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The effects of a one-hour walk in different natural environments on working memory and rumination

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Selma Polte BSc

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Abstract

Urbanization is rapidly expanding, with more than two-thirds of the global population forecasted to live in cities by 2050. Although urban living provides many health benefits, it is also related to increased psychological and physiological risks, such as the development of psychiatric disorders, i.e. due to heightened social stress. At the same time, exposure to nature has been suggested to promote mental health and well-being, indicating that the development of natural spaces in urban areas might alleviate some of the negative effects of urbanization. However, it is currently unclear which type of nature (green space, blue space) creates most benefits. This research explores the influence of a one-hour walk in different natural environments on working memory performance and self-reported rumination levels in adults in Berlin. Participants (n=99) were randomly allocated to one of the three conditions: open green space, covered green space, blue space. In contrast to our hypotheses, no difference in the effects of these types of environments on working memory and rumination could be identified, suggesting that the type of nature may not be that decisive. Nevertheless, this study contributes to the field of environmental psychology and neuroscience, by being among the first ones to experimentally investigate the effects of exposure to different natural environments on cognitive and affective phenomena. Thus, this research highlights the importance of

incorporating natural areas into urban planning and policies to target mental health challenges intensified by urban stressors.

Abstrakt

Die Urbanisierung nimmt rapide zu und Prognosen zu Folge werden bis 2050 mehr als zwei Drittel der Weltbevölkerung in Städten leben. Obwohl urbanes Leben viele Vorteile bietet, ist es auch mit erhöhten psychologischen und physiologischen Risiken verbunden, wie einem höherem Risiko psychiatrische Krankheiten zu entwickeln, beispielsweise durch größeren sozialen Stress. Gleichzeitig haben Studien gezeigt, dass Naturkontakt psychische Gesundheit und Wohlbefinden fördern kann. Dies gibt Hoffnung zu der Annahme, dass die Entwicklung von naturnahen Flächen in städtischer Umgebung einige der negativen Auswirkungen von Urbanisierung mindern könnte. Bisher ist jedoch unklar, welche Art von Natur (Grünflächen, Wasser) die größten Vorteile bietet. Das Ziel dieser Studie ist es zu untersuchen, welchen Einfluss ein einstündiger Spaziergang in unterschiedlichen natürlichen Umgebungen auf das Arbeitsgedächtnis sowie auf Grübeln bei Erwachsenen in Berlin hat. Proband*innen (n=99) wurden zufällig einer von drei Naturbedingungen zugeteilt: Park, Wald und See. Im Gegensatz zu unseren Hypothesen konnten jedoch keine Unterschiede in den Effekten dieser Naturbedingungen auf Arbeitsgedächtnis und Grübeln identifiziert werden. Dies deutet darauf hin, dass die Art der Natur möglicherweise nicht so entscheidend ist wie bisher angenommen. Dennoch trägt diese Studie entscheidend zu den Bereichen der Umweltpsychologie und

-neurowissenschaften bei, in dem sie eine der ersten Studien ist, die die Effekte von unterschiedlichen Naturbedingungen in einem experimentellen Design auf kognitive und affektive Phänomene untersucht. Hierdurch wird hervorgehoben, wie wichtig die Entwicklung von naturnahen Flächen in der Stadtplanung und -politik ist, um psychische Gesundheit in Städten zu stärken.

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Introduction

We live in a world of rapidly increasing urbanization. While today more than half (55%) of the world's population reside in cities, this share is forecasted to rise to more than two-thirds (68%) of the global population by 2050 (United Nations, 2019). Despite many health-related benefits of urban dwelling, i.e. direct access to healthcare, sanitation, and nutrition, living in a city is also related to higher risks of pollution, social deprivation, crime (Godfrey & Julien, 2005) and various psychiatric disorders (Peen et al., 2007). Particularly, the risk of developing schizophrenia is higher in urban compared to rural areas, which is possibly related to increased exposure to social stress (Lederbogen et al., 2013). Additional research also suggests that increasing urbanization might be associated with higher levels of depression, particularly among older adults (Purtle et al., 2019).

At the same time, a longitudinal study conducted in the United Kingdom found that persons who relocated to a greener space reported improved psychological health throughout the three years following their move (Alcock et al., 2014). This study is in line with various research from the field of environmental psychology suggesting a positive effect of exposure to nature on overall health and well-being (R. Russell et al., 2013). Thus, spending time in nature is related to both physiological and psychological benefits. Physiological components include lower levels of the stress hormone cortisol, decreased blood pressure and a lower pulse rate (Park et al., 2010) as well as higher levels of physical activity and reduced risk for cardiovascular diseases (Jimenez et al., 2021). Some studies also suggest improvements in immune function and inflammation (Oh et al., 2017). Furthermore, exposure to nature has repeatedly shown to positively influence various factors of mental health, including stress, anxiety, depression, and emotional response (Oh et al., 2017). Additionally, studies also indicate an improvement in cognitive functions after spending time in nature, such as higher working memory performance (Bratman, Daily, et al., 2015). With mental and brain disorders being one of the most pressing health issues in Europe (Wykes et al., 2015), acknowledging the positive impacts of natural environments presents a clear opportunity for intervention.

The remaining part of the introduction is organized as follows: Firstly, the two theoretical frameworks, which underpin this research, are introduced. Secondly, the phenomena of working memory and rumination are presented. Subsequently, a short overview regarding the state of art on research on green spaces and blue spaces and their relation to mental health is presented. Finally, the research problem, research questions, and hypotheses are outlined.

Theoretical Frameworks

There are two main theoretical frameworks conceptualizing the positive effects of exposure to natural environments, which differentiate between affective and cognitive benefits. Stress reduction theory (SRT) (Ulrich et al., 1991) focuses primarily on the relation between nature exposure and affect. Stress can be defined as the psychological, physiological, or behavioral response of an individual towards a challenging or threatening situation (Baum et al., 2020). In turn, ‘recovery’ or ‘restoration’ from a stress response includes positive shifts in psychological and physiological states as well as in behavioral aspects (Ulrich, 1979). According to SRT, unthreatening natural environments lead to a greater stress recovery than urban settings. More specifically, the restorative functions of natural scenes *after* a stressor play a major role in inducing positive emotional states, decreasing physical arousal, and fostering sustained levels of attention. While considering different theoretical perspectives, i.e. cultural (Ulrich & Simons, 1986), arousal (Berlyne, 1973; J. A. Russell, 1974), the SRT primarily draws on findings from the ‘psycho-evolutionary’ framework by Ulrich (1983). This framework claims that restorative responding to unthreatening natural environments favored humans during evolution, i.e. through quick diminishing of stress responses after an encountered threat or by promoting the recharge of physical energy. Accordingly, humans developed a ‘biological preparedness’ to respond to unthreatening natural but not to urban environments.

There are various empirical research supporting SRT. For example, an interventional study by Sudimac et al. (2022) found that amygdala activity was reduced after a one-hour walk in nature but in contrast it remained unchanged after a one-hour walk in urban environment. This finding implies that spending time in nature may have a positive impact on brain regions associated with stress, fostering health and well-being. Additionally, another in situ study by Li et al. (2018), in which everyday exposure to nature was assessed, suggests that greater time spent in nature was significantly related to better mood.

Attention restoration theory (ART) (Kaplan, 1995) on the other hand highlights the relation between nature exposure and cognitive functions by suggesting that the capacity to focus can be restored through exposure to natural environments. In this context, it is important to differentiate between two types of attention. ‘Involuntary attention’ describes the phenomenon of effortless attention, i.e. when a stimulus in the environment is spontaneously capturing one’s attention, whereas ‘directed attention’ occurs when someone is actively forcing themselves to pay attention to a stimulus. Thus, directed attention requires mental effort and can be fatigued over time, potentially leading to a decrease in cognitive performance and higher stress levels (Kaplan & Berman, 2010). According to ART, nature can function as ‘restorative environment’, due to the following four components. Firstly, natural settings such as the seaside, mountains or lakes allow people to experience the feeling of ‘getting away’, which is an important resource for restoring attention. Secondly, many features in natural environments are perceived as ‘soft fascinations’, i.e. clouds, sunsets, or snow patterns, which capture attention effortlessly. Thirdly, natural areas often provide a sense of extent and connectedness to a larger world, i.e, through the way of how trails and paths are designed. Finally, natural environments are often perceived as highly compatible, meaning that people find it less effortful to be in natural than in urban settings (Kaplan, 1995). In sum, all these features of natural environments have the potential to capture involuntary attention through a ‘bottom-up process’, while at the same time minimizing the need for directed attention. Therefore, it is hypothesized that interaction with natural environments allows for cognitive resources to recover, leading to improvements in attention and well-being. In contrast, urban environments are expected to require direct attention to overcome continuous stimulation, i.e. by avoiding traffic or disregarding distracting information, thus, providing less opportunities for cognitive restoration (Kaplan & Berman, 2010).

Various studies have empirically tested the hypotheses of ART. For example, a study by Bratman et al. (2015) shows that a 50-min walk in nature increases working memory capacity compared to a walk in urban environment. Another in situ study by McDonnel & Strayer (2024) exploring effects of nature exposure on attention further showed that a walk in nature was not only experienced as more restorative than a walk in the city, but that it also indicated a greater executive control capacity at the neural level. Hence, both studies propose that time spent in nature can lead to significant effects on some cognitive functions, including working memory and attention.

It is important to note that the frameworks of SRT and ART are not mutually exclusive but rather focus on two different aspects of nature, namely on stress and attention respectively.

Working memory and rumination

Investigating the impact of nature on working memory and rumination is important because of their implications for cognitive processing and mental well-being.

Working memory

Working memory can be defined as a system involved in temporarily storing and manipulating information, which are required for complex cognitive processes, including i.e. learning, decision-making, or language comprehension (Baddeley, 1992). Previous research indicates that working memory capacity also predicts performance in a variety of assessments representing real-world situations (Engle, 2002). Thus, focusing on how exposure to nature influences working memory capacity can lead to interesting findings on strategies fostering cognitive performance and productivity.

There are different studies investigating the influence of nature on working memory. Dadvand et al. (2018) established a positive association between lifelong exposure to greenness and gray matter volume in the prefrontal cortex. The prefrontal region was also associated with test scores in cognitive assessments, whereby higher volume indicated better working memory capacity and lower levels of inattentiveness. These results suggest that growing up in a greener area might be advantageous for the development of the brain and associated cognitive processes. Next to longitudinal studies, there is also research on short-term exposure to natural environments and working memory. In a study by Bratman et al. (2015) participants were randomly allocated to go on a 90-min walk in an urban or a natural environment, and underwent affective and cognitive assessment before and after the walk. The findings revealed that participants in the nature environment outperform participants in the urban environment in terms of working memory capacity. This suggests that also short-term exposure to nature, i.e. recreational visits might be beneficial for cognitive performance. Additionally, further studies have shown that not only direct exposure to nature but also the viewing of natural images is associated with higher working memory performance compared to urban images (Ailsworth, 2023; González-Espinar et al., 2023). It is especially interesting to note that this effect remained even when aesthetic preference for natural environments was controlled for (González-Espinar et al., 2023).

Rumination

The other aspect, which is important for the current study, is rumination. Rumination can be defined as a process of perseverative cognition centering around negative thoughts, which can lead to emotional discomfort (Sansone & Sansone, 2012). It is associated with various psychological disorders, including depression and anxiety (Nolen-Hoeksema, 2000). Focusing on the potential impact of nature exposure on rumination might lead to important findings for designing strategies aimed at reducing rumination and fostering mental health. Several studies investigated the influence of nature on levels of rumination. While a lab-based study by Golding et al. (2018) found no significant effect of viewing images of nature on rumination, it found effects on positive mood, the feeling of 'being away' and soft fascination. In contrast, the interventional study by Bratman (2015) introduced above, in which subjects participated in a 90-min walk, resulted in a significant decrease of rumination, anxiety, and negative affect as well as maintenance of positive affect in the natural compared to the urban condition.

By investigating working memory capacity and levels of rumination in the framework of exposure to natural environments, this study seeks to contribute to a better understanding of the cognitive and affective impacts of nature exposure. Findings could potentially help to design interventions and policies with the aim of increasing cognitive processing and mental well-being.

Green spaces

Although the definition of green space may differ between various studies, the term typically relates to open areas of vegetation, i.e. parks as well as conservation areas, i.e. forests, but may also extend to backyards, farms or other spaces, which are primarily defined by vegetation (Nutsford et al., 2016). A meta-analysis by Kondo et al. (2018) on the link between urban green space and health found a positive correlation between green space exposure with attention, mood and physical health but a negative correlation with mortality, heart rate frequency and violent behavior. Additionally, access to green spaces in the direct or close neighborhood is also correlated with improved mental health (Wood et al., 2017). Considering several studies suggesting various benefits of exposure to nature, it remains important to further explore the effects of different kinds of green spaces and cognitive and affective functions.

Open green spaces

A recent longitudinal study by Kühn et al. (2023) on the relationship between green space and brain structure further investigated the difference between green space caused by tree cover versus open green spaces, including corresponding sky associated visibility. Here, the authors found a positive relation between grey matter volume in prefrontal regions and green open space and sky visibility, however, a negative relation between these regions and covered space. Interestingly, sky view was the primary predictor in the prefrontal cortex, and thereby, in the region in which the analyses converged. In a previous study, viability of sky also helped to classify areas as 'natural' (Sztuka et al., 2022). These findings are in line with the prospect refugee hypothesis (Gatersleben & Andrews, 2013). This theory suggests that humans experience environments with high levels of prospect and low levels of refugee as more restorative, because they require less directed attention, i.e. to find the way or identify potential hazards. Therefore, they are preferred over covered spaces with no clear vision, which may even increase stress levels and fatigue of attention (Gatersleben & Andrews, 2013). This hypothesis is also supported by a study on urban parks, suggesting that especially 'green ground cover' as well as 'green niches' are associated with higher levels of restoration (Peschardt et al., 2016).

Covered green spaces

However, there is a diversity of perspectives within the current research community and other studies suggest a positive relationship between local tree cover, independent of green space, and improved overall health (Ulmer et al., 2016). In line with this, there is various research focusing on the positive physiological effects of forest bathing. A systematic review by (Park et al., 2010) indicates that exposure to forests can lower levels of cortisol, blood pressure, sympathetic nerve activity, and pulse rate, and increase parasympathetic nerve activity compared to urban environments. Next to these physiological measurements, behavioral and neural aspects might also be affected by exposure to covered green spaces. One study suggests that urban green spaces involving tree canopy may help to alleviate social loneliness, perhaps particularly in women (Astell-Burt et al., 2023). In contrast, vast open space might be associated with higher levels of social loneliness for women. However, the explanation for why that might be is currently unclear. Furthermore, a study investigating the effects of surrounding environments on latent brain factors in elderly found a positive correlation between forest cover and integrity of the amygdala (Kühn et al., 2017). This finding indicates that forests might be promoting amygdala integrity, yet no causal inference can be made based on the study.

These various findings emphasize that there is still an ongoing debate on the impact of open versus covered green spaces on cognitive processes as well as on mental health.

Blue spaces

Blue spaces are typically defined as water bodies, i.e. lakes, oceans, and rivers but might also encompass built features, i.e. canals, water fountains (Nutsford et al., 2016).

Previous studies have often classified blue spaces as part of ‘green spaces’, as they mostly occur together and share many advantages such as restoration, opportunity for physical activity, and reducing urban heat island effect (White et al., 2020). Yet, there is a growing body of research focusing exclusively on blue space and their effects on physiological and psychological states specifically. Living in close proximity to blue spaces is related to higher levels of physical activity (Georgiou et al., 2021). Greater amounts of blue spaces within a certain geographical area are also associated with higher levels of perceived restoration (Georgiou et al., 2021), providing evidence for ART (Kaplan, 1995). Additionally, findings suggest that exposure to blue spaces can create immediate benefits for health, particularly for mental health and well-being (Britton et al., 2020; McDougall et al., 2022). For example, one longitudinal study with an older population found that sea view is positively correlated with lower levels of depression (Dempsey et al., 2018). Various studies also suggest that blue spaces support social connectedness both during and after exposure by creating possibilities to connect with family and friends (Britton et al., 2020; White et al., 2020).

Importantly, Nutsford et al. (2016) found that visibility of blue spaces – but not green spaces – is related to lower levels of psychological distress in a city, suggesting that blue spaces may have a higher stress reducing potential then green spaces. In line with this, Ulrich (1981) delivered empirical evidence indicating that blue spaces, to a greater extent than green spaces, are particularly important for positively influencing emotional state as well as keeping attention and interest. These findings give rise to the assumption that blue spaces may have a higher restorative potential than green space.

Research problem

While various empirical research support the restorative functions of nature on cognitive capacities and mental health, studies vary largely across the type of natural environment they are investigating, and it is unclear which specific features of natural environments are related to beneficial effects. There are some studies suggesting open green spaces and visibility of the sky to provide most benefits (Gatersleben & Andrews, 2013; Kühn et al., 2023; Peschardt et al., 2016) while others find local tree cover as more advantageous (Astell-Burt et al., 2022; Park et al., 2010; Ulmer et al., 2016). Additionally, recent studies emphasize the potential benefits not only of green spaces but also of blue spaces on cognition and well-being (Britton et al., 2020; Dempsey et al., 2018; Georgiou et al., 2021; McDougall et al., 2022; Nutsford et al., 2016; Ulrich, 1981; White et al., 2020). As far as we are concerned, there is no existing research yet investigating the effects of exposure to different natural environments on working memory and rumination. The current study aims to address this gap by experimentally comparing the effects of a one-hour walk in open green space vs covered green space and blue space on these variables.

Research Questions and Hypotheses

Based on the research gap identified above, the goals of this study are two-folded. Firstly, this study seeks to test whether previous findings on the positive effects of nature exposure on working memory and rumination (Bratman, Daily, et al., 2015;

Bratman, Hamilton, et al., 2015) can be confirmed. Secondly, this study aims to extend the current knowledge by investigating possible differences in effects of exposure to different natural environments (open green space, covered green space, blue space) on working memory and rumination. The main research questions (RQs) are:

RQ1: Does exposure to nature affect working memory capacity?
RQ2: Does exposure to different types of nature (open green space, covered green space, blue space) affect working memory performance differently?
RQ3: Does exposure to nature affect levels of rumination?
RQ4: Does exposure to different types of nature (open green space, covered green space, blue space) affect levels of rumination differently?

Due to previous literature showing a positive association between green spaces and working memory, and a decrease in rumination after exposure as well as blue spaces and restorative functions, it is predicted that exposure to natural environments would increase working memory capacity and decrease levels of rumination. Since there is evidence in the literature favoring both open green space (Gatersleben & Andrews, 2013; Kühn et al., 2023; Peschardt et al., 2016) as well as covered green space (Astell-Burt et al., 2022; Park et al., 2010; Ulmer et al., 2016) regarding its impact on well-being and cognitive processes, the hypothesis is two-directional. Additionally, we expect better working memory capacity and rumination levels after exposure to blue spaces, because some studies suggest that it is more restorative than green spaces (Nutsford et al., 2016; Ulrich, 1981).

Explorative Research: The influence of weather

While this thesis primarily focuses on the effects of exposure to different natural environments on cognitive and affective functions, the correlation between various weather variables and changes in working memory and rumination levels will also be researched in an explorative approach. Previous work suggests that weather accounts for a great influence on psychological state and well-being, including effects on mood and cognitive performance. In a recent study, Cao et al. (2023) collected physiological, psychological, and aesthetic preference data of 50 participants, who experienced various urban green spaces under both sunny and cloudy weather conditions. While the authors found that physiological and psychological advantages of green space exposure were more prominent on sunny days, their results allow for further differentiation with regards to specific features of the selected areas. Urban green spaces with a high sky visibility were attributed a higher physiological restorativeness on sunny days, whereas areas with calm water provided stronger emotional restorativeness on days with cloud cover. Finally, natural spaces with low sky visibility were experienced as more restorative in both weather conditions. Hence, this research highlights not only the important influence weather has on perceived restorativeness of urban green spaces, but furthermore, that the restorative potential can differ with regard to environmental features under the two weather conditions.

Additionally, previous research suggests that also daylight (Beute & de Kort, 2013; White et al., 2021) as well as temperature and vegetation (White et al., 2021) can influence the restorative potential of nature exposure with further consequences for mental health and well-being. Finally, seasonality must also be considered as an important factor moderating psychological effects of weather. For instance, Keller et al. (2005) have conducted two correlational studies and one experiment manipulating time of the participants spent outdoors, where they found that pleasant weather was associated with heightened mood, improved memory, and cognitive flexibility, when the data was collected in spring. However, these findings could not be replicated in other times of the year; in contrast, higher temperatures were linked to lower mood in summer.

These studies highlight the great influence that weather potentially has on the results of psychological studies conducted in the real world. Therefore, an explorative part of the analysis will firstly assess if weather is a confounding variable to this study and secondly, investigate potential correlations between a variety of weather variables (including temperature, rain, amount of sunlight, and cloudiness factor), weather perceptions (sunny, cloudy, rainy, warm, wet, loud) and changes in working memory and rumination. This explorative analysis will contribute to a better understanding of the findings from the main research questions.

Chapter summary

To summarize, this thesis investigates the cognitive and affective influences of exposure to natural environments. The goal is to explore how different natural environments – open green space, covered green space, and blue space – are impacting working memory and rumination levels. Furthermore, weather as possible confounding variable will be researched through an explorative analysis approach. Findings of this research could potentially help to inform decision-making processes and policies towards the design of urban green and blue spaces, with the aim of enhancing cognitive functions and mental health of citizens.

Further outline of the thesis

The subsequent chapters of this thesis are structured as follows: Chapter two outlines the methodological considerations of this research, including participants, study procedure, and the tasks used. Chapter three presents the employed data analysis methods and the results of the study. Chapter four discusses the findings, addresses the limitations of this study, and points out possible directions for future research. Chapter five offers some concluding remarks.

Methodology

The following chapter introduces the methodological considerations of this study. Firstly, participants and data management will be discussed. Secondly, the study design, including the different tasks, is explained. Thirdly, the intervention in the form of a one-hour walk as well as the three different study locations are presented. Finally, both the working memory task as well as the rumination questionnaire are described.

Participants

We recruited a majority of the participants through the internal database of the Max Planck Institute for Human Development in Berlin, Germany, called *Castellum*. Additionally, a few participants were contacted via university groups. The final sample included n=99 participants (55 female, total mean age = 30.92 years, SD = 8.84, age range = 18-50 years). Inclusion criteria for participants were fluency in German language, right handedness, and no diagnosed psychological disorders. No prior experience regarding participation in experimental studies or MRI scanning was required. The sample size was derived from the previous intervention study by Sudimac et al. (2022), in which 63 participants were randomly allocated to the two conditions of nature vs. urban environment. As this study compares three conditions (open green space, covered green space, blue space), a minimum requirement of 96 participants, resulting to 32 per condition, was determined. Recruited participants were allocated randomly to the three conditions, while sustaining a balance in both gender distribution and time of the day (morning vs. afternoon).

The ethical approval for the study was gained by the University Medical Center Hamburg-Eppendorf (LPEK-0594). Data was gathered and stored in accordance with the regulations of the Max Planck Institute for Human Development as well as local data privacy protocols. Participants were notified that they could ask for the deletion of their data without indicating a reason at any time point, also in the future. All participants consented to involvement in the study in written form. Participants were renumerated financially for their participation in the experiment. Data was acquired in the time from April to July 2023 in Berlin.

Study Procedure

This study is part of the larger fMRI study "WalkGreen: Effects of a one-hour walk in different green spaces on brain" investigating the potential differential effects of exposure to different natural environments on brain function and stress. A protocol of the study procedure is displayed in **Figure 1**. After signing the informed consent, participants were familiarized with the study protocol and instructions for the MRI task. Subsequently, participants filled out demographic and various behavioral questionnaires, including measures of working memory capacity and trait rumination (see 3.4). Next, participants underwent the first of two MRI scanning sessions. MRI imaging was obtained on a Siemens Tim Trio 3T Scanner with a 32-channel head coil. In the first scan, participants were exposed to the Fearful Faces Task (FFT), a Perceptual Speed task, and the International Affective Picture System (IAPS). The IAPS was chosen, because nature exposure was expected to have the highest restoration potential after experiencing stress (Ulrich et al., 1991). Participants also answered the questions on state rumination during the fMRI scan. After the intervention, participants completed the working memory task as well as the trait rumination questionnaire again. During their second scan (after the walk) participants underwent the Social-Evaluative Task (SET) instead of IAPS to induce a new stressor. They also answered the state rumination questions again. Additionally, during both fMRI sessions, physiological measurements in the form of heart rate variability, breathing, and electrocardiography were collected.

Figure 1: *Overview of study protocol.*

Intervention

The intervention of this study consisted of a one-hour walk in one of the three natural environments in-between the two MRI sessions. Participants were taken by taxi to the assigned location. They were equipped with a phone from the Max Planck Institute as well as a packed lunch, while leaving their own phone at the institute. To measure physiological activity in the form of heart rate and electrodermal activity, participants wore an Empatica 4 wristband during the walk. Additionally, the provided phone included an app to track the GPS of the participant's walk, and played a loud signal after 30 minutes, directing the participants to turn around. After the signal, participants would walk back in the direction they came from for another 30 minutes and then being driven back by taxi again. Participants were allowed to eat the packed lunch on the walk; however, they were instructed not to stop during the intervention.

Study locations

Grunewald forest (covered green space)

The assigned location for covered green space was a path in the Grunewald forest in Berlin. The path was close to the Max Planck Institute (6.7 km) and could be accessed by taxi in approximately 15 minutes. The route for study participants was along Teltower Weg, which is a path beginning at the junction of Königsweg and Teltower Weg, heading towards the north of Grunewald forest. Spanning over 3,000 hectares, Grunewald is the most spacious forest in the Berlin metropolitan region. It predominantly features ever-green trees and shrubs as well as birch. Parts of the

Grunewald forest are protected as conversational areas to safeguard domestic fauna, particularly birds and amphibians, prohibiting access of the public. While the Grunewald forest encompasses many lakes and ponds as well as the river Havel, the chosen walking route deliberately did not pass any waterscapes. Additionally, the route was devoid of manmade structures and traffic noise. Grunewald forest is known for recreational activities, including walking, running, and cycling (based on Sudimac & Kühn, 2024).

Tempelhofer Feld (open green space)

The assigned location for open green space was Tempelhofer Feld. Tempelhofer Feld is around 7.3 km away from the Max Planck Institute and can be reached by taxi in circa 11 minutes. The walking route began at the Tempelhofer Damm and went towards the East crossing through the park. Historically, Tempelhofer Feld was being used as a military parade ground and as an airport, however, in 2010 it re-opened as a recreational area, which still includes asphalt paths and buildings of the former airport site. Covering over 355 hectares, it is now Berlin’s largest city park. The park can be accessed by six different entries and is open from 6 am to 11 pm in summer. Tempelhofer Feld contains around 6 km of asphalt road, which is being used for running, biking, and inline skating as well as areas for urban gardening and picnicking.

Krumme Lanke lake (blue space)

The assigned location for blue space was lake Krumme Lanke. Krumme Lanke is approximately 7.5 km from the Max Planck Institute and can be reached by taxi in around 16 minutes. The chosen walking route for study participants started at the Fischerhüttenweg in the South of the lake and went along the Western side of the lake. The lake Krumme Lanke is part of a 41,02 hectares large chain of lakes within Grunewald forest. Its shore is around 2 km long and being used for walking, running, and biking. Additionally, there are various spots offering swimming possibilities. Images and locations of the three study areas are being depicted in **Figure 2.**

Figure 2: *Map of the three different locations for the walk.* Covered green space (top left), blue space (bottom left) and open green space (bottom right). The red shape indicates the location of the Max Planck Institute, from where the participants started (OpenStreetMap, 2024).

Tasks and Questionnaire

Working memory task

To measure working memory capacity, a performance-adapted visual version of the Digit Span Backwards task (DSB) was used (Bowden et al., 2013). DSB was administered because it was applied in a previous study comparing the effects of walk in natural vs. urban environment on working memory capacity (Sudimac et al., 2024). Performance on this task is measured in scores ranging from 0 to 14, whereby greater scores implicate greater working memory capacity. Participants were assessed with DSB twice, before and after the walk. However, they were tested with different digits to prevent participants from remembering digits from the first task.

Rumination questionnaires

To assess the level of rumination before and after the walk, participants answered questions regarding both trait rumination and state rumination. To investigate trait rumination, participants were administered a German translation (König, 2012) of the rumination-reflection questionnaire (RRQ) (Trapnell & Campbell, 1999). The RRQ was originally developed with the intention to distinguish between the two types of ruminative and reflective ways of thinking. The decision to use the RRQ for this research was based on previous studies using the questionnaire to investigate the impact of nature exposure on rumination, i.e. (Bratman, Hamilton, et al., 2015; Sudimac et al., 2024). Since this study was conducted in German, the translation by König (2012) was applied. This version consists of twelve ruminative items, i.e. “Sometimes I find it difficult to switch off thoughts about myself” (“Manchmal fällt es mir schwer, Gedanken über mich selbst abzuschalten”), which are being ranked on a 5-point Likert scale, ranging from one (“strongly disagree”) to five (“strongly agree”).

However, as Sudimac et al. (2024) pointed out, it can be challenging to measure changes in trait rumination in the course of a single day. It might be more appropriate to measure changes in state rumination (SR), which typically refers to thoughts in the previous hour, as i.e. conducted by Lopes et al. (2020). Therefore, to also capture possible changes in state rumination, participants were asked to additionally rate the following three items: 1) During the past five minutes, I could not get certain thoughts out of my mind, 2) During the pastcfive minutes, I kept thinking about something over and over again, 3) During the past five minutes, I had difficulties suppressing thoughts about myself. These items were adapted from previous studies (Brose et al., 2011; Kühn et al., 2013), whereby two of them are taken from the Stress Coping Inventory (Janke & Erdmann, 2002). Although they were previously rated on an 8-point scale, the environment of the MRI scanner only allowed for a 4-point Likert scale in this study. Like with the DSB, participants completed the questionnaires on trait and state rumination questionnaire before and after the walk to allow for a pre-post analysis of the data.

Chapter summary

This chapter has introduced the methodological approach taken in our study. A total of healthy 99 participants have been recruited and randomly assigned to walk in open green space, covered green space or blue space. Before and after the intervention, participants took part in an fMRI scan at the Max Planck Institute and were administered several cognitive and psychological assessments. For this thesis, especially the Digit Span Backwards task to assess working memory performance as well as questionnaires regarding trait and state rumination are important. Ethical approval and data privacy regulations were strictly adhered to during the entire study.

Data analysis and Results

The following chapter first introduces the steps of data analysis. Subsequently, a table of demographic control variables between the three experimental groups is depicted. Next, the main results of this research on working memory performance, trait rumination levels, and state rumination levels are presented and visualized. Finally, results of the explorative analysis on weather are introduced.

Data analysis

As specified in the preregistration, the data were winsorized. Winsorizing is a data transformation technique, in which extreme values (3*SD) in the dataset are replaced by maximum and minimum thresholds. In the DSB data set, one outlier for upper limit was replaced using winsorizing.

To check the prerequisites for ANOVA, all data sets were screened with the Levene's Test for Equality of Variances and the Shapiro-Wilk Normality test. Levene's Test for Equality of Variances is applied to assess whether the variances of two or more groups are equal. A test statistic greater than 0.05 indicates that the null hypothesis should be rejected and the variances between groups are significantly different. The Shapiro-Wilk Normality test is used to examine whether a data set is normally distributed or not. A calculated value less than 0.05 means that the data deviates from normal distribution. None of the data sets followed normal distribution, meaning that the assumptions for ANOVA were not met. Therefore, a non-parametric two-way ANOVA for trimmed means with interactions was applied (t2way function in R Studio) (Wilcox, 2012), as it is robust against violations of normality. The non-parametric ANOVA allows to investigate the main effects of two factors and their interaction on a dependent variable. For this study, time as within-subject factor (pre vs. post walk) and environment as between-subject factor (open green space vs. covered green space vs. blue space) and their interactions on the DSB, RRQ, and SR data sets were examined. This test does not provide degrees of freedom as an adjusted critical value is utilized (Wilcox, 2012). As multiple hypothesis testing was applied, p-values are being corrected for with the False Discovery Rate (FDR). FDR is an approach to manage the expected proportion of incorrected rejections in relation to total rejections, which is less conservative than the Bonferroni correction (Benjamini & Hochberg, 2000). Finally, post hoc t-tests are calculated to examine the influence of each environment.

Results

Demographic variables

To control possible cofounding variables impacting the main results, various demographic factors were compared. No difference in chosen demographic factors could be detected, as shown in **Table 1** below:

Table 1: *Control variables for demographic values in three different natural environments.*

Variable	**Grunewald (n=33)**	**Tempelhofer Feld (n=33)**	**Krumme Lanke (n=33)**	**df**	**F-value**	**p-value**
	Demographics					
Age (mean ± SD)	*29.09± 6.59*	30.30± 9.72	31.90 ± 9.35	2; 96	0.88	0.42
Sex: female (%)	*54.55*	48.48	51.52	2; 96	0.12	0.89
Country of origin: Germany(%)	*87.88*	84.85	93.94	2; 96	0.70	0.49
Income: under 1250 euros (%)	*45.45*	51.52	54.55	2; 96	0.28	0.76
Occupation: students (%)	*48.48*	42.42	33.33	2; 96	0.78	0.46
High school diploma (%)	*87.88*	72.73	84.85	2; 96	1.42	0.25

In the following sections, the results for working memory, trait rumination, and state rumination will be presented separately.

Working memory results

Contrary to what we expected, we did not find an environment-by-time interaction across any of the natural environmental types. Nevertheless, as hypothesized, the DSB score data showed significant results for the factor time as depicted in **Figure 3.** This suggests that there is an overall improvement from pre to post walk regardless of environment.

Table 2*: Results of robust ANOVA for working memory (DSB).*

Predictor	F-value	*p-value (FDR corrected)*
condition	2.97801	0.528
time*	2.9863	0.009
condition x time	1.8203	0.657

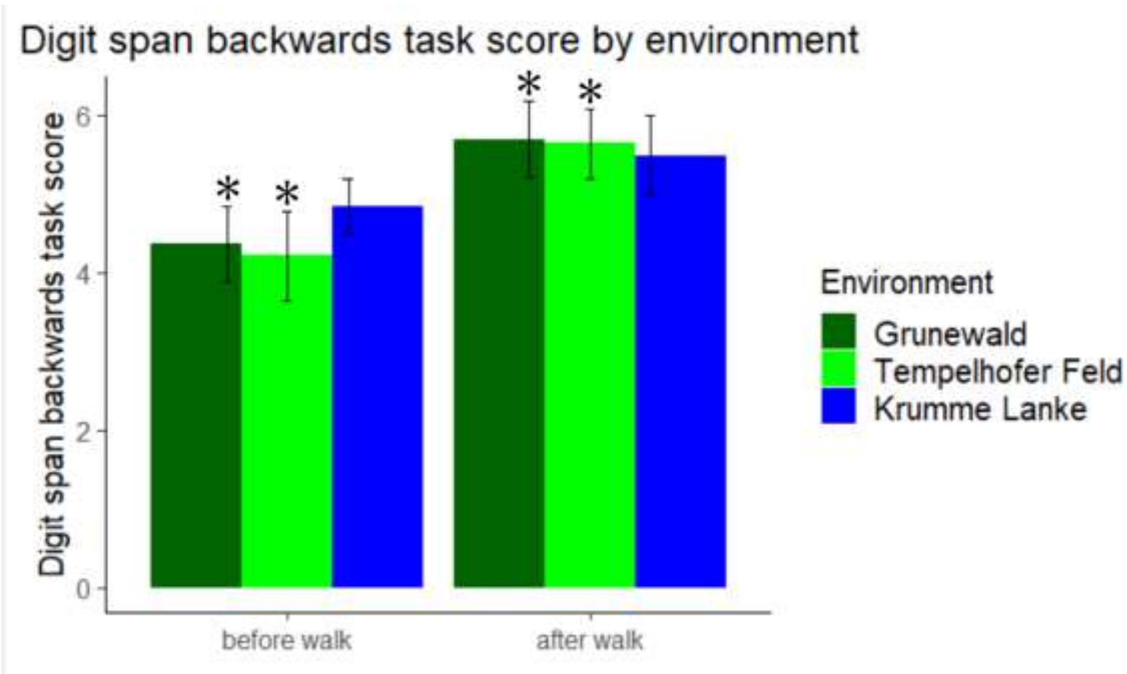

Figure 3*: Visualization of working memory (DSB) results per condition.* For all figures, significant differences between pretest and posttest indicated by asterisk (*P < 0.05) and error bars indicate one standard error of the mean.

Trait rumination results

There was no significant change between pre- and post-test levels of trait rumination in any of the environmental types, as shown in **Figure 4**.

Table 3*: Results of robust ANOVA for trait rumination*

Predictor	F-value	*p-value (FDR corrected)*
condition	0.8418	0.850
time*	2.7376	0.303
condition x time	1.1915	0.910

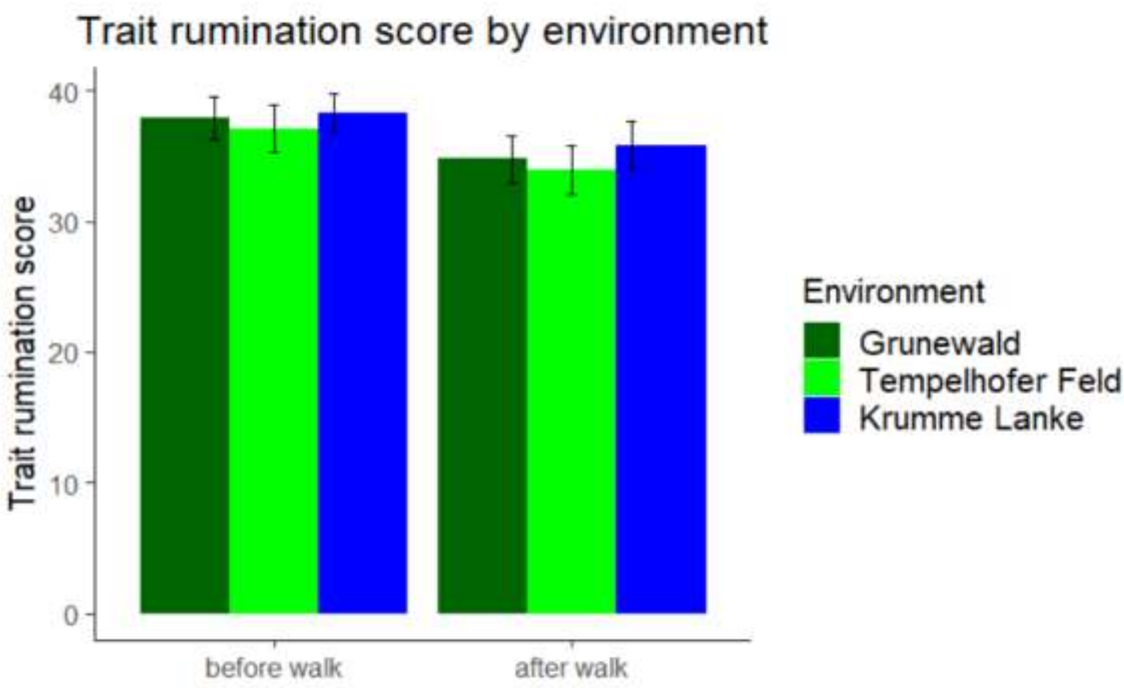

Figure 4: *Visualization of trait rumination (RRQ) results per condition.*

State rumination results

Again, there was no significant change between pre- and post-test levels of state rumination in any of the environmental types, as shown in **Figure 5.**

Table 4: *Results of robust ANOVA for state rumination.*

Predictor	F-value	*p-value (FDR corrected)*
condition	1.7204	0.849
time*	3.8975	0.303
condition x time	0.2215	0.655

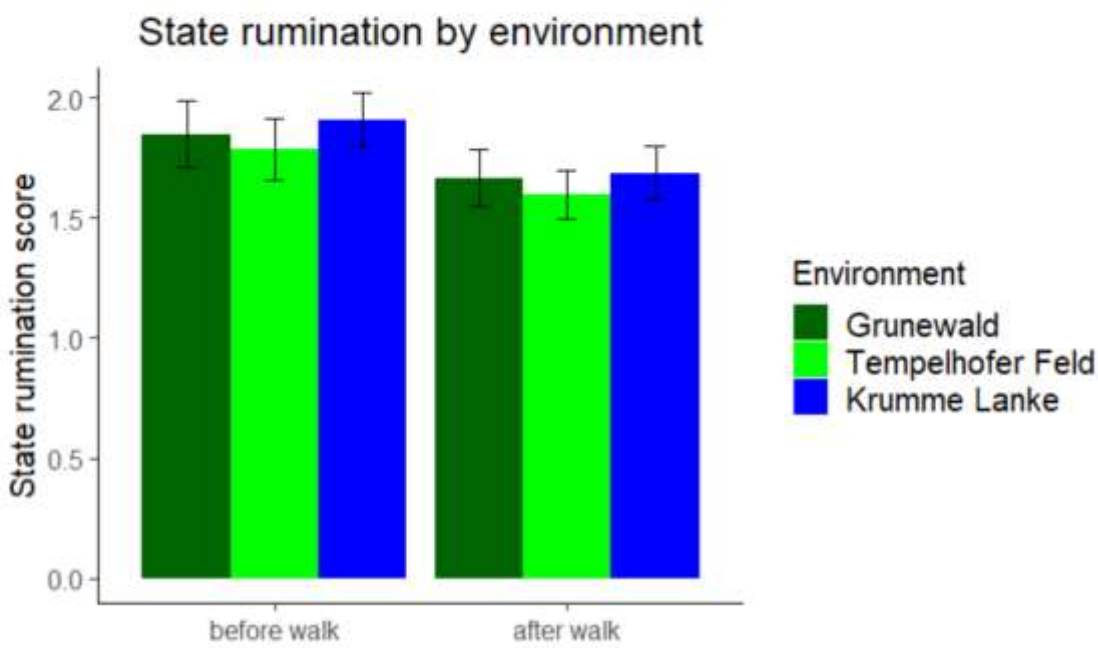

Figure 5: *Visualization of state rumination results per condition.*

Explorative analysis: Weather

The aim of the explorative analysis was to investigate if weather was a potential confounding factor in this study and if there are correlations between weather and working memory and rumination. Therefore, data for air temperature (in °C), sunshine (minutes during 60-minute walk), rain (defined as precipitation in liquid form only), and cloudiness factor (on an 8-point scale) were acquired from the German Meteorological Service (https://www.dwd.de/) for the weather stations in Berlin-Dahlem (for walks in Grunewald and Krumme Lanke) and Berlin-Tempelhof (for walks in Tempelhofer Feld). The choice for quantification of weather regarding these four variables was informed by the study by Sudimac et al. (2022). Data was retrieved for the time period from 04.04.2023 to 07.07.2023, with one data point for every hour.

Additionally, we were also interested in the participants' perception of the weather and their physical surroundings during their one-hour walk. Therefore, participants were asked to rate the following weather and environmental conditions regarding their walk on a visual analogue scale from 0 to 100 in a post-walk questionnaire: loud, cloudy, sunny, rainy, wet, and warm.

Firstly, to investigate if weather or the participants perception of weather were confounding factors of this study, one-way ANOVA for each of the weather variables (air temperature, sunshine, rain, and cloudiness) was conducted separately. Additionally, separate one-way ANOVA for each of the subjective perceptions of weather (loud, sunny, rainy, wet, warm) were conducted, to determine whether there were statistically significant differences between the three groups. Results are presented in **Table 4** below:

***Table 4**: Control variables for weather values in three different natural environments.*

Variable	Grunewald (n=33)	Tempelhofer Feld (n=33)	Krumme Lanke (n=33)	df	F-value	p-value
	Weather variables					
Day time: afternoon sessions (%)	*42.42*	36.33	42.42	2, 96	0.16	0.85
Air temperature (mean ± SD)[a]	*16.38 ± 6.5*	17.55 ± 6.25	17.42 ± 6.16	2, 96	0.34	0.72
Cloudiness (mean ± SD)[b]	*5.55 ± 2.15*	5.15 ± 2.35	4.97 ± 2.58	2, 96	0.51	0.62
Sunny: minutes during 60-minute walk (mean ± SD)	*31.88 ± 24.43*	38.45 ± 24.79	37.27 ± 24.76	2, 96	0.67	0.52
Rainy: walks in the rain (%)	*12*	12	15	2, 96	0.34	0.72
	Weather perceptions					
Loud[c]	*28.18± 19.37*	25.73± 21.50	29.82 ± 22.89	2, 96	0.31	0.74
Sunny[c]	*56.00± 33.98*	58.30± 31.73	55.7 ±37.86	2, 96	0.05	0.95

Rainy[c]	*9.8±25.12*	12.90±30.71	6.39±18.50	2, 96	0.55	0.58
Wet[c]	*17.64±25.12*	10.61±18.50	21.67±30.71	2, 96	1.36	0.26
Warm[c]	*58.56±18.51*	60.82±22.45	64.73±18.65	2, 96	0.80	0.45

Note: In all tables weather values relate to 60 minutes of the walking time; weather data were acquired from the German Meteorological Service (https://www.dwd.de/); df = degrees of freedom; n = 99 (based on Sudimac & Kühn, 2024).

a = Degree Celsius (°C)
b = Amount of cloudiness on an 8-point scale
c = self-reported perception on a visual analogue scale from 1 to 100

We observed no significant difference between the three conditions in any of the weather variables, suggesting that neither weather nor the perception of weather were confounding the main results of this study.

Secondly, linear regression analysis to examine potential effects of weather variables and perceptions of weather on changes in working memory, changes in trait rumination, and changes in state rumination were calculated. No correlations between weather variables (air temperature, cloudiness, sunshine, rain) or weather perceptions (loud, sunny, rainy, wet, warm) and changes in any of the dependent variables could be determined when assessing the whole sample as presented in **Tables 5-7** below:

Table 5*: Linear regression analysis between weather variables and weather perceptions and changes in working memory performance.*

Variable	**β**	**t-value**	**p-value**
	Weather variables		
Air temperature (mean ± SD)[a]	0.02	0.51	0.60
Cloudiness (mean ± SD)[b]	-0.15	-0.92	0.36
Sunny: minutes during 60-minute walk (mean ± SD)	0.01	0.13	0.89
Rainy: walks in the rain (%)	0.37	0.41	0.66
	Weather perceptions		
Loud[c]	-0.01	-0.19	0.85
Sunny[c]	0.23	2.13	0.37
Cloudy[c]	0.02	1.53	0.13
Rainy[c]	0.02	1.23	0.20
Wet[c]	*-0.01*	-0.76	0.45
Warm[c]	*-0.01*	-0.40	0.69

Table 6: *Linear regression analysis between weather variables and weather perceptions and changes in trait rumination levels.*

Variable	**β**	**t-value**	**p-value**
	Weather variables		
Air temperature (mean ± SD)[a]	0.01	0.95	0.34
Cloudiness (mean ± SD)[b]	0.03	0.87	0.39
Sunny: minutes during 60-minute walk (mean ± SD)	0.01	0.01	0.39
Rainy: walks in the rain (%)	0.42	1.82	0.07
	Weather perceptions		
Loud[c]	0.01	1.50	0.14
Sunny[c]	-0.01	-0.20	0.85
Rainy[c]	-0.01	-0.83	0.41
Wet[c]	0.01	1.37	0.18
Warm[c]	0.01	0.30	0.77

***Table** 7: Linear regression analysis between weather variables and weather perceptions and changes in state rumination levels.*

Variable	**β**	**t-value**	**p-value**
	Weather variables		
Air temperature (mean ± SD)[a]	0.06	0.07	0.39
Cloudiness (mean ± SD)[b]	-015	-0.61	0.55
Sunny: minutes during 60-minute walk (mean ± SD)	0.01	0.02	0.69
Rainy: walks in the rain (%)	-0.16	-1.07	0.29
	Weather perceptions		
Loud[c]	0.03	1.28	0.21
Sunny[c]	0.02	0.84	0.40
Rainy[c]	0.01	0.25	0.81
Wet[c]	0.01	0.64	0.53
Warm[c]	-0.02	-0.72	0.47

Subsequently, when examining correlations between weather and perceptions in weather with changes in working memory and rumination levels by natural environmental type, a weak negative correlation between sunshine and change in working memory performance after a walk in a covered green space was detected ($t(1)= -2.07$, $p=0.049$, SE=0.023). No other correlations for any of the three natural environments could be identified.

Chapter summary

This chapter provided an overview of the steps in data analysis that were taken as well as a presentation of the results. Data was checked for missing variables and winsorized, according to pre-registration. Wilcoxon rank-sum test for robust analysis was chosen, ss prerequisites for ANOVA were not meet. P-values were corrected with False Discovery Rate (FDR). No significant environment by time interaction was found. However, the factor time was significant in the working memory task. Finally, potential correlations between various weather variables as well as weather perceptions with working memory and rumination were assessed by linear regression analysis.

Discussion

This chapter critically discusses the presented findings and contextualizes them within the existing body of literature. Additionally, it addresses the most important limitations of this study and introduces ideas for future research directions.

Previous studies have demonstrated various benefits of nature exposure on overall health and well-being (R. Russell et al., 2013), including both physiological (Jimenez et al., 2021; Oh et al., 2017; Park et al., 2010) as well as psychological benefits (Bratman, Hamilton, et al., 2015; Oh et al., 2017). However, it is not clear yet, which type of natural environment is most advantageous and there is evidence for beneficial outcomes of both open green space (Gatersleben & Andrews, 2013; Kühn et al., 2023; Peschardt et al., 2016), covered green space (Astell-Burt et al., 2022; Park et al., 2010; Ulmer et al., 2016), and blue space (Nutsford et al., 2016; Ulrich, 1981). This study examined the effects of a one-hour walk in three different natural environments on working memory performance and rumination levels.

The analysis showed that there was no significant interaction effect between time and environmental type for working memory, trait rumination, and state rumination. Furthermore, when controlling for possible cofounding variables, it was shown that there were no significant differences between the three experimental groups with regards to demographic factors, weather variables and perceptions of weather. Subsequently, no correlations between weather variables and weather perceptions with changes in working memory and rumination levels could be detected when analyzing the whole sample. Yet, a statistically weak negative correlation between changes working memory and sunshine in the covered green condition was identified. The findings are discussed in more detail below.

Working memory

Although no significant interaction effect between location and time for any of the environmental type could be found, the working memory task showed significant results for the factor time. This indicates that working memory performance increased from before to after the walk. Since this change is independent of the type of natural environment, there are different possible explanations for this observation.

A likely reason for improved working memory over time independent of natural environment is a potential practice effect. Even though participants were administered different sequences of numbers in the pre and post DSB task, previous studies suggest that practice effects can influence the results in working memory tasks (Chen et al., 2019). Hence, there is a possibility that part of the improvements in working memory performance are due to the repeated participation in the task rather than due to the intervention alone.

Additionally, the increase in working memory independent of the natural environment also poses the question of whether the walk itself, as a physical activity, may have contributed to changes in working memory performance levels. Previous findings suggest that physical activity is associated with positive effects on brain structure and cognitive functions (Raichlen et al., 2020). Additionally, while no studies investigating the effects of walking on rumination levels directly could be found, there is evidence indicating that physical exercise mediates stress-related rumination on cortisol response (Puterman et al., 2011). Hence, while physical activity in nature seems to be the ideal scenario, it would be insightful to explore which role either of them play with regards to improved health and cognition, and what their interactions are. For this, it would be insightful to explore the physiological data collected in this study, i.e. to find out whether the positive findings by Park et al. (2010) regarding a lower heart rate can be replicated. However, the analysis of physical parameters was beyond the scope of this thesis.

Rumination levels

There were no significant interaction effects between time and environmental type for trait rumination and state rumination. As discussed in previous studies (Sudimac et al., 2024), trait rumination might not be the most suitable measure for this study because it includes items such as *"I often think about episodes in my life",* referring to the longer term, which is unlikely to change after an intervention of only one hour. Therefore, the lack of significant improvements in trait rumination was not surprising. However, for future studies it could be insightful to follow up on these findings through a longitudinal study design, investigating whether trait rumination scores change over time when being exposed to urban green and blue spaces. An interesting study to consider for this is the research by White et al. (2013), which found a beneficial effect of living close to nature on the mental health and well-being of more than 10,000 people over the course of almost two decades (White et al., 2013).

Considering the limitations of the trait rumination questionnaire for this study, the momentary state of rumination was additionally assessed in the form of three questions. However, no significant change from pre to post levels for any of the conditions could be detected. While this finding is in contrast to our hypothesis and previous research, i.e. Bratman et al. (2015), there are also other studies showing a null effect of nature exposure on rumination levels (Browning et al., 2023).

While reasons for this absence of significant effect on rumination are not completely understood yet, one possible explanation might be that the chosen study locations enclose mixed landscapes (combination of natural and human built objects), which is the case for most urban green and blue spaces. Although the most expansive natural environments in Berlin were selected for the walk, participants still reported on trash, loud music, highway noise, too many other people, e-bikes and scooters, cigarettes, and unpleasant scents. Especially Tempelhofer Feld is characterized by built structures, including concrete roadblocks and asphalt paths and frequently visited by people. Hence, some of the restorative effects of the natural environments might have been lost due to the influence of urbanization. In spite of significant changes in rumination levels, many participants still have indicated in an open question that they enjoyed the walk by sharing their thoughts, such as “I discovered a good place to swim” or “The trail was beautiful”.

In line with this, a recent publication by the World Health Organization (WHO) acknowledges the importance of accessible green and blue places for overall health and well-being (World Health Organization, 2021). The report highlights that especially during COVID-19 lockdowns, individuals particularly missed spending time in nature. As health benefits of exposure to natural environments are increasingly recognized, this report suggests that benefits may vary across the type and characteristics of natural environments. Though the report indicates that there is no "golden standard" of natural space that works for everyone, it suggests that different types of green and blue spaces generate different advantages and disadvantages, which also depend on the climate and vegetation.

Correlations with weather variables

Next to climate and vegetation, previous studies suggest that weather might have a great influence on psychological state, including effects on mood and cognitive functions (Beute & de Kort, 2013; Cao et al., 2023; Keller et al., 2005; White et al., 2021). For example, Keller et al. (2005) investigated the effects of weather on cognition and well-being, and found a positive association between pleasant weather (higher temperature) and mood, working memory, and cognitive flexibility. Furthermore, seasonality and time spent outdoors were suggested as primary moderating factors of the psychological effects of weather. In contrast to their findings, our study did not find significant correlations between air temperature and changes in working memory and rumination respectively. However, it needs to be considered that time regularly spent outdoors by the participants, which was mentioned as one of primary moderating factors, was not controlled in this study. As previous studies showed that visiting nature at least once a week is positively correlated with overall health and well-being (Martin et al., 2020), the frequency and amount of time spent outdoors by participants might have influenced the results. Additionally, research suggests that also self-reported levels of nature connectedness can mediate restoration in nature (Berto et al., 2018), which might further impact cognitive functions and perceived rumination. Thus, for future research, it would be interesting to also investigate potential correlations between time spent outdoors and nature connectedness and a change in the outcome variables.

Furthermore, Cao et al. (2023) suggests that the effects of weather on the restorative potential of urban green and blue spaces might differ by their specific features. For example, they found that areas with high sky visibility are more restorative on sunny days, while blue spaces are more restorative on cloudy days. Areas with low visibility of sky are equally restorative under both weather conditions. In our study, no differences in association between sunny or cloudy weather and changes in working memory or rumination could be found for high sky visibility (open green space) and blue space. However, a negative association between sunshine and change in working memory performance ($B=-0.047$, $SE=0.023$, $t=-2.07$, $p=0.047$) after a walk in covered green space was detected. Yet, it is important to be aware that this correlation is only statistically weak and the explanation for this observation is not clear yet. Further studies would be needed to confirm the results.

Reasons for a lack of significant correlations between weather variables and changes in working memory and rumination levels can be manifolded. Firstly, cognitive and affective phenomena, such as working memory and rumination are subject to multifactorial influences, including i.e. also sleep quality, diet, stress, and general mental and physical health (Gómez-Pinilla, 2008; Killgore, 2010; Lupien et al., 2009). These factors might have a stronger or more direct influence on the investigated variables than weather. Secondly, the study by Keller et al. (2005) suggests that while weather can influence cognitive functions and mood, these effects vary to a high degree among individuals. For example, some people might be highly susceptible to weather changes, while others are not. This variability among participants could possibly explain while no or only weak correlations with weather could be detected.

Next to differences among individuals, also study designs examining weather effects on psychological states largely differ. While the study by Keller et al. (2005) compared different conditions of participants walking (indoors and outdoors) and dancing (indoors) before engaging in the tasks, the intervention by Cao et al. (2023) allowed participants to sit or walk around in the assigned study locations. In contrast, in our study, participants were instructed to continue walking on a designated route without a break. Hence, the form and intensity of physical activity as well as the environment might have affected working memory and rumination more than weather.

Limitations

Notably, this study needs to be seen in light of several limitations. Firstly, there might have been individual differences among the participants, regarding their experience with scientific studies, working on a computer, and going for a long walk in nature on their own. As with many other studies within the field of human psychology, the occurrence of a WEIRD (Western, Educated, Industrialized, Rich, and Democratic) sample might also be a critical factor (Henrich et al., 2010). Furthermore, there were also some limitations regarding the protocol, which might have impacted the results. Most evidently, the taxi ride to and from the location for the walk was difficult to control. Thus, while the instructor of the study always gave the taxi driver the same guidelines, some participants remarked that the drivers were talkative, turned on music or that there was a smell of smoke in the car. Also, the problem of waiting for the ride of both the participant or the taxi driver might have possibly induced stress or reduced restorative effects of the nature walk. One potential solution to solve this issue might be to choose locations which are within walking distance from the experimental site or to use virtual reality instead. However, the latter might impact the ecological validity of the results.

Secondly, some participants also felt insecure about leaving their personal phone at the institute and going for the walk only with the phone provided by the Max Planck Institute. If participants voiced concerns that leaving their phone would lead to more stress than the walk might generate benefits, they were allowed to take their own phone but had to turn it off completely.

Thirdly, the choice of locations for the walk itself also raised some challenges. As mentioned before, Tempelhofer Feld incorporates many human built structures, including asphalt roads and old airport buildings, which might limit its perceived “naturalness”. Furthermore, lake Krumme Lanke also encompasses canopy, similar to the one in Grunewald Forest, which often prevents clear view on the water. While this is representative for most blue spaces in the metropolitan area of Berlin, also previous studies suggest that green and blue spaces often occur together: green spaces are dependent on water to stay green, while blue spaces are often included in green infrastructure, i.e. park lakes (White et al., 2020). However, the mixed occurrence of green and blue space might have diminished differences between the conditions. Thus, a solely blue space in a non-urban environment, i.e. the oceanfront, as investigated in the study by Dempsey et al. (2018) might lead to less ambiguous results.

Despite the limitations of this study, there are various possibilities to utilize the data and improve the protocol for future research directions. Extending the research to larger samples and various study sites would be beneficial as well as reducing the transportation to the study areas and identifying research locations with clear differences in landscape.

Future research directions

The findings of this study may point in various future research directions. Firstly, it would be interesting to compare the results on working memory and rumination levels of this study with the results from a one-hour walk in an urban condition, to see to what extent previous findings on the beneficial effects of nature exposure, i.e. by Bratman et al. (2015) can be replicated. The study by Sudimac et al. (2022), in which 33 participants went on a walk in a busy urban environment in Berlin, would be especially suitable for this. Comparing findings of this study with an urban condition would provide the opportunity to have a control group to better investigate which of the detected changes in working memory and rumination levels are likely due to the environment itself and which are due to other factors, i.e. physical activity.

Secondly, it would be insightful to focus on 'green prescription'. The approach of green prescription refers to the idea of 'bringing people to nature' by promoting participation in nature-based activities (Van den Berg, 2017). Green prescription can thereby be directed at the general population, i.e. in the form of green gyms or community gardens but can also be part of therapeutic approaches for individuals, including i.e. care farms, walk-and-talk mentoring, or horticultural therapy. A recent meta-analysis on the effect of nature prescriptions revealed beneficial outcomes for cardiometabolic and mental health as well as increases in walking (Nguyen et al., 2023). With more studies investigating the relationship between green spaces and therapy as well as drug prescriptions (Astell-Burt et al., 2022), they may find green prescriptions to be a more holistic and cost effective measure.

Further exploring the idea of green prescription could be especially important in the treatment of patients with depression. Thus, while many studies have shown beneficial effects of exposure to nature on rumination in healthy participants (Bratman, Daily, et al., 2015; Lopes et al., 2020; Owens & Bunce, 2022), so far, there is only little research investigating green interventions in the context of depressed individuals. However, considering that rumination is a core symptom of depression, it would be insightful to further study green prescription in patients. Interventions could, thereby, be in the form of a walk in nature as applied in this study but also through other means, i.e. nature-based meditation as suggested by Owens & Bunce (2022). Systematic comparisons of the effects of both different kinds of interventions as well as different types of nature, could aid to identify which are most suitable for decreasing rumination. Potential findings could contribute to green prescriptions specifically tailored for patients with depression but also inform future policy making on the integration of natural spaces.

Another potential idea for future research would be to explore the effects of nature exposure in virtual reality. As highlighted before, virtual reality might have the potential to decrease some of the confounder of this study procedure, i.e. by eliminating cofounding factors introduced by the taxi ride. Furthermore, virtual reality may offer opportunities for nature exposure for people with physical disabilities or persistent health conditions (H. Li et al., 2021) or more generally, when access to nature is limited (Reese et al., 2022). Various studies have found that nature exposure in virtual reality can lead to beneficial effects, which can be both psychological, i.e. improved restoration, attention, and cognitive functioning (H. Li et al., 2021; Reese et al., 2022; Yu et al., 2018) as well as physiological, i.e. decreased blood pressure and heart rate (Yu et al., 2018), and even to greater nature connectedness (Leung et al., 2022). Effects of nature in virtual reality have, thereby, consistently been shown to be comparable to effects from exposure to actual natural environments (Reese et al., 2022; Yu et al., 2018). A possible option for future research focusing on virtual reality would be to investigate different modalities, through which nature exposure is impacting psychological and physiological states, i.e. by only focusing on the effects of soundscapes versus visual input.

Chapter summary

This chapter discussed the findings of the study with relation to existing literature. No significant time-by-environment interactions could be found for any of the variables. Important limitations of this study include differences among participants, and issues related to the walk locations as well as the study protocol. Nevertheless, the findings are an interesting contribution to the field of environmental psychology, which could be explored by further studies in order to contribute to the concept of green prescription.

Conclusion

This study examined the effects of a one-hour walk in different natural environments on working memory and rumination levels in adults in Berlin. Drawing from current research, three conditions – open green space, covered green space, and blue space – were examined in comparison through an interventional study. Contrary to our hypotheses, no significant interaction between location and time for any of the conditions could be detected. While the study needs to be considered in the light of some limitations, it provides valuable insights by being among the first studies to experimentally test open versus covered green space and blue space in situ. The results give also rise to future research directions, potentially focusing on the concept of 'green prescription'. Thereby, findings could further inform policies and decision-making processes for the future development of urban green and blue spaces. Considering the growing impact of social and environmental challenges, such as urban deprivation, biodiversity loss, pollution, extreme weather events, and climate change, intersections between psychology and urban policy-making might become increasingly important in the future.

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