose if they wanted the researcher to wait at the start or whether they would go back to the waiting area of the laboratory by themselves. Back in the laboratory, the participant made a shortened questionnaire, the working memory task again (T2), and for the last time the shortened questionnaire.

**Design**

This research used a *mixed design* with within-subjects and between-subjects. Two experimental conditions were assessed: a short walk duration (10 minutes) and a long walk (25 minutes) (between-groups). Working memory was assessed at two time points: before and after the nature exposure (repeated measures with a within-subjects approach). The time points at which working memory was assessed were before the walk (T1) and after the walk (T2).

**Statical analyses**

This study made use of a mixed design, with between (duration) and within (nature exposure) factors as well as a moderator (neuroticism). First, the normality assumption of the dependent variable (working memory scores) was checked through histograms and QQ Plots. To determine the internal reliability of the NEO, a Cronbach’s Alpha analysis was used. The Mauchly’s Test of Sphericitywas used to determine the homogeneity of the covariances. The relationship between nature exposure and working memory was analyzed through a Repeated Measures ANOVA. The within factor was “nature exposure” consisting of two levels: T1, before the nature exposure, and T2, after the nature exposure. During these time moments, the working memory task was assessed. “Duration” was the between factor consisting of the long and short nature exposure. Neuroticism was first analyzed as an independent factor as well, to make sure to test if it initially had an effect. The variable “weather” was assessed as a covariate to see if it would moderate the relationship.

**Results**

This study investigated the effect of different nature exposure durations on working memory, whilst also researching the moderating effect of trait neuroticism. Working memory scores at both T1 and T2 were slightly bimodally skewed. Table 1 shows descriptive statistics for T1 data of the working memory task based on neuroticism, gender, and age. The Mauchly’s Test of Sphericity showed a non-significant effect. This means that the variances for both groups of exposure were equal.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Duration | *N* | *M* | *SD* |
| Nature Exposure T1 | Short  Long | 16  30 | 102.25  93.23 | 30.93  36.80 |
|  | Age | *N* | *M* | *SD* |
| Nature Exposure  T1 | 20-24  25-28 | 42  4 | 97.14  88.25 | 35.76  24.17 |
|  | Neuroticism | *N* | *M* | *SD* |
| Nature Exposure  T1 | Low  High | 25  21 | 98.80  93.48 | 36.41  33.41 |
|  | Gender | *N* | *M* | *SD* |
| Nature Exposure  T1 | Male  Female | 13  33 | 100.69  94.67 | 27.15  37.62 |

**Table 1**

*Descriptives Time of Exposure T1 based on categorical variables*

First, the main effect of nature was analyzed through a Repeated Measures ANOVA. The main effect of nature showed a significant effect, *F*(1)= 12.16, *p=* >.001. In table 2, the mean scores show a higher score for T2, which could imply that the T2 scores for the *N-*back Task were higher. The results for the interaction effect of exposure duration on working memory showed a non-significant effect, *F*(1)= 2.09, *p=* .155. Thus, this supports the hypothesis that both exposure times would result in higher *n-*back Task scores.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Duration | *N* | *M* | *SD* |
| Nature Exposure T1 | Short  Long  Total | 16  30  46 | 102.25  93.23  96.37 | 30.93  36.80  34.79 |
| Nature Exposure T2 | Short  Long  Total | 16  30  46 | 110.25  112.57  111.76 | 32.20  35.03  33.73 |

**Table 2**

*Mean scores N-back Task based on Time of Exposure*

Neuroticism as a between factor nor within factor alone did not create a significant change in working memory, *F*(1)= .03, *p=* .858. Accordingly, persons scoring low on neuroticism did not have higher scores on the *n-*back task.

The variable Weather did also not influence the direction of the relationship when analyzed as a between factor alone or as a within factor. The main effect of Nature exposure\*Weather was thus not significant, *F*(1)= .31, *p=* .583.

Tables 5 and 6 show the within-subjects and between-subject effects of the complete model including the variables Duration, Neuroticism, and Weather. As seen from the partial Eta Squared, nature itself did explain quite some variance in the working memory scores compared to the other variables.

**Table 5**

*Repeated Measures ANOVA Within-Subjects effects*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | *Df* | Mean square | *F* | *p* | *ηp2* |
| Nature Exposure | 1 | 3140.82 | 9.20 | .004 | .20 |
| Nature Exposure\*Duration | 1 | 1013.83 | 2.97 | .093 | .07 |
| Nature Exposure\*Neuroticism | 1 | 157.59 | .46 | .501 | .01 |
| Nature Exposure\*Weather | 1 | 67.60 | .20 | .659 | .01 |

**Table 6**

*Repeated Measures ANOVA Between-Subjects effects*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | *Df* | Mean square | *F* | *p* | *ηp2* |
| Intercept | 1 | 621372.35 | 292.33 | <.001 | .89 |
| Duration | 1 | 61.79 | .03 | .866 | <.01 |
| Neuroticism | 1 | 633.20 | .30 | .588 | .01 |
| Weather | 1 | 2196.76 | 1.03 | .316 | .03 |

**Discussion**

This study aimed to investigate the relationship between different durations of nature exposure on working memory performance and how neuroticism would moderate this relationship. The main finding is that there was no significant difference between the two exposure duration considering the working memory scores. This means that nature had a beneficial effect on working memory regardless of the duration of the exposure. Accordingly, the first hypothesis considering that both times of exposure would result in higher working memory scores is confirmed. Also, it did not matter if the weather was bad or good that day. Furthermore, neuroticism did not play a role in the change of working memory scores, nor did it moderate the relationship between exposure and working memory. Thus, these results suggest that neuroticism does not play a role in the relationship between nature exposure and working memory. The hypothesis that persons scoring low on neuroticism would score higher on the working memory task is thus not confirmed.

The findings that nature exposure leads to better working memory function are in line with the Attention Restoration Theory by Kaplan (1995). It can be suggested that the exposure to nature therefore may work through a bottom-up process of attention, which replenishes the resources of directed attention, which in turn leads to higher performance on such tasks.   
 The other proposed theory, the Stress Reduction Theory, proposes that higher cognitive performance as a result of nature exposure works through a combined process between the cognitive- and affective systems (Ulrich, 1983). However, in this sub-project affect was not considered. But from my colleague student, it is known that there was a significant effect was found for positive effect, not for negative effect. Also, a moderating effect for neuroticism was found only for positive affect. So, it could be that nature exposure led to a higher positive affect and therefore higher working memory task scores.

We had expected that persons scoring high on neuroticism would experience more stress than persons scoring low on neuroticism; possibly because they tend to experience the *interpretation bias* at a higher rate (Vinograd et al., 2020). However, neuroticism did not moderate the relationship between nature and working memory scores. It must be noted that, however, working memory scores were lower for the high neuroticism group before exposure as well as after. Still, this finding was not significant. The null results of neuroticism on the relationship could have multiple explanations.

First, state personality characteristics like neuroticism may do not influence the relationship between nature exposure and working memory. It could be suggested that neuroticism influences positive and negative affect, but not cognition through nature exposure. According to the author’s knowledge, no main effects of nature on neuroticism have been previously found either. Second, it could also be plausible that the questionnaire on neuroticism or the sample being investigated was not a good representation of low and high-scored trait neuroticism. There was little variance in neuroticism scores, which led to too little statistical power to possibly find a relationship. Third, working memory might not be a good outcome measure to investigate the effect of neuroticism. It could be that neuroticism moderates other aspects of cognition through nature exposure. For instance, individuals that score high on neuroticism score lower on fluency tasks, response time tasks, and verbal memory tasks (Chapman et al., 2017; Wettstein et al., 2017). Perhaps the effects of nature on cognition moderated by neuroticism are not visible through working memory.

Considering these explanations and the effect of affect from my colleague students in this project, both theories could be applicable and further research is needed to see what theory the results are more in line with.

Even though no firm decision can be made about what theory is more suitable, some explanations for the null results of duration can be made. The non-significant effect of duration is not in line with some other research about nature exposure duration (Shanahan et al., 2016). The study of Shanahan et al. (2016) investigated the dose-nature framework, in which the health outcomes and nature experiences of an individual are linked. They found that 30 minutes or more of exposure to green spaces led to less depression and high blood pressure rates. However, the dose-effect of nature on working memory, as researched in this study, has not been investigated according to the author’s knowledge. Different explanations could be applied to this non-significant relationship.

First, it could simply be that there is no duration effect of nature on working memory. This explanation could be justified by the study of Largo-Whight et al. (2017), which showed that a 10-minute walk already had positive effects. It could possibly be that the frequency of exposure to nature matters more than the duration of the exposure itself (Cox et al., 2018). Cox and colleagues (2018) studied how frequently participants spent at least 10 minutes in their garden compared to the total minutes they have spent in their garden, which both resulted in positive effects on mental and physical health. Exposing oneself more frequently instead of for longer periods could possibly be also applicable to working memory as an outcome measure. For instance, easy access to greenery is associated with more contact with natural environments, which in turn results in an accumulation of positive short-term health effects, and thus a more long-term health effect (Cox et al., 2017). Second, the dose-effect of nature exposure may lie within the quality of the nature exposure and not necessarily the duration of the exposure (Shanahan et al., 2016; Cox et al., 2017; De Vries et al., 2021). Different theories propose that the type of nature someone is in matters (De Vries et al., 2021). A study by de Vries et al. (2021) showed that people tend to score higher on subjective overall well-being measures on natural coasts and low-lying vegetation (De Vries et al., 2021). Different types of natural environments may also result in different attention restoring effects. It must be noted, however, that all these explanations are hypothetical because the outcome measures used were more focused on the well-being and mental health. Thus, further research is needed to see if a relationship between one of these factors and working memory could be found.

Some strengths and limitations should be addressed. First, a strength of this study is the fact that the nature exposure was sufficiently controlled. The participants had to leave their phones, could not talk to strangers, and had to walk alone. Participants were not distracted which strengthens the study, because statistical noise is less likely. On the other hand, translating this research to practice can be a challenge as exposing oneself to nature could also be with music, going on a walk with someone. It would be interesting to investigate if the beneficial effects of nature exposure are still present when people listen to music or podcasts or talk with someone else. Another strength is that this study is the first to investigate the effect of neuroticism on the relationship between nature exposure and working memory. If persons scoring high on neuroticism would have more difficulties with negative affect and thus have less spare working memory capacity, nature exposure interventions could be promising. However, further research is needed to confirm the relationship between the effects of nature exposure on working memory through a model of neuroticism and affect.

Some limitations should also be considered. First, the working memory task was the same and therefore a practice effect could have been taken place. However, this was necessary to compare the time points. Participants have said that they experienced the task as difficult, but that the second time went better because they now knew what they were supposed to do. Part of the variance of the differences in scores before and after the nature exposure could therefore also possibly be attributed to the practice effect. In the future, doing more practice runs before actually starting the real task could help to get more reliably repeated measures.

Second, the nature exposure was conducted through a nature walk. Therefore, two important points to consider are the following. First, exercise is another factor that can be seen as beneficial for well-being, including cognitive function (Mandolesi et al., 2018; Weinberg & Gould, 2018). Next to this, a seated control condition was not present. It could be possible that exercising for a longer time with moderate intensity results in different outcomes on working memory than exercising with high intensity for a short duration (Chang & Etnier, 2009). It has been shown that moderate-intensity exercise improves working memory and cognitive flexibility, and high-intense exercises ameliorate the speed of information processing (Chang & Etnier, 2009). Taken from sports psychology, the effects of exercise largely depend on the intensity, frequency, and duration of the exercise (Weinberg & Gould, 2018). Thus, researching sitting in nature, and acting out different intensities and durations of nature exercises could be beneficial in understanding the additive positive effect of nature.

Lastly, defining nature objectively is a very broad and difficult thing to do. Forestland compared to plain fields, great or small amounts of vegetation, or having a lot of wildlife, for example, could all result in very different definitions of what nature is. Not only objectively defining nature, but also the subjective definition of nature to a person is very variable. Culture and ethnicity would probably an important role in this subjective definition. For example, someone from the Netherlands could find wildlife stress-provoking, whereas someone from Africa or Australia would not. However, the sample of this study contained almost only Dutch participants, which would make the nature exposure and their definition of nature possibly more similar.

Taking these limitations together, implications for future research are important to consider. As it was beyond the scope of this study to examine different natural environments and forms of exposure, it would be promising to conduct research that takes these into account. Next, it would be good to replicate the study and take affect into account, to further understand the mechanisms of neuroticism. Finally, as the duration of exposure did not create significant differences in working memory scores, creating a short nature walk intervention during office days, for example, could be promising. However, the data contributes to a clearer understanding of the beneficial effect of nature exposure on working memory.

Taking together, exposing oneself to nature could be of significant worth for well-being and cognitive functions. As we deplete our attention resources daily by living in urban environments and working non-stop, short, efficient nature interventions could balance out the use and restoration of one of our most used cognitive functions.

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