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Forests that restore – the effect of managed versus natural forests on human psychological restoration

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Academic dissertation

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ABSTRACT

Growing evidence indicates that forests enhance mental well-being by reducing stress. However, urbanization and intensive forestry in Finland are causing urban and peri-urban forests to decline, fragment, and become less accessible. Forests are also increasingly younger, more monocultural, and simpler in structure, potentially affecting their restorative quality. This is concerning, as city living is linked to mental health issues, with over 50% of Finnish disability pensions attributed to mental problems (OECD).

Research on the field has largely focused on comparing green and built environments or examining physical activity in nature. Many studies emphasize forest preferences, assuming that liked features predict restoration. However, these studies often rely on images rather than real forest settings, and the effects of different forest management regimes on restoration remain understudied. This dissertation seeks to address these gaps.

The dissertation examined four spruce-dominated forests with varying management levels: an urban recreation forest, a mature and a young commercial forest, and an unmanaged old-growth forest. Sixty-six participants visited each forest once. Psychological changes and forest preferences were assessed, and the influence of individual background and mental state on restoration across forest types was examined.

The mature commercial forest and old-growth forest were the most restorative, yet the results also showed that all forests reduced stress. The urban recreation forest was more restorative than the young commercial forest, but less so than the other two. Preferences varied, but the old-growth and mature commercial forests were the most valued. Perceived beauty correlated with restorativeness in all forests, while perceived biodiversity was linked to restoration in all except the urban recreation forest. While preferences and restoration were connected, the relationship was not entirely consistent. A notable association between work stress and restoration emerged in the old-growth and mature commercial forests, with a stronger effect in the old-growth forest. Additionally, risk of depression was significantly linked to restoration only in the old-growth forest.

These findings highlight the importance of preserving natural forests and maintaining ecological integrity in forests near residential areas.

Keywords: silviculture, stress, well-being, old-growth forest, mental well-being, forest characteristics

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TIIVISTELMÄ

Tutkimustieto metsien stressiä lievittävistä vaikutuksista mielenterveyteen on lisääntynyt. Tästä huolimatta kaupungistuminen on johtanut kaupunki- ja kehysalueiden metsien vähenemiseen ja pirstoutumiseen, ja intensiivinen metsänhoito on samalla yksipuolistanut niiden rakennetta. Metsät ovat yhä vaikeammin saavutettavissa, rakenteeltaan monotonisempia ja nuorempia, mikä saattaa heikentää niiden psykologisesti elvyttävää vaikutusta. Samalla, kaupunkiasuminen on yhdistetty mielenterveysongelmiin, ja Suomessa jo yli 50 % työkyvyttömyyseläkkeistä johtuu mielenterveyden häiriöistä.

Useimmat kenttätutkimukset elvyttävistä ympäristöistä ovat keskittyneet vertaamaan vihreitä ympäristöjä rakennettuihin ympäristöihin, tai liikuntaa näissä ympäristöissä. Metsien preferensseistä, kuten siitä, mitä ominaisuuksia metsissä pidetään miellyttävinä tai epämiellyttävinä, on tehty paljon tutkimusta. Preferenssien ja elvyttävien ympäristöjen välillä on ajateltu olevan myös yhteys. Mieltymystutkimukset perustuvat useimmiten valokuva- ja videotarkasteluihin, joissa visuaaliset ärsykkeet ovat keskiössä. Niissä ei tavallisesti ole kuitenkaan huomioitu kokemuksia aidoissa metsäympäristöissä. Harvemmin on myöskään tutkittu metsänhoidon tai luonnontilaisen metsän vaikutusta elpymiseen. Tämä väitöskirja pyrkii selvittämään näitä tutkimusaukkoja.

Neljä eri hoitotason kuusivaltaista metsää valittiin tutkimukseen: urbaani virkistysmetsä, hakkuukypsä ja nuori talousmetsä sekä luonnontilainen vanha metsä. Yhteensä 66 osallistujaa vieraili kussakin metsässä kerran. Metsäkäyntien yhteydessä arvioitiin psykologisia muutoksia ja metsien miellyttävyyttä, ja lisäksi tutkittiin, miten osallistujien taustatekijät ja mielenterveyteen liittyvä tilanne vaikuttivat elpymiseen eri metsissä.

Kaikki metsät elvyttivät eli lievittivät stressiä ja tehokkaimpia olivat hakkuukypsä talousmetsä ja luonnontilainen vanha metsä. Urbaani virkistysmetsä oli elvyttävämpi kuin nuori talousmetsä, mutta heikommin elvyttävämpi kuin kaksi vanhempaa metsää. Kahdesta elvyttävimmästä metsästä pidettiin myös kaikkein eniten. Koettu kauneus oli yhteydessä elpymiseen kaikissa metsissä, kun taas koetun biodiversiteetin ja elpymisen välille löytyi yhteys kaikissa muissa paitsi urbaanissa virkistysmetsässä. Mieltymysten ja elpymisen välinen yhteys tunnistettiin, mutta se ei ollut täysin johdonmukainen. Työstressin ja elpymisen välillä havaittiin yhteys luonnontilaisessa vanhassa metsässä ja hakkuukypsässä metsässä, mutta yhteys oli voimakkaampi vanhassa metsässä. Merkittävä yhteys havaittiin myös luonnontilaisessa vanhassa metsässä depressioriskin ja elpymisen välillä.

Tulokset korostavat luonnonmukaisten ympäristöjen säilyttämisen ja metsien monimuotoisuuden ylläpitämisen tärkeyttä asuinalueiden lähellä.

Avainsanat: metsänhoito, stressi, hyvinvointi, vanha metsä, mielen hyvinvointi, metsän ominaisuudet

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While working in the field of peatland ecology and climate change, I became increasingly concerned about how psychological well-being is connected to the ways in which we reshape our landscapes. This concern led me to combine forest sciences with psychology—an interdisciplinary journey that has now culminated in this doctoral dissertation. I want to express my gratitude to everyone who has enabled and been involved in the creation of this research. Alone, this would have been impossible.

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Helsinki, Finland 21.04.2025
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LIST OF ORIGINAL ARTICLES

The dissertation comprises the following articles, which are referenced by their Roman numerals in the summary text:

I Simkin J, Ojala A, Tyrväinen L (2020). Restorative effects of mature and young commercial forests, pristine old-growth forest and urban recreation forest – A field experiment. Urban For Urban Gree 48: article id 126567. https://doi.org/10.1016/j.ufug.2019.126567.

II Simkin J, Ojala A, Tyrväinen L (2021). The perceived restorativeness of differently managed forests and its association with forest qualities and individual variables: A field experiment. Int J Environ Res Public Health 18: article id 422. https://doi.org/10.3390/ijerph18020422.

III Simkin J, Ojala A, Tyrväinen L. The associations of natural and differently managed spruce forests on restoration among people with varying mental health state: A field experiment. Manuscript.

AUTHOR´S CONTRIBUTION

I In this article, the doctoral candidate conducted and was responsible for the data collection through field experiments and carried out the data analysis. The candidate drafted the initial manuscript, and the final version was collaboratively written with all co-authors.
This publication has not been used, nor will it be used, in any other dissertation.

II In this article, the doctoral candidate conducted and was responsible for the data collection through field experiments and carried out the data analysis. The candidate drafted the initial manuscript, and the final version was collaboratively written with all co-authors. This publication has not been used, nor will it be used, in any other dissertation.

III In this publication, the doctoral candidate conducted and was responsible for the data collection through field experiments and carried out the data analysis. The candidate drafted the manuscript, and the final publication, currently in draft form, will be collaboratively written

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1 INTRODUCTION

1.1 Human–nature relationship in a changing world

As humans, we seem to be culturally double-blind about our relationship to nature; we have a strong belief in human evolution and that we are part of nature, but at the same time we live inside the Western idea that has distinguished humans as being separate from nature (Martinez 2003). Nearly all of the natural environment around us has been altered by human activity, significantly impacting its quality. As a result, over 75% of the planet's surface is now covered by anthropogenic biomes (Ellis and Ramankutty 2008). In the European Union, for example, forests cover about 43% of the total land area, but only 4% of them remain unmodified (European Parliament 2019). The inevitable consequence of the scarcity of natural environments has been proven to affect the health and viability of different species and to further the decline of biodiversity. Although there have been several studies that have highlighted how dependent also people are on nature and its diversity (Hanski et al. 2012; Hiedanpää and Bromley 2016), the effects of the scarcity of natural environments on human health have been less studied. In fact, surprisingly little attention has been paid to the potential associations that the quality of nature has on well-being, and, to an even greater extent, whether the anthropogenic biomes have a different effect on human health and wellbeing compared to the unmodified environments.

1.2 Urbanization and the concurrent rise in mental health challenges

By 2050, approximately 68% of the global population is projected to live in urban areas (United Nations, 2018), a trend also observed in Finland, where new construction developments have increasingly replaced forests and other natural areas in major cities (Tiitu et al. 2017). As a consequence, a prominent share of urban residents have begun to defend their urban nature. Thus, attitudes towards a densified housing policy, i.e. infill development, in Finnish neighborhoods have undergone a recent shift. In 2010 over half of the respondents approved of infill development, but by 2016 the approval had dropped to only one-third (Tiitu et al. 2017).

At the same time, modern societies are confronted with the escalating challenge of a rising incidence of non-communicable diseases, with mental health problems being among the most severe. Physical and mental health are strongly linked: “There is no health without mental health” (Promoting Mental Health 2004). Modern urban living has brought many advantages to humans, but the modern lifestyle has also been connected to a passive and stressful lifestyle (WHO 2016). The increased level of physical inactivity has been identified as the major cause of chronic diseases (Booth et al. 2012), and the increase in exposure to environmental stressors such as pollution and noise is not helping (Hartig et al. 2011).

If this stressful lifestyle persists, it may contribute to depressive disorders (Hammen, 2005), which rank among the top causes of years lived with disability according to The Global Burden of Diseases, Injuries, and Risk Factors Study 2017 (GBD 2017). Paradoxically, while modern societies allocate substantial resources to treating mental health disorders, many of these conditions could be mitigated or even prevented through a stronger emphasis on proactive and preventive measures. Thus, the WHO has proposed supporting

natural environments as one solution to combat these challenges (WHO Regional Office for Europe, 2017), and has stated that in order to preserve human health the land-use pressure on natural environments should be reduced (Nature and Health 2021).

1.3 Forests in Finland: Management and recreational use

Human activities have significantly altered natural biodiversity, often leading to monocultural landscapes or substantial shifts away from the original diversity. The impact of anthropogenic influences is also evident in Nordic forests, despite the region being among the least densely populated and most forest-rich areas in Europe. For instance, in Finland, where forests cover 77% of the land area, approximately 86% of these forests are available for timber production (Peltola et al. 2019). Forest management practices typically produce more monocultural landscapes, with less diverse structure and fewer elements of biodiversity (Vanha-Majamaa et al. 2007). Such management practices, with a focus primarily on maximizing wood production, can temporarily diminish the recreational value of forests, particularly until they reach maturity (Silvennoinen 2017). Nevertheless, forests remain widely regarded as attractive landscapes by the public (Daniel and Boster 1976). Mature, managed forests are often appreciated for their aesthetic qualities, especially if management practices allow forests to reach sufficient maturity (Silvennoinen 2017; Tyrväinen et al. 2017). It is thus important to balance the production objectives with recreational and aesthetic values.

In Finland, the traditional aim of commercial forests has been to achieve the highest possible economic and timber quality yields. The even-aged forest management targeting to clear cut harvesting has been the most commonly used management system in Fennoscandia (Kuuluvainen et al. 2012), although in the future forest owners are planning to utilize uneven-aged forestry more extensively (Juutinen et al. 2020). The growth from clear cut harvesting to mature forest takes an entire human lifetime, even though the forest owners have a legal obligation for reforestation. An even age forest has been thinned several times before reaching maturity, resulting in sparse tree density with a relatively open view. Due to the canopy cover, there is often not much undergrowth in such forests, making it easy to walk through and thus often favored for recreational use. The young corresponding forest, conversely, is unappealing for recreational purposes due to its relatively monotonous appearance, resulting from its single-species composition and significantly higher tree density (Silvennoinen 2017; Miina et al. 2022).

The dominant tree species in Finnish commercial forests is pine (Pinus sylvestris), followed by spruce (Picea abies). Birch (Betula pendula) is considered the most economically significant deciduous species. However, recreational forests differ in their management from commercial forests. In recreational forests, management aims to prioritize landscape aesthetics, tranquility, biodiversity, and accessibility, in addition to ensuring visitor safety and forest vitality. Mixed tree species and uneven-aged structures are particularly favored, and the rotation period has been extended due to a desire expressed by recreationists to increase the proportion of old-growth forests (Saukkonen and Valkonen 2022). Even-aged management practices may also be applied in recreational forests, though typically on a smaller scale. Natural regeneration methods, such as small gap fellings that promote regeneration, are frequently employed.

In Finland, municipalities own the majority of urban forests and bear the responsibility for their management and safety. They follow a national forest maintenance classification

system that distinguishes forests used for recreation based on specific management objectives and restrictions (The Finnish Association of Landscape Industries 2020). The more significant a forest's role in recreation, the more its management diverges from conventional commercial forestry practices (Saukkonen and Valkonen 2022).

However, a considerable proportion of peri-urban and rural forests used for recreation and nature-based tourism are also commercial forests. Based on data presented by Neuvonen et al. (2022, Table 1), these areas are predominantly privately owned, accounting approximately 21% of such forests, whereas municipal ownership is around 6%, and state ownership around 3%. Only a small portion of local recreational activity took place on state-owned lands: less than 1% occurred in state recreational and hiking areas, around 4% in protected areas, and approximately 3% in multiple-use areas.

Although the majority of Finland's forests are under some form of management, a few patches of natural or near-natural forests have also been preserved relatively close to inhabited areas. These forests are typically Western taigas in their late succession stage - classified according to the Natura 2000 Habitat Directive Forest Type - where human activity has had little to no impact. The characteristic features of these forests include abundant dead standing and fallen trees, endangered species, diverse species composition, and a wide range of tree ages and sizes (Airaksinen and Karttunen 2001). Typically, these forests display a multilayered structure with varying gap dynamics driven by tree mortality (Kuuluvainen and Aakala 2011). These forests are remnants of the original Fennoscandian natural forests (Airaksinen and Karttunen, 2001).

Table 1. Finland's local recreation use instances by owner groups and purposes in 2020. Modified from the original table by Neuvonen et al. (2022).

Approximate share of recreation visits		%
Municipally-owned	Recreation and hiking area	49
	Conservation area	2
	Economic or multiple-use areas	6
	Total area	**57**
State-owned	Recreation and hiking area	1
	Conservation area	4
	Economic or multiple-use areas	3
	Total area	**8**
Owned privately or by others	Private conservation area	1
	Private economically use area, private land, or forest estate	21
	Other recreational area	6
	Total area	**28**
Privately-owned	Private holiday apartment	7

Forests have long provided Finns with livelihoods and wealth. The forest industry has been a major employer, and its share of exports has been significant. However, the forestry sector has been undergoing a transformation since the 2000s, with the aim of reforming the sector and ensuring a better forest future with improved social impact and value (Donner-Amnell 2022). The dominant discourse around wood production is also gradually losing its dominant position in Finnish print media (Takala et al. 2019). At the same time, the multi-use of forests has gained more attention and is one of the main concepts guiding European forestry (Hoogstra-Klein et al. 2017).

Besides being an engine of economic growth, forests have historically been an integral part of Finns' cultural identity, creating a distinct human-forest relationship (Halla et al. 2021). Forests play an important role as a place to relax, gather nature products, and boost physical activity. Thus, the majority of recreation visits among Finns take place in forests (Neuvonen et al. 2022). In forests, activities such as berry and mushroom picking, gathering firewood and other natural products, as well as hunting, are carried out. Forests are also used for activities such as observing nature, walking dogs, hiking, trail running, and mountain biking (Neuvonen et al. 2022). The importance of forests in supporting human well-being was clearly evident in the Finnish national recreational use inventory (LVVI) study, which explored, among other things, the motives for outdoor activities. Stress relief and relaxation in nature was the second most important motivation for engaging with nearby nature, mentioned by 83% of respondents, followed by the maintenance of physical fitness (Neuvonen et al. 2022). However, despite the significance of the amenity values provided by forests, the intensity of logging has remained high, the age of the forest regeneration has decreased, and the decline in biodiversity has not been halted (Kniivilä et al. 2020). Moreover, the growing trend of urbanization is exerting mounting pressure on land-use, thereby limiting the opportunities to increase the number of individuals able to connect with these natural spaces. As this happens, the remaining nature takes on an even more important role.

1.4 Well-being effects of nature and the importance of its quality

A considerable number of studies have identified the positive effects that nature has on human health and well-being (e.g. van den Bosch and Ode Sang 2017; Brito et al. 2022). According to Pereira et al. (2021), by increasing the exposure to green spaces in European cities, numerous premature deaths could be avoided. Even short-term visits to nature are found to be good for mental and physical health (Beil and Hanes 2013; Tyrväinen et al. 2014). Nature exposure enhances the positive mood and decreases the negative mood (Korpela and Ylen 2009; Park et al. 2011; Tsunetsugu et al. 2013). It increases vitality (Ryan et al. 2010; White et al. 2013; Tyrväinen et al. 2014) and perceived restoration[1] (van den Berg et al. 2003; Pasanen et al. 2018) and eventually helps to reduce stress (Ulrich et al. 1991; Hartig et al. 2003). Thus, Shanahn et al. (2016) suggests that nature visits could be of great help in preventing the increasing numbers of mental illnesses such as depression. Visits to nature also lower blood pressure (Yau et al. 2020; Liu et al. 2021) and the level of saliva cortisol

[1] In environmental psychology, **restoration** (elpyminen in Finnish) refers to the potential improvement in attention and relief from mental fatigue when spending time in or observing nature (Kaplan, 1989). According to ART and SRT, replenishing cognitive resources and physiological markers also leads to reduced stress levels.

(Tyrväinen et al. 2014; Saito et al. 2019). Moreover, compared to walking trips in the city, walking in the forest increased the levels of intracellular anti-cancer proteins in the forest group, but not in the city group (Li et al. 2008). Overall, there is substantial evidence, particularly regarding stress relief in nature environments, showing that nature plays a significant role in preventing and maintaining well-being (Bowler et al. 2010; Hartig et al. 2014; Cheng et al. 2021). What kind of nature is most effective in illness prevention and stress relief however, is still unknown.

Not only the presence of nature environments, but also their quality (see Table 2 for the definition used in this study) and diversity—encompassing both species richness and environmental variability—appear to influence health and well-being. However, few studies have examined whether more natural areas have distinct effects on human health. A 21-year follow-up study by Engemann et al. (2019, 2020) found that growing up near natural areas in urban settings was associated with a reduced risk of developing mental illnesses, such as schizophrenia. The researchers emphasized that the protective effects of nature may be more strongly linked to its quality rather than mere quantity. Similarly, Donovan et al. (2021) reported that early-life exposure to diverse natural environments during the first two years of residence protected children in New Zealand from leukemia.

While studies such as Engemann et al. (2019) and Donovan et al. (2021) have primarily relied on vegetation indexes or land cover data—often at a relatively coarse scale—these findings highlight the need to further investigate the importance of the quality of our remaining natural environments.

Finally, the growing study evidence supporting the biodiversity hypothesis, according to which contact with natural environments is good for our health, underlines the importance of more diverse environments; e.g., the increasing prevalence of inflammatory disorders and allergies in humans has been linked to the lack of microbial biodiversity in our living environments (Hanski et al. 2012; Lehtimäki 2017; Haahtela 2019). Incorporating diverse natural elements into urban settings resulted in the diversification of children's microbiota and enhanced the regulation of their immune system (Roslund et al. 2020, 2021). There is also a theory that being exposed to microbial species present in natural surroundings may contribute to mental well-being by impacting on human immune responses (Schmidt 2015). Nonetheless, there are numerous pathways through which nature influences human well-being (Marselle et al. 2021a). Figure 1 illustrates the various mechanisms by which nature can impact human health and well-being.

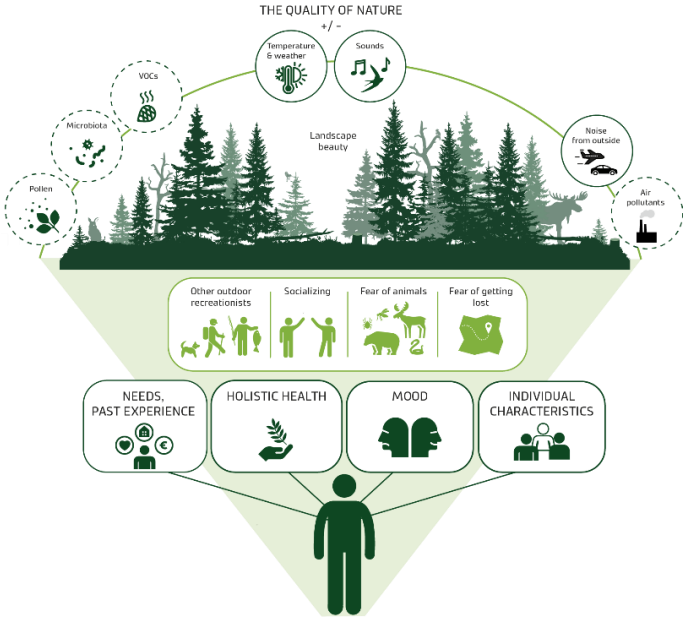


Figure 1. Pathways through which nature can affect the holistic health of humans. The quality of nature encompasses all aspects perceived through the senses, such as the forest's aesthetic values and perceived biodiversity. Moreover, for example the pollen and the actual biodiversity, such as microbiota, can affect humans physically and mentally. In this dissertation, all of the pathways shown in this figure were considered, except for those indicated by dashed lines. VOCs = Volatile Organic Compounds, including terpenes and phytoncides.

1.5 Gaps in the knowledge

Mental health disorders are placing a growing burden on public health systems, necessitating new approaches to prevention and intervention. This dissertation explores how forest environments contribute to mental well-being, aiming to provide insights for forest management and land use planning to promote health-supportive environments. A deeper understanding of how both natural and modified environmental elements affect well-being is crucial, particularly in Finland, where forests play a significant role in national identity.

Despite the common assumption that all forests provide restorative benefits, forests vary considerably in their characteristics. Many forests have undergone some degree of management, affecting structural features such as stand age, brightness, walkability and also biodiversity. Commercially managed forests, in particular, often differ significantly from pristine forests. However, we lack sufficient knowledge on how different forest management regimes—whether in commercial, recreational, or protected forests—affect perceptions of restoration and well-being.

Forest management plays a critical role in balancing ecological, economic, and social objectives, yet its impacts on human well-being remain underexplored. The limited research

in this area is partly due to the scarcity of studies conducted in real-world forest settings, especially those comparing different types of managed and unmanaged forests.

Previous studies on forest exposure have largely focused on wilderness hiking, where participants spend prolonged periods in remote settings (Kaplan and Kaplan 1989). While valuable, such research does not adequately reflect the more common short-term visits to nearby forests. At the start of this doctoral research, only a few had investigated brief visits to different types of forests, such as those by Martens et al. (2011) and Sonntag-Öström et al. (2011; 2014; 2015).

Martens et al. (2011) found that managed forests elicited stronger changes in affect compared to "wild" forest. However, the wild forest had undergone some management practices relatively recently. Sonntag-Öström et al. (2011; 2014; 2015) found no significant differences in restorative effects between forest types, but identified key environmental characteristics (e.g., openness, brightness, peacefulness) that were preferred by individuals with exhaustion disorder. However, these studies did not focus on comparing the natural forests to managed forests.

Another critical knowledge gap concerns the role of individual differences in shaping well-being effects. While Martens et al. (2011) found no associations between sociodemographic factors and well-being outcomes, other studies suggest that nature connectedness and nature orientedness may play a role. For example, Davis and Gatersleben (2013) found that individuals with stronger nature connections reported more awe-inspiring experiences in wild settings, while Ojala et al. (2019) found that individuals with low urban-orientedness experienced greater restoration in urban park and forest compared to a built environment.

Research has also shown that nature environments can offer greater psychological benefits for individuals with mental health challenges. Previous research suggests that individuals with poorer mental health may derive greater benefits from walking in rural settings compared to those with better mental health (Roe and Aspinall, 2011). However, individuals with poorer mental health also experienced positive effects from urban walks, whereas those with better mental health did not show similar benefits. Another study found walks in urban settings had even negative effect for individuals with psychosis (Ellett et al. 2008). While it is widely accepted that restorative needs vary between individuals (Hartig 2007), there is still a lack of empirical research on how these experiences differ across subpopulations.

A substantial body of research has examined human perceptions of landscapes and forests, consistently indicating that people exhibit universal preferences for certain natural elements (Ulrich, 1983; 1986). These preferences appear to be cross-cultural (Herzog et al. 2000) and may originate from an inherited tendency to favor environments that historically supported survival (Kaplan and Kaplan 1989). Commonly preferred features include large, mature trees, brightness, and good visibility (Karjalainen 2000; Silvennoinen et al. 2001). Additionally, individuals tend to appreciate forests that provide a sense of safety and where it is easy to walk (Herzog and Kutzli 2002; Tyrväinen et al. 2003). Various evolutionary theories have been proposed to explain these preferences, and while modern survival strategies have shifted, the underlying evolutionary-based theories have not been disproven.

While people may prefer certain nature environments, these preferences do not necessarily align with the environments that provide the most restorative benefits, although some studies have identified a relationship between preference and restoration (Staats et al. 2003; van den Berg et al. 2003; Korpela and Ratcliffe 2021). Findings remain particilarly inconsistent when comparing managed and natural forests. For example, Martens et al.

(2011) found that perceived attractiveness was not associated with changes in well-being, raising questions about the relationship between visual appeal and restorative outcomes. Similarly, Takayama et al. (2017b) reported that while both thinned and unmanaged forests provided similar restorative experiences, participants preferred the thinned forest over the unmanaged one. Likewise, Han (2010) found that restoration was not a strong predictor of preference or scenic beauty, whereas Chiang et al. (2017) observed that optimal stress reduction occurred in the most preferred interior forest locations.

Many preference studies still rely on static images to investigate the affective responses, but there has been criticism regarding whether these methods of depicting landscapes are equally effective in eliciting emotional responses in viewers (Thompson 2012; Silvennoinen et al. 2022). Thus, preferences for scenes of the same forest landscape, created using different visualization methods, have been observed to have little correlation between them (Daniel and Meitner 2001). Nonetheless, the preference for an image is not a reflection of a multisensory experience, and thus cannot be representative of the holistic experience. Therefore, the associations between preferences in general and the restoration of authentic forest environments remains unclear.

To comprehend these gaps, we must first explore the mental well-being effects experienced in authentic forest environments and then compare the findings with the results of what kind of forest people prefer. By reflecting on the current knowledge we have on forest preferences, we can explore whether these properties are the same as those that provide the mental well-being effects. To understand the results, a theoretical understanding for both the preferences and well-being effects has to be cross reflected. Moreover, considering the impact of individuals' background variables, it is essential to determine whether these factors may lead to varied outcomes across various environments.

1.6 Aim and structure of the dissertation

The overall aim of this dissertation is to study whether forest management has an effect on how the forests contribute to psychological well-being, as well as to explore what forest characteristics are associated with higher restorativeness. Changes in psychological well-being are assessed using restorative effects, which include changes in restoration, vitality, and emotions.

Furthermore, the aim was to find out whether individuals with different sociodemographic and individual characteristics (such as their relationship to nature or mental well-being status) experience restoration differently in varying types of forests. By integrating approaches from both preference and psychological well-being research, this dissertation also seeks to deepen the understanding of how forests support human well-being. Simultaneously, the consistency between preferences and well-being outcomes is examined.

Finally, the study aims to provide insights into how forest management practices could better account for human well-being, informing future forest operations and land-use planning. Figure 2 illustrates the main research approaches and how the key metrics are organised under each of them in this dissertation.

To address these aims, forests representing typical commercially and recreationally used forests in the region, as well as a forest in as natural a state as possible, were selected for the experimental setup. The research aims of this dissertation can be summarized with the

following questions (the sub-study in which the topic was investigated is indicated in brackets).

1. How does forest management impact restorative effects? (I)
2. How do perceived (restorative) qualities differ in differently managed forests? (II)
3. How do individual variables effect perceived restorativeness (PRS), restoration (ROS), and the perceived qualities of a forest? (II, III)
4. What are the linkages between preferences and restorativeness/restoration? (I, II, III)

Three individual studies in this dissertation assess interdisciplinary people-environmental interactions through the linkages of silviculture and environmental psychology. Although this dissertation weighs mostly on the restorative environment research tradition, it also applies other theories from the landscape preference field and urges utilizing several theories to explain complex multidimensional processes. This dissertation does not consider landscape planning, environmental psychology, or forestry as separate entities, but rather as interconnected disciplines. The focus of the studies is on the effects of short-term forest visits to different types of forests on psychological well-being.

The summary of this dissertation proceeds as follows:

First, key concepts relevant to this study are introduced. This is followed by a brief overview of how nature is perceived, after which the focus shifts to presenting theoretical perspectives and research findings on forest preferences and the psychological well-being effects of nature and forests. Additionally, research findings on individual differences in well-being effects are presented. Next, the research methods and results are described, followed by a discussion of the research questions in light of the findings. This is achieved by evaluating the quality and appearance of forests through psychological changes over time. Subsequently, the dissertation accumulates knowledge on the association between forest characteristics and individual differences in restoration. Additionally, the potential influence of mental well-being—specifically perceived stress and depression—on restoration across different forests is examined. Furthermore, the interconnections between human mental well-being and preferences are explored. Finally, conclusions are drawn, and potential implications of the findings are discussed.

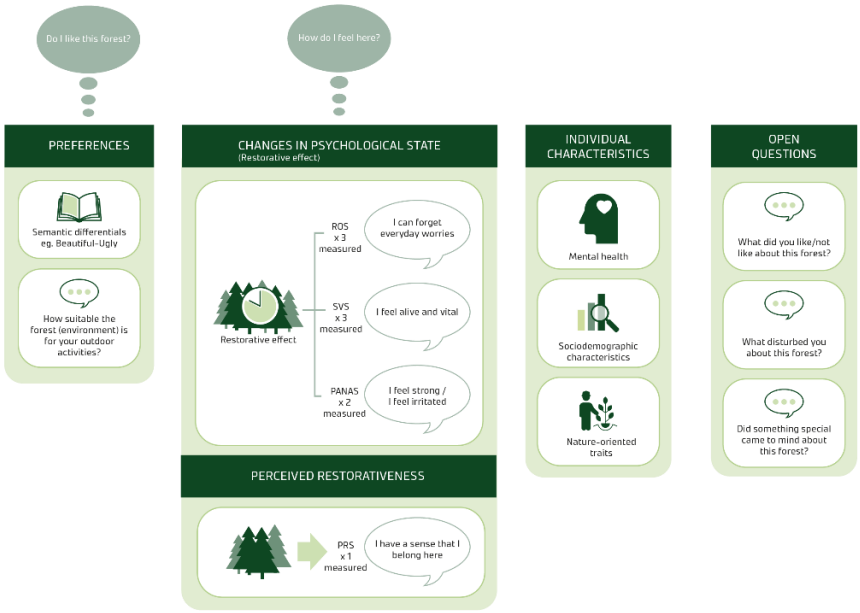


Figure 2. The research questions in this dissertation were approached by examining several aspects of participants' experiences: their preferences for the forests, whether they experienced stress relief (i.e., changes in psychological state during the visit), their perception of the forest's restorativeness, the influence of individual variables, and the role of forest characteristics in shaping the overall experience. Abbreviations: ROS = Restoration Outcome Scale, SVS = Subjective Vitality Scale, PANAS = Positive and Negative Affect Schedule.

1.7 Key concepts

1.7.1 Health, well-being, and stress

According to the World Health Organization, "Health is a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity" (World Health Organization 1948). This definition highlights the multidimensional nature of health and underscores the importance of mental and social factors alongside physical health. An essential component of maintaining health and well-being is effective stress management.

The stress response has historically helped humans survive in challenging situations. It triggers the fight-or-flight response, leading to physiological changes such as increased heart rate and adrenaline production (Nolen-Hoeksema 2009). These responses enable rapid reactions, which in critical situations can be life-saving. However, while acute stress is a natural and beneficial reaction, prolonged stress can have detrimental effects on both physical (Brotman et al. 2007) and mental health (Marin et al. 2011).

When stress persists over time, the body attempts to adapt by activating the stress regulation system, known as allostasis (Hintsa et al. 2019). Allostatic load results from

prolonged maladaptation, where the body continuously strives to maintain balance through allostatic processes (McEwen 1998). Chronic overactivity or underactivity of these processes can accumulate and negatively impact multiple organ systems, ultimately contributing to disease (McEwen 1998). Given the serious consequences of chronic stress, there has been a growing interest in developing stress reduction interventions, particularly in workplace settings.

Within the WHO definition of health, this dissertation focuses specifically on mental well-being as a foundation for mental health, further exploring strategies to support and maintain mental well-being.

1.7.2 The quality of nature - in the context of naturalness or managed quality

The concept of "quality" in nature can encompass a wide range of factors. When considering the diverse array of environments that fall within the scope of terms such as "green environment" or "natural environment," or simply under the umbrella of "nature," we realize the extent of the scale involved. In practical terms, many studies do not exclude human-made elements when defining nature or natural environments (Hartig 2014). Thus, our relationship with nature is inherently anthropogenic. In fact, more than 75% of the planet's ice-free land has been transformed into anthropogenic biomes (Ellis and Ramankutty, 2008). This human-centric perspective is evident even in our language when discussing nature. For example, in Finnish, the term "forest" traditionally encompasses not only natural forests but also commercial forests, without explicitly distinguishing between them with prefixes such as "commercial" or "protected. However, it is evident that natural forests and commercial forests vary significantly in their characteristics and attributes.

The public perceives a wide range of green environments as representations of natural settings (Hartig et al. 2011). However, the term "natural" in English is inherently imprecise, with its meaning shaped by social, cultural, and historical contexts (Shrader-Frechette and McCoy 1995). In an ecological context, it typically refers to an environment that lacks apparent signs of human intervention.

Despite this, prevailing definitions of "natural"—and even "forest"—often overlook ecologically significant elements characteristic of natural forests, leading to misrepresentations of biodiversity patterns within these ecosystems (Rouvinen and Kouki 2008). Similarly, the terms "natural" and "wild" have been inconsistently applied in environmental psychology research.

For example, in studies comparing the health effects of built and natural environments, "natural" frequently refers to urban parks or woodlands, rather than genuinely natural or wild landscapes. Likewise, in studies contrasting managed and unmanaged forests, the latter often includes forests that have only recently been left without management—sometimes for just a few years—rather than truly long-term unmanaged forests that have developed over decades.

Theoretically, a "pristine" or "natural" forest is a place without human interference. For instance, the boreal forests in the northern regions, which do not have any signs of forestry or agriculture, are often considered intact, pristine forests (Josefsson 2009). However, many of these remote forests have been inhabited for generations, serving as resource areas for local communities. As a result, they cannot universally be regarded as pristine reference conditions, even in the absence of recent management (Josefsson 2009). Given the pervasiveness of human influence, defining pristine forests in absolute terms remains challenging (Rouvinen and Kouki 2008). Ultimately, the interpretation of these terms varies

across cultural contexts; for example, what is considered “wild” or “old-growth,” as well as perceived level of naturalness in forests, may differ significantly between Nordic countries and southern Europe (O’Brien et al. 2021).

In this dissertation, the term “pristine” forest is used in places to refer to the natural old-growth forest to ensure consistency and clarity in terminology. However, it is important to acknowledge that this forest has been influenced by surrounding agricultural activities, and light selection felling was conducted near the experimental area approximately 70 years ago. Additionally, it remains uncertain whether any forest management practices were applied directly within the experimental area over a hundred years ago. The forest is classified as Western taiga (Boreaaliset luonnonmetsät in Finnish) under the NATURA 2000 Habitat Directive, with the habitat code 9010 (Natura 2000 2015). Furthermore, since the definitions of “old-growth”, “old” and “mature” forests may sometimes overlap, referring to this forest as “pristine” serves to prevent potential confusion.

In addition to a forest’s naturalness or management state, many other characteristics influence its overall quality. These include forest type, size, stand age, structure, brightness, openness, variability, biodiversity including microbiota, soundscape, external noise levels, and perceived safety. Furthermore, factors such as volatile organic compounds (VOCs), pollen, emissions, temperature, and seasonal variations can also influence forest quality. This study examines a selection of these characteristics, while aspects such as VOCs, pollen, microbiota, emissions, and seasonality are not included in the analysis. Also, infrastructure elements within forests, such as fireplaces and rest areas, were excluded from this study. However, trail networks were included, as they are an integral part of the forest experience and cannot be considered separately from the forest itself.

1.7.3 Landscape and scenic beauty

The concept of landscape has been studied across multiple disciplines, including landscape architecture and design, landscape ecology, geography, and forestry. As an analytical term, “landscape” is complex and varies in definition depending on the authority. For instance, the European Landscape Convention defines landscape as “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe 2000). This “area” typically refers to a broader entity that collectively forms a landscape.

While this dissertation draws on environmental psychological theories on restorative environments, it also incorporates frameworks from landscape research. However, the primary focus is on forests within the landscape, rather than the landscape itself. Therefore, although theories from landscape research are relevant, the emphasis remains on understanding the role of forests in promoting well-being.

The concept of beauty has long been explored in philosophy, with Greek philosophers laying its early foundations. However, it was not until the 18th century that Immanuel Kant established the basis for the aesthetic appreciation of nature. Additionally, naturalist Charles Darwin contributed to this understanding by explaining that the human experience of beauty in nature evolved gradually through evolutionary processes (Pitkänen 2004).

In landscape preference research, early studies focused primarily on aesthetics, particularly through the expert paradigm, which examined experts' perceptions of visual quality (Zube et al. 1991). Psychologists studying environmental aesthetics frequently emphasized the role of complexity, as described in Kaplan and Kaplan's Preference Matrix

(Kaplan and Kaplan 1989). However, the beauty of landscapes and nature is not solely determined by their physical features, but also by the observer's perception (Laurie 1975).

Furthermore, the experience of beauty in nature is influenced by cultural and individual variables (Kaplan and Herbert, 1987; Tyrväinen et al. 2010). Silvennoinen (2017) also notes that evaluating forest landscapes from a purely aesthetic and objective perspective may be impossible, as observers are never entirely external—their perceptions are influenced by expectations of how the area could be used, such as for recreation or conservation. Table 2 summarizes the key concepts used in this dissertation

Table 2. Definitions of the key concepts of this dissertation.

Concept in English	Concept in Finnish	Definition of concept
Forest regime	Metsäregiimi/ Metsänhoidon järjestelmä	A forest regime refers to the overall system for managing and governing forest resources, with the goal of balancing ecological, economic, and social objectives.
Health and well-being	Terveys ja hyvinvointi	State of complete physical, mental, and social well-being.
Landscape	Maisema	An area perceived by people as a unique space shaped by the interplay of both natural elements and human activities.
Mental health	Mielenterveys	Mental health is discussed when there are diagnosed illnesses.
Mental well-being	Mielen hyvinvointi	Since this dissertation does not address potential diagnoses individuals might have, the term “mental well-being” is used when discussed the results of this dissertation.
Preference	Maisema-arvostus tai mieltymys	The preference for a scene is indicative of the viewer's individual appreciation of it, including the extent to which the viewer finds it appealing (Kaplan and Kaplan 1989).
Restorative effects / changes in psychological state	Elvyttävä vaikutus / muutos psykologisessa kokemuksessa	Temporal change in psychological state, i.e. restorative effects, including perceived restorative outcome (ROS), vitality (SVS), and positive and negative emotions (PANAS).
Scenic beauty	Maiseman kauneus	The feature of the object according to its perceiver, whose cultural background, individual variables, and expectations affect the perception. Often aestheticians’ description for aesthetic preference (Thompson 2012).
Stress	Stressi	A state of emotional or mental strain or tension resulting from adverse or demanding circumstances.
Older forest	Iäkkäämmät metsät	The term “older forests” refers to a stage where the predominant tree stand has reached at least the economically viable regeneration age (Airaksinen and Karttunen 2001).
Quality of (nature) / forest	(Luonnon) / metsän laatu	The different levels of naturalness in a (nature) / forest from an anthropogenic perspective (pristine, wild, natural, managed etc.), and the different quality attributes of a forest that research has shown people appreciate. Note: This definition applies in this form only in this dissertation.

2 THEORETICAL FRAMEWORK OF THE DISSERTATION

2.1 Two main perspectives on perceiving the landscape

The concept of landscape quality encompasses ecological, cultural-historical, aesthetic, and well-being values, which have been widely studied across multiple disciplines. Researchers have sought to understand how individuals perceive and interpret their surroundings, as well as the cognitive processes involved in this perception. Many empirical studies in this field primarily utilize visual methods to provide insights that inform land-use planning and forest management. Landscape architects and landscape ecologists define landscapes in a site-specific manner, whereas humanists place greater emphasis on human emotions and aesthetic perceptions (Kontturi 2000; Silvennoinen 2017). There are several different approaches to studying visual landscape quality (Daniel and Meitner 2001), among which the subjectivist and objectivist perspectives are most widely recognized (Lothian 1999).

In the objectivist approach, aesthetic quality is considered an inherent property of the physical landscape. In contrast, in the subjectivist approach, it is regarded as a mental construct shaped by perception. Planners and designers have predominantly relied on the objectivist perspective, where experts evaluate visual landscape quality (Tveit et al. 2012). The outcomes of this approach are easily applicable in management practices, as they provide clear, measurable data, such as respondents' preferences for forest stand density. Conversely, research in visual landscape assessment has more usually applied a subjectivist approach, in which laypeople assess visual landscape quality (Tveit et al. 2012). Within this framework, environmental perception is shaped by cognitive and affective processes (Tveit et al. 2012). When individuals perceive their environment, their responses are influenced by their past experiences, future expectations, and sociocultural background (Zube, 1982). For instance, people organize their perceptions using various criteria, including aesthetic appeal and perceived safety. In contrast to the objectivist approach, the subjectivist approach has been less often used in practice, as it focuses on the cognitive processes and mind of the individual and is therefore more difficult to implement (Thompson 2012). The division between these approaches has been discussed by Ruddel et al. (1989), who highlight the limitations of each approach, and therefore a holistic understanding that requires integrating both approaches.

This doctoral dissertation examines how different forest environments are perceived, which characteristics are valued, and how these perceptions relate to well-being outcomes. The study also explores how individual differences—such as personal background, relationship with nature, and mental well-being status—shape restorative experiences in forests. The theoretical framework integrates landscape perception theories, environmental psychology, and cognitive processes, recognizing that well-being effects are influenced by past experiences, sociocultural background, and future expectations (Figure 3). By applying a multidisciplinary approach, this research aims to provide scientifically grounded insights into the links between forest management, landscape quality, and human well-being, offering valuable perspectives for land-use planning and forest policy development.

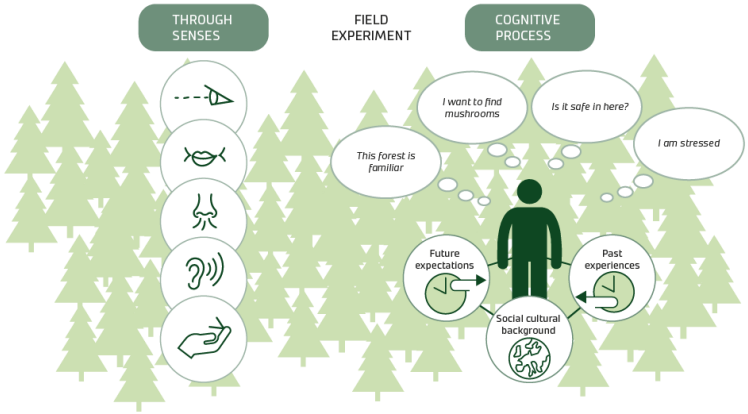


Figure 3. Conceptual framework of the forest experience in this dissertation. The experience arises from the interaction between sensory input (e.g., sights, sounds, smells) and cognitive processing (e.g., safety evaluation, memories), shaping how the forest is interpreted and how it influences well-being.

Various theoretical models have been developed within different psychological frameworks to explain how and why humans experience the environment. Some of these theories are strongly rooted in evolutionary perspectives, explaining our innate inclination toward certain natural environments. These theoretical models serve as a foundation for understanding landscape perception and restorative experiences in forests. The following section introduces the most relevant theories, beginning with those related to landscape preferences, which are further explored alongside empirical findings. This is followed by an overview of theories on restorative environments, after which empirical research on these environments is presented. Lastly, the section examines how studies have addressed individual differences in the experience of well-being in natural settings.

2.2 Theories on landscape preferences and their empirical examination

2.2.1 Four key theories

Despite individual differences in background factors such as demographics, research on environmental preferences shows remarkable consistency across various settings (Kaplan and Kaplan 1989). The widely applied Biophilia Hypothesis (Kellert and Wilson 1993) suggests that humans are naturally drawn to environments that enhance survival. Similarly, the ability to perceive and assess surroundings helps individuals detect potential dangers, while a preference for safe environments further supports well-being (Appleton 1975; Kaplan 1982). Additionally, familiarity with nature can contribute to a greater sense of safety and make the environment easier to interpret.

Landscape preferences have been widely explained through four main theoretical frameworks: the preference matrix, prospect-refuge theory, psycho-evolutionary theory, and

habitat selection theory. Also these theories share the common idea that humans favor landscapes with features that historically supported survival, highlighting their evolutionary basis.

According to the preference matrix proposed by Kaplan and Kaplan (1989), individuals develop an appreciation for their environment by actively exploring and interpreting nature. Humans have an inherent need to explore, and preferred environments support this need by offering clear and coherent information. Such environments enable people to make sense of what they see and navigate it effectively. Both the desire to explore and the ability to interpret environmental cues are influenced by prior experiences. The preference matrix identifies four key informational properties that make an environment preferable: coherence, legibility, complexity, and mystery. Coherence refers to how a scene is organized, ensuring that an orderly environment directs attention effectively. Legibility refers to scenes that are easily navigable and memorable, enabling individuals to orient themselves within the environment (Kaplan and Kaplan 1989). When elements within the environment are repeated, they contribute to outlining the area and making it easier for individuals to navigate mentally. This process can be understood through the concept of a cognitive map, where individuals predict what might happen and how to respond, thereby lessening the cognitive load (Kaplan 2001). Kaplan emphasizes the importance of a "one mental model," where the environment is perceived as a consistent whole. Mystery and complexity, however, are linked to exploration, with mystery prompting further curiosity and information-seeking, while complexity reflects the richness and variety of visual elements in the scene (Kaplan and Kaplan 1989).

According to prospect-refuge theory, human environmental perception is deeply influenced by biology. The theory suggests that individuals instinctively seek environments that provide both protection and clear visibility—sheltered spaces offer refuge during threats, while open vistas enhance situational awareness (Appleton 1975).

In psycho-evolutionary theory, landscape preferences are understood within a broader emotional and psychological response to nature. While preference is an important affective factor, responses to nature are primarily immediate and unconscious emotional reactions, rather than deliberate cognitive processes (Ulrich et al. 1991). In addition to positive preferences, individuals may also experience negative emotional responses, such as fear or sadness, depending on the environmental context.

According to habitat selection theory, environmental perception develops over time. As individuals spend more time in a given environment, they continuously assess its benefits and risks (Orians and Heerwagen 1992). If the environment adequately meets their needs and expectations, they remain engaged, further exploring and evaluating its overall suitability.

2.2.2 Preferred qualities of forest landscapes

Extensive research on forest landscapes has provided comprehensive data on Nordic individuals' preferences for specific forest features, reinforcing the theoretical constructs presented above. Surveys conducted in northern regions indicate that preferences tend to favor forests of older age and with larger trees size (e.g. Pukkala et al. 1988; Silvennoinen et al. 2001; Gundersen and Frivold 2008), while younger forests are generally less favored (Kellomäki 1975; Lindhagen and Hörnsten 2000). Forests characterized by good visibility and some undergrowth are preferred (Silvennoinen et al. 2001; Hertzog and Kutzli 2002; Tyrväinen et al. 2017). Brighter forests are generally more appreciated than the darker ones (Karjalainen 2002; Karjalainen 2006; Frick et al. 2018). Moreover, forests with good light and that are undemanding to navigate were preferred among those with some mental health

burden or stress (Horne 2002; Sonntag-Öström et al. 2015). The feeling of safety is also important (Karjalainen 2000; Tyrväinen et al. 2003), with good visibility and accessibility serving as significant predictors of safety in forest environments (Hertzog and Kutzli 2002).

In contrast, clear-cutting is consistently among the least preferred forest management practices (Karjalainen 2006; Gundersen and Frivold, 2008; Ribe 2009; Kearney and Bradley 2011). In Finland, visible signs of logging, such as old stumps or logging residues, are generally not appreciated (Karjalainen 1996; Silvennoinen 2017; Tyrväinen et al. 2017). According to a review study covering European forests, intensive forest management tends to reduce recreational value (Edwards et al. 2012).

Several authors have also observed a preference for environments perceived as being in a natural state, even though they were not in natural state (Karjalainen 1996; Silvennoinen 2017; Tyrväinen et al. 2017). However, it appears that while the concept of the natural forest is valued, certain visible indicators of naturalness, such as deadwood, may not be preferred (Tyrväinen et al. 2003; Silvennoinen 2017). In fact, decaying and dead trees have not been very well liked according to earlier studies (e.g.Tyrväinen et al. 2003; Gundersen and Frivold 2008; Gundersen et al. 2017; Frick et al. 2018). Furthermore, Frick et al. (2018) reported that the study by Stelzig (2000) found deadwood to evoke feelings of sadness in some individuals. However, the increased awareness of the ecological importance of dead wood may lead to improved perceptions (Brunson and Reiter 1996; Tyrväinen et al. 2003). Additionally, a survey conducted in Sweden in both 1977 and 1997 revealed that pristine forests were not considered highly suitable for recreational use, although perceptions of their suitability did show some improvement over the two decades of the studies (Lindhagen and Hörnsten 2000). Nonetheless, preferences also appear to be influenced by individual background characteristics such as age and education level (Lindhagen and Hörnsten 2000; Tyrväinen et al. 2003).

Although the four theories align with preference results, findings on managed versus natural forests remain inconsistent, highlighting the need for further research. A study conducted in Washington and Oregon, USA, found that both old-growth and mature commercial forests were highly rated for their scenic beauty (Ribe 2009). Similarly, in Finland, Karjalainen (1998) found that managed and natural pine forests were equally preferred, whereas other Finnish studies have shown a stronger preference for managed forests over natural ones (Savolainen and Kellomäki, 1981; Tyrväinen et al. 2017). Moreover, Tyrväinen et al. (2003) found that managed forests were the most preferred when compared to unmanaged forests. Notably, most preference studies have relied on image-based assessments rather than direct forest visits, except for Savolainen and Kellomäki (1981), who compared both methods. Similarly, Silvennoinen et al. (2022) examined forest attractiveness through photographs and in-person evaluations of managed pine forests among 110 participants, including forestry professionals and outdoor specialists. While photo-based and on-site evaluations correlated strongly, this link weakened in more complex forests. The researchers suggested that photo assessments are work well for visually simple pine forests, but in forests with more complex structure, more comprehensive visual input, like multiple images or 3D models, is needed for reliable assessment. They also observed an interesting result regarding the interaction between view type and participants' attitudes toward forest management, noting that assessments based on photos became more challenging when values were involved.

Given that field experiments in differently managed and natural forests are central to this dissertation, the study by Savolainen and Kellomäki (1981) offers useful insights into how image-based and real-world evaluations of old-growth forests may differ. The study included

36 forestry students who assessed both photographs and actual forests, and 25 outdoor enthusiasts who evaluated only images. While the overall patterns were similar, image-based assessments tended to be more critical, and outdoor enthusiasts gave more extreme ratings than the forestry students.

Notably, forestry students ranked old-growth forests among the most preferred, whereas outdoor enthusiasts placed them among the least preferred. This difference appeared to be linked to how the two groups perceived the versatility of the forests: outdoor enthusiasts rated old-growth forests low in versatility, while forestry students gave them high ratings. A likely explanation is that the outdoor group may have interpreted sparse undergrowth as a lack of structural diversity, whereas forestry students recognized it as a typical feature of old, biodiverse forests that support endangered species. The evaluations of old-growth forests via images aligned with evaluations in real forests among forestry students. However, the use of black-and-white images in the study may have influenced perceptions, failing to capture the multilayered structure of old-growth forests. It remains unclear whether outdoor enthusiasts would have rated these forests differently if they had visited them beforehand or received information about their ecological value. However, modern research benefits from color photography, which more accurately represents forest characteristics.

The forest preferences outlined above serve as a foundational framework for the study questions and hypotheses within this dissertation, given their perceived significance in relation to well-being indicators (Staats et al. 2003; van den Berg et al. 2003; Hartig et al 2011; Korpela and Ratcliffe 2021).

2.3 Theories on restorative environments and their empirical examination

The study field of restorative environments is based on two complementary theories. The Attention Restoration Theory (ART) explains the restorative effects of nature from a cognitive perspective, while the Stress Reduction Theory (SRT) focuses on physiological responses, such as heart rate changes and emotional alleviation, leading to stress reduction. Both theories suggest that nature plays a role in recovery from stress and mental fatigue. The restorative effects of natural and urban environments are often examined using an experimental paradigm, where healthy volunteers first undergo a stress-inducing procedure (e.g., watching a scary movie) (Joye and van den Berg 2012). Participants are then exposed to either an authentic or simulated nature or built environment. Psychological and physiological responses are then measured at multiple time points—before the induction, after it, and following environmental exposure (Joye and van den Berg 2012).

2.3.1 Attention Restoration Theory (ART)

Kaplan and Kaplan (1989) developed Attention Restoration Theory (ART), which describes how nature environments support psychological restoration. Restoration refers to the process of recovering from cognitive fatigue, which impairs one's ability to manage daily tasks and challenges (Hartig et al. 2011). When directed attention is sustained for long periods, mental fatigue accumulates, leading to Directed Attention Fatigue (DAF) (Joye and van den Berg, 2012). ART posits that nature facilitates recovery by engaging involuntary attention, allowing the brain to restore cognitive resources. It identifies four key experiential qualities that define a restorative environment (Kaplan and Kaplan 1989):

- Fascination – Effortless engagement with an environment that captures attention naturally.
- Being Away – A break from daily routines, providing mental distance from stressors.
- Extent – A sense of coherence and richness that makes the environment feel like a complete world.
- Compatibility – A feeling that the environment aligns with individual inclinations and needs.

As mentioned earlier in Chapter 2.2.2, the Kaplans discuss the mental model map in relation to the Preference Matrix, particularly emphasizing its connection to legibility—one of the four key factors predicting landscape preference. Legibility refers to how easily an environment can be understood and navigated, enabling individuals to form a coherent mental representation of their surroundings (Kaplan and Kaplan 1989). However, the concept of extent in ART also plays a role in mental model formation, as it contributes to the sense that an environment is rich, interconnected, and large enough to allow for further exploration (Kaplan 2001). While legibility supports immediate spatial comprehension, extent fosters a deeper, immersive experience that enhances cognitive restoration.

Restoration occurs in distinct stages. First, the mind is cleared of distractions, allowing directed attention to recover. Next, the "matters of one's mind" gain space, bringing subconscious concerns to the surface. Addressing these issues is essential, as they may have silently burdened the mind and depleted attentional resources. Finally, deep restoration requires sufficient time and a supportive environment, enabling self-reflection and greater clarity on priorities, goals, and future actions (Kaplan and Kaplan 1989.)

2.3.2 Stress Reduction Theory (SRT)

Restoration in nature is closely linked to emotions. According to the Stress Reduction Theory (SRT), also known as the Psycho-Evolutionary Theory, as discussed in section 2.2.1 (Ulrich, 1983; Ulrich et al. 1991), individuals experiencing stress may find relief in natural environments through positive emotional responses, which in turn lead to a reduction in physiological stress markers. While Ulrich (1983) primarily emphasizes the visual aspects of nature, he acknowledges that restorative experiences engage multiple senses, making them multimodal.

Ulrich (1983) describes stress reduction in nature as a two-stage process, where affective responses (such as an immediate "like" or "dislike" reaction) occur first, followed by cognitive processing. However, affective and aesthetic responses cannot be treated as entirely separate phenomena. Ulrich uses "affects" and "emotions" interchangeably, but distinguishes between mood (a prolonged, less intense emotional state) and immediate emotions. Aesthetic responses—such as finding an environment visually pleasing—are affective reactions that contribute to restoration. While affective responses are universal, cognitive preferences for nature are shaped by individual experiences, meaning that restoration is both instinctive and subjective. However, affective and cognitive responses can be measured separately (Ulrich, 1983).

SRT also shares similarities with Attention Restoration Theory (ART) in identifying environmental characteristics that contribute to restoration. SRT highlights seven landscape features that evoke positive affective responses:

- Complexity
- Structural properties
- Depth/spatiality cues
- Ground surface texture
- Absence of threat
- Presence of water
- Deflected vistas (Joye and van den Berg 2012).

Empirical research has largely supported these characteristics, except for complexity and ground surface texture, where results have been inconsistent. This variability is partly due to differences in how these terms are defined across studies, making comparisons challenging (Karjalainen 2006).

The positive change in emotions while in nature has also been recognized by others (Korpela and Ylen 2009; Salonen 2020). Salonen (2020), however, brings up the important aspect that the well-being effects of nature cannot be explained only with stress reduction, as there is also evidence of nature being impactful for unstressed people. Moreover, the familiarity with natural environments can enhance how restorative the qualities are perceived and improve individual well-being (Purcell et al. 2001; Sonntag-Öström et al. 2015; Tang et al. 2015).

2.3.3 Nature providing well-being effects

Nature environments have been found to reduce stress and enhance well-being. However, most studies exploring the well-being effect of nature have compared the restorative effects of green environments and built areas after exposure to these areas (e.g. Hartig et al. 2003; Lee et al. 2009; Bowler et al. 2010; Van den Berg et al. 2016). The studied "natural" environments have typically been urban green areas, such as parks or recreational woodlands. Another recurring element in these studies is the examination of physical exercise in green environments, with results indicating that physical activity promotes psychological well-being more effectively outdoors than indoors (Plante et al. 2007; Thompson Coon et al. 2011; Pasanen et al. 2014).

Despite the extensive research on the well-being effects of nature, there is still relatively limited evidence, particularly from real environmental conditions, regarding whether different types of nature environments promote well-being differently (see Marselle et al. 2013; Tyrväinen et al. 2014; Kabisch et al. 2021). However, based on a few studies, it appears that different types of nature environments may indeed influence well-being differently. Tyrväinen et al. (2014) and Kabisch et al. (2021) found that urban woodland or parks with old trees exhibited stronger restorative effects compared to more urban or modern parks. In the study by Marselle et al. (2013), which examined a 13-week period of group walks in the Walking for Health program, different nature environments were compared to urban environments. The type of environment was not found to be significantly related to mental well-being, depression, or positive affect. However, walks in farmland compared to urban environments were associated with less perceived stress and negative affect, as well as greater mental well-being. Additionally, although not a field experiment, a study where individuals were asked to recall their feelings of restoration in different nature environments within the last week found that coastal environments were perceived as the most restorative, followed by rural and urban environments (White et al. 2013). Woodlands/forests and

hills/moorland/mountains were also comparable to coastal environments in terms of their restorative effects (White et al. 2013).

Biodiversity is often considered an essential quality of nature, yet its relationship with well-being remains unclear. A review by Marselle et al. (2019) found that while some studies suggest biodiversity enhances mental health and well-being, others have not identified significant associations. In urban settings, biodiversity may have both positive and negative impacts: while diverse ecosystems can promote well-being, exposure to viruses or pollen may pose health risks (Marselle et al. 2021b).

Perceptions of naturalness are also complex. A meta-analysis by McMahan and Estes (2015) found no significant differences in emotional well-being between managed and wild natural environments, suggesting that perceptions of naturalness may not always align with actual environmental conditions. However, when participants viewed images and videos of different landscapes, more natural-looking environments were rated as more restorative (Carrus et al. 2013). Marselle et al. (2016) also found that perceived naturalness was positively associated with perceived restorativeness, although this may depend on individuals' expectations of their surroundings (Shin et al. 2010).

Aesthetics plays a crucial role in these perceptions, as beauty is often cited as one of nature's most valued qualities (Horne 2002; Schroeder 2002). Naturalness and aesthetic appeal are closely linked (Gobster and Westphal 2004), further reinforcing the importance of subjective perceptions in shaping well-being outcomes.

Forests and forest quality enhancing well-being

While studies comparing different types of nature environments remain limited, experimental research specifically examining the well-being effects of various forest types and attributes is even scarcer and yields inconsistent results (Martens et al. 2011; Sonntag-Öström et al. 2014; Beute et al. 2023). Sonntag-Öström et al. (2014) found that heart rate was lower in a lakeside forest compared to a spruce forest and a rock outcrop forest. Martens et al. (2011), comparing managed and wild forests in urban settings, reported greater positive affect and lower negative affect in the managed forest, though no differences in arousal levels were found. Notably, the wild forest had only been free from management for six years, which may have influenced the results.

Since the commencement of the field experiment in this dissertation, a growing number of studies have examined how forest characteristics and specific management practices affect well-being. In Japan, Takayama et al. (2017a) assessed the same 80-year-old forest before and after light thinning, using the same participants six months apart. No differences were found in restoration or appreciation between conditions. In a follow-up study, they compared the thinned forest with an unmanaged, denser forest of the same age (Takayama et al. 2017b). While participants evaluated the thinned forest more positively, both forests were equally restorative. Importantly, both were plantation forests, not pristine woodlands.

Janeczko et al. (2021) compared three 160–170-year-old forests in Poland: two commercially managed forests and one natural primeval forest within a nature reserve. One of the managed forests had decaying ground trees, while the other contained standing dead trees damaged by bark beetles. The greatest increase in positive feelings occurred in the natural forest reserve, whereas the smallest increase was observed in the bark beetle-damaged commercial forest (Janeczko et al. 2021).

Other studies also highlight the role of naturalness in well-being outcomes. Tomao et al. (2018) examined common natural forest elements such as shrubs and stand density and found

a negative association with perceived benefits. However, stand structure and variety in openness—features often found in natural forests—enhanced the restorative experience. Additionally, a meta-analysis by Li et al. (2022) suggested that wild environments may boost vigor and comfort more effectively during exercise compared to urban green spaces.

In a recent Austrian study, the impact of different smaller sites within forested areas was examined and were found to contribute to the restorative quality of forest. The fern glade, characterized by an open area in the forest with various plant species, received the highest score for restorativeness and was statistically as restorative as the mossy stones, which represent a stream with minimal water flow underneath the stones. These two places were rated more restorative than the forest glade (a spruce monoculture) and the outlook (a larger scenic area in the mountains but bordering a road with some traffic and noise). It is noteworthy that the sites with the highest restorative scores exhibited greater biodiversity richness (Cervinka et al. 2020). Furthermore, a higher perception of biodiversity, potentially influenced by the structural characteristics of the forest, was significantly related to improved well-being outcomes according to a recent field-experiment study conducted in three countries (Austria, Belgium, and Germany) (Rozario et al. 2024). In contrast, no association was observed between actual tree species richness and well-being outcomes (Rozario et al. 2024).

Furthermore, Stoltz et al. (2016) found tree age, sparsity, and tree height to be the most important qualities indicating a restorative forest, according to of a group of experts who visited forests in Sweden. However, in an Italian study where the relationship between tree age and self-reported benefits was investigated through field experiments, no such association was found (Tomao et al. 2018).

Based on these studies, it appears that naturalness and/or biodiversity may have significance for human well-being. This is also indicated by an study from South-Korea, where wild and tended forests were compared. Women with a metabolic syndrome took half-day trips in these forests while their bio-physiological and psychological reactions were monitored (Lee et al. 2018). Positive changes were observed in both forests, but the effect was stronger in the wild forest, possibly due to higher phytoncide levels. One of the phytoncides was associated with an improved acute insulin response (Lee et al. 2018). Additionally, terpenes, which are a type of VOC, have also been suggested to activate natural killer (NK) cells in the human immune system and may help prevent tumor formation. While these effects have been partly studied in mouse models and human cell lines, exposure to nature has been shown to increase NK cells, with higher terpene levels detected in forest air (Zielińska-Błajet et al. 2021).

Despite these insights, research on the well-being effects of natural or pristine forests remains limited. Results may also be influenced by local contexts as well as individual differences.

2.3.4 The association of individual variables on well-being effects in nature

Background characteristics influencing well-being responses in nature

Sociodemographic characteristics such as gender, age, education, childhood living environment, and individual variables such as one's relationship with nature and current state of the health, may also influence how people perceive and restore in the nature. Several survey studies have explored these associations.

For example, in the study of Ode et al. (2016), women and older people experienced greater aesthetic value and subjective well-being in urban green spaces compared to men and younger people. Only the physically active middle-to-older aged adults received mental health benefits from green spaces, according to Astell-Burt et al. (2013). Furthermore, women emphasized the health benefits from green areas more than men (Tyrväinen et al. 2007), and van den Berg et al. (2016) suggested that the association between purposeful visits to green spaces is stronger among those with a low level of education. Then again, in the results of a cross-sectional survey conducted in Sweden, the association of perceived green quality to self-reported well-being remained after adjusting for sociodemographic factors (de Jong et al. 2012).

Hinds and Spark (2011) did not find any differences in their participants' connection with natural environments between rural and urban childhood living environments, whereas Adevi et al. (2012) found that people preferred landscapes experienced during childhood. However, surprisingly, van den Berg et al. (2016) found the association to be stronger for those who had limited nature experience during childhood compared to those who had spent lots of time in nature during their childhood. The researchers propose that these individuals may have become less responsive to the mental health advantages obtained from spending time in green areas, likely because they had grown familiar to interacting with nature regularly over the course of their lives.

There are fewer studies exploring the associations of sociodemographic characteristics and individual variables to experiences in nature that are actually conducted by field experiments in real nature. Among these, neither Martens et al. (2011) nor Tomao et al. (2018) found a connection between sociodemographic factors and perceived restorativeness. Nevertheless, growing evidence is suggesting that some associations might be found. Interestingly, noise sensitivity was shown to potentially modify the restoration effect of the environment (Ojala et al. 2019). Pyky et al. (2019) also identified high nature relatedness to be an important factor in participation in green exercise. As already mentioned, the higher levels of nature connectedness have also been linked to awe-inspiring experiences in more natural environments such as wilderness settings (Davis and Gatersleben 2013), as well as heightened restorative effects in more natural environments, such as urban forests (Ojala et al. 2019).

A few studies have examined whether different forest environments have varying effects depending on an individual's mental well-being status. Sonntag-Öström et al. (2014) found no differences in restorative effects between different forest types among patients suffering from exhaustion disorders. A study conducted in Japan explored whether depressive tendencies were associated with physiological responses and stress relief when visiting thinned and unmanaged forests (Saito et al. 2019). While no differences were found in heart rate between the two forests, the decrease in saliva cortisol and blood pressure was more pronounced in the managed forest. However, the reduction in systolic blood pressure was negatively correlated with depression in the unmanaged forest, but not in the thinned forest. The authors emphasized the need for further research to understand why the unmanaged forest might be more effective in providing stress relief for some individuals (Saito et al. 2019).

The role of awe in nature and its neurological basis

Although this dissertation does not focus on neuroscience, recent findings from that field offer compelling insights into the role of awe in nature-related well-being and are therefore

briefly discussed here. Awe is typically defined as an emotional response to perceptually vast, complex, or powerful stimuli that challenge existing mental frameworks while encouraging cognitive accommodation (Shiota et al. 2007). In natural settings—particularly wilderness areas—such experiences can evoke a sense of wonder and foster feelings of connection and perspective (Kaplan and Kaplan 1989).

Empirical research has increasingly demonstrated that awe is not only psychologically significant but also linked to measurable neurophysiological processes. For instance, Hu et al. (2017) identified awe as one of ten positive emotions associated with distinct patterns of electroencephalographic (EEG) activity. In their study, awe clustered with other so-called "encouragement" emotions—such as inspiration, hope, and gratitude—which are thought to involve more complex cognitive processing than other positive affective states. Similarly, Chirico and Gaggioli (2021) reported correlations between awe and neural activation patterns related to cognitive engagement.

Moreover, other studies have found that awe may reduce activity in the brain's Default Mode Network (DMN), a network associated with self-referential thought and mind-wandering (van Elk et al. 2019). Dysfunctions in the DMN have been implicated in various neuropsychiatric conditions, including depression and schizophrenia, where it is often hyperactive or hyperconnected (Whitfield-Gabrieli and Ford 2012). In these contexts, awe may play a regulatory role by attenuating excessive inward focus and rumination, potentially offering therapeutic value.

From a psychological standpoint, awe may facilitate stress reduction by helping individuals let go of constant cognitive control, thereby supporting deep relaxation (Kaplan and Kaplan 1989). It has also been shown to promote perspective-taking and reduce self-centeredness (Piff et al. 2015; Stellar et al. 2018; Perlin et al. 2020). In this sense, awe may be an underexplored yet meaningful component of nature-based restoration, particularly in settings that evoke vastness and natural complexity.

3 MATERIALS AND METHODS

This dissertation consists of two quantitative studies and one study that integrates both quantitative and qualitative methods. The research adopts a controlled field setting, drawing inspiration from the methodology employed in a previous study by Tyrväinen et al. (2014) conducted in Helsinki, Finland. This dissertation partially replicates the aforementioned study, utilizing the same forest area, Keskuspuisto (Helsinki Central Park) as a control forest due to its established positive effects on stress reduction. Alongside the control forest, three additional forests were chosen for experiment. The selection of four forests was a deliberate compromise to mitigate the risk of a high dropout rate among participants, although even this number posed challenges for participants to complete all visits.

3.1 Study site selection

There were several criteria for how the experiment forests were selected. Firstly, given that the urban recreation forest was predominantly spruce-dominated, it was essential for the other forests to share the same dominance of spruce to ensure consistency in the effects across sites. Additionally, spruce is the most prevalent tree species, covering 40,1% of forested land

in the Uusimaa region (southern Finland), where the experiment took place. Another criterion was to choose forests that closely resembled the typical forests of the area and were commonly utilized for recreational purposes. The mature commercial forest (referred to as "Mature") and old-growth forest (referred to as "Pristine") were selected as experimental forests based on previous forest landscape preference studies indicating a preference for older forests for recreation. The inclusion of the old-growth forest was particularly important due to the gap in understanding how natural forests affect people. Additionally, a young commercial forest (referred to as "Young") was chosen, as 40,2% of forested land in southern Finland consists of young forests (aged < 40 years). Mature forests (aged 81-120 years) make up 15,4%, while only 3,5% constitute old-growth forests aged over 120 years, which have developed naturally without forest management. The remaining approximately 40% comprise middle-aged forests (aged 40–80 years).

In selecting potential forests for the experiment, several factors needed consideration. Firstly, the forests had to be easily accessible by car and within a 45-minute drive from the designated meeting point near Pasila railway station, ensuring convenience for participants from various parts of Helsinki. Given the study's focus on the genuine potentially restorative qualities of forests, efforts were made to minimize the presence of other potentially restorative or stressful elements within the experimental sites. For instance, significant topographical variations or the presence of watercourses were avoided, as these factors have been shown to influence stress relief through either increased physical activity in diverse terrain (Marselle et al. 2014) or enhanced relaxation induced by water features in the landscape (White et al. 2010; 2013). Additionally, the selected forests had to be situated outside the flight noise zone and characterized by minimal or no traffic noise. Moreover, the size of the forests needed to be a large enough to perform a 30-minute walk without visibility of anything beyond the forest boundaries. Based on these criteria, the following forests were selected for inclusion in the study: (see also Table 3).

Table 3. Forest characteristics. This chart was published in Reference Simkin et al. (2020).

Forest site	**Urban**	**Pristine**	**Mature**	**Young**
Location	Helsinki/urban	Sipoo/rural	Sipoo/rural	Sipoo/rural
Age	95	>120	100	40
Stand basal area (m^2/ha)	30	36	32	35.1
Tree height (m)	26	33	27	16
Diameter breast height, d.b.h (cm)	30	35	28	16
Stand wolume (m^3/ha)	370	524	403.1	298.5
Dominant tree species	Spruce (*Picea abies*)	Spruce (*Picea abies*)	Spruce (*Picea abies*)	Spruce (*Picea abies*)
Other tree species	Few: pine, birch, aspen, rowan	Few: pine, birch, aspen, rowan	Few: pine, birch, aspen, rowan	Few: pine, birch, rowan

The control forest, Keskuspuisto (Central Park), is a 95-year-old spruce-dominated urban recreation forest (Figure 4). It is the largest forested area in Helsinki, located approximately 11 kilometers from the city center. Managed solely for recreational purposes, this forest has high biodiversity values, including a significant amount of dead wood. It features expansive walking and cycling trails, as well as a network of smaller footpaths, all heavily used for recreational activities, leading to visible signs of erosion.

The old-growth forest is a large, spruce-dominated forest area exceeding 120 years in age and protected via the Natura 2000 network of protected areas (Figure 5). It has remained unmanaged for several decades and has multi-layered canopies and gaps typical of naturally developed old-growth forests. The forest boasts a high level of biodiversity, featuring numerous species typically found in old forest. It has an extensive amount of standing dead wood and decaying fallen trees, partly attributed to recent damage inflicted by the European spruce bark beetle (Ips typographus). The use for outdoor recreation is low.

The 100-year-old spruce dominated mature commercial forest (Figure 6) is situated close to the Sipoonkorpi national park and also next to a recently harvested clear-cut area. Characterized by an even-aged stand structure, this forest exhibits a more managed appearance. The forest has some dead wood scattered across the forest floor, which increases the biodiversity in the forest. It has fewer trails than that of the urban recreation forest, and the use for outdoor recreation is low.

The 40-year-old spruce dominated young commercial forest (Figure 7) is situated near agricultural fields. This monoculture forest has undergone active management practices for timber production, with thinning residues remaining on-site. The use for outdoor recreation is low.

Figure 4. The urban recreation forest (Urban). The figure was originally published in Simkin et al. (2020).

Figure 5. The old-growth forest (Pristine). The figure was originally published in Simkin et al. (2020).

Figure 6. The mature commercial forest (Mature). The figure was originally published in Simkin et al. (2020).

Figure 7. The young commercial forest (Young). The figure was originally published in Simkin et al. (2020).

3.2 Participant recruitment

Only volunteers who had lived in the Helsinki metropolitan area for a minimum of two years were recruited, ensuring a comparable exposure to urban environments. Participants were also required to hold full-time employment. Initial recruitment efforts involved email invitations to corporate human resource managers and dissemination through various social media platforms, resulting in 222 pre-registrations. As the first invitation round yielded mostly women, a second round specifically targeted male participants. Of these, 29 volunteers were excluded for not meeting residency criteria, nine for their current unemployment status, and two because their occupation was related to nature and well-being, which could potentially lead to biased results. Ultimately, 182 pre-registrants meeting the eligibility criteria were contacted via email or phone. To ensure a diverse participant group with varying backgrounds and levels of interest in nature, selection criteria included age, gender, profession, background in nature conservation issues, studies related to nature, possible connections to the forest industry, and forest ownership. Despite the initial interest, many volunteers withdrew their participation due to scheduling challenges, resulting in a final sample of 70 participants. Of these, 66 completed visits to all four study sites and were included in the subsequent data analyses.

Prior to the second year of field experiments, a power analysis was conducted based on the first-year results of selected ROS items to determine the required sample size to achieve adequate statistical power. The analysis indicated that, with a significance level of $\alpha = 0.05$ and a statistical power of 0.80 using ANOVA, a minimum of 24 to 52 participants would be

required. Additionally, a post-hoc power analysis was performed to assess the achieved power for the collected data. The observed power was very high for all other questionnaires, with values of 0.96 for the ROS questionnaire, 0.97 for the SVS questionnaire, 0.99 for the PANAS positive questionnaire, and 1.0 for the PRS questionnaire. However, the observed power for the PANAS negative questionnaire was notably lower at 0.48.

The participants recruited to this study were employees who already had a working day behind them at the time of the experiment. In this way, it was possible to find out how a visit to nature restored from the possible stress load experienced during the working day. To explore the actual effect that nature has on mental well-being, this dissertation tried to minimize the possible effect of physical and social well-being.

Prior to the commencement of the experiment, all enrolled participants received an information package outlining the study's procedures, voluntary participation nature, confidentiality assurances, and funding details. Additionally, they were provided with a background questionnaire. Participants were not informed that all the sites they would visit would be forests, but rather that the aim was to study restorative nature. By excluding a person's own choice of what kind of forest he or she would prefer to visit, as well as the prior information of what kind of nature environment they would be taken to, it is possible to evaluate the results without the effect of prior information such as hopes, expectations, or preferences towards nature. This also avoids the influence of favorite place effect (Korpela and Hartig 1996; Korpela and Ylen 2009).

Upon receiving detailed instructions regarding the experiment and information on participant rights in accordance with the principles outlined in the Declaration of Helsinki by the World Medical Association, participants signed a written consent for their voluntary involvement. As determined by the Finnish Advisory Board on Research Integrity, an ethical review was not required, as the study did not expose the participants to any harm and all the necessary information regarding the study was provided. Furthermore, no incentives were offered to participants for their involvement in the study.

3.2.1 The study participants

In total, 66 participants (aged 26–65, M = 43.38, SD = 10.68) visited all four forests (Table 4). Of them, 59% were women and 74% had higher education. Their average working week was 43 hours (SD = 7.80). Self-rated health was generally good (M = 1.77, SD = 0.80) and physical condition moderate (M = 2.32, SD = 0.88) on a 5-point scale (1 = very good; 5 = very poor). On the experiment day, 44% reported low stress, 30% moderate stress, 25% high stress, and 1% were not at work. Stress levels remained consistent across forest visits.

Table 4. Background characteristics of the participants. This chart was published in Reference Simkin et al. (2020).

Gender	%
Women	59
Men	41
Age, years	
26-35	32
36-45	26
46-55	27
56-65	15
Childhood dwelling area	
Urban center	15
City suburb	34
Municipality center	12
Municipality suburb	21
Rural area	18
Household income level, €/year	
Below 30 000	17
30 000–50 000	26
50 000–70 000	18
70 000–90 000	13
90 000–110 000	9
Over 110 000	17
Education	
Academic degree (bachelor, master, PhD)	74
Short-cycle tertiary education	12
High school	9
Vocational/basic level	5
Job related to nature	23
Education related to nature	21
Education related to forestry	11
Forest ownership	9

3.3 Experimental procedure

The four forests were visited in a randomized order on random weekdays. To minimize potential bias related to the order of visits, each forest was assigned a code, and the order of visits was counterbalanced so that each forest occurred equally often as the first, second, third, and fourth visit across participants. To enhance study validity, a within-subjects design was employed, wherein all participants visited each forest once (Field 2013). On average, the participants visited one forest per week, although some visited multiple forests in the same week because several participants needed to reorganize their scheduled visiting days due to their own timetable changes. To avoid the possible social effects of getting familiar with each other, nobody visited the forests in the same group. To minimize the group effect, the group sizes were kept small, of one to six individuals, with instructions to focus on their personal experiences.

Participants received an SMS reminder on the morning of each visit day, along with guidance on appropriate attire. In case of poor weather conditions, the experiment day was canceled. Participants were picked up from a designated meeting point in Pasila, Helsinki, always at precisely 14:30, and transported to the experiment sites by minivan. The destination city was told only at the beginning of the drive to the site, and discussions were discouraged during transit. The journey duration was controlled to last between 30 to 40 minutes.

Upon arrival at the forest site, participants completed the first questionnaire in or near the minivan (T1) and were provided with snacks before entering the forest. Subsequently, participants sat 15 minutes on chairs placed inside the forest and observed nature (T2), before embarking on a 30-minute guided walk led by a researcher (Figure 8). All questionnaires were completed using paper and pen. Another researcher carried a device for noise measurement and walked behind the group. The walking speed and routes were standardized, and breaks were incorporated to maintain consistency. During the brakes, a few minutes were used to view the environment. To mitigate the impact of physical activity, a seated session was also included, followed by a slow-paced walk at approximately 1.1 km per hour. The route in all sites was approximately half a kilometer long. Throughout the experiment, participants were instructed to remain silent, refrain from taking photos or using their cell phones, and avoid picking mushrooms or berries.

Temporal changes in restoration, vitality, and mood during the experiment were assessed using questionnaires, along with perceived restorativeness and other questions about the forest characteristics after each forest visit. Participants also provided feedback on their experiences after each visit. The experiment took approximately 2.5 to 3 hours and was conducted from summer to autumn in 2016 and from spring to autumn in 2017. A few visits took place in September and October 2017. In addition, one participant completed three of the visits during September and October 2016, and one visit in early June 2017. The experiments began as soon as the doctoral candidate was accepted into the doctoral program and funding for the PhD research was secured. This study did not focus on seasonal variation and the aim was to examine forest environments during the growing season, when the trees were in leaf. Moreover, no experiments were conducted in winter, as the study required entry into the forest interior, which would have been impractical in some areas due to deep snow and freezing temperatures without specialized equipment. Additionally, no experiments took place during the peak holiday season in July, as participants were required to have completed a workday prior to the study, and the majority of Finns are on vacation during this period. However, a potential association between the seasons or visit dates and the well-being experiences reported in the forest was examined, and no such association was found.

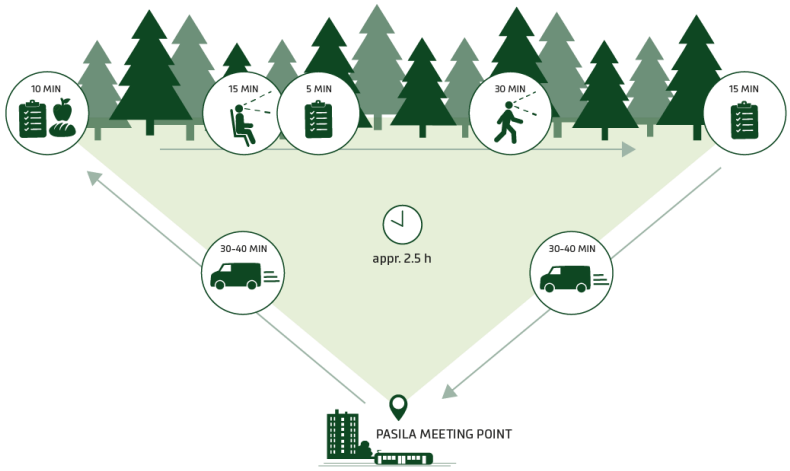


Figure 8. The course of the experiment, which each participant repeated four times on different days.

3.3.1 Measures

Background information

Before the first visit, participants answered background questions covering various aspects such as working hours, childhood residence, household income, education, self-evaluated health status, membership in nature conservation organizations, forest ownership, and nature-related work (Table 4). Participants also completed the short version of the Nature Relatedness Scale (NR-6) (Nisbet and Zelenski 2013). This scale included six items—for example, "I always think about how my actions affect the environment" and "I feel very connected to all living things and the earth"—each rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In addition, they assessed their perceived stress using the Perceived Stress Scale (PSS-10) (Cohen and Williamson 1988), which consisted of items such as "In the last month, how often have you felt that you were unable to control the important things in your life?", rated on a 5-point Likert scale from 1 (never) to 5 (very often). Participants also completed the Depression Scale (DEPS) (Salokangas et al. 1995), where items like "During the past month, I have felt hopeless about the future" were rated on a 4-point Likert scale from 1 (not at all) to 4 (extremely).

Measures on site

During the experiment, participants completed questionnaire items at three different time points: just before entering the forest near the vehicle (T1), after sitting for 15 minutes on chairs within the forest (T2), and immediately following a 30-minute walk in the forest (T3)

(Table 5). The measures included both psychological scales assessing participants' subjective experiences and items related to perceived forest characteristics. In addition, participants were asked open-ended questions to elaborate on their experiences

At T1, participants reported their current level of work stress using the single-item TSK scale (Elo et al. 2012) rated on a 5-point Likert scale (1 = not at all; 5 = very stressful). They were also asked whether they had experienced flu symptoms during the past three days.

Restoration was assessed using the Restoration Outcome Scale (ROS; Hartig et al. 1998; Staats et al. 2003; Korpela et al. 2008) which includes six items. Three items capture relaxation and calmness ("I feel restored and relaxed" "I feel calm" "I have enthusiasm and energy for my everyday routines"), one item focuses on attention restoration ("I feel focused and alert"), and two items assess mental clarity ("I can forget everyday worries" "My thoughts are clear").

Vitality was measured with the Subjective Vitality Scale (SVS; Ryan and Frederick 1997) consisting of four statements: "I feel alive and vital" "I don't feel very energetic" "I have energy and spirit" and "I look forward to each new day." Both ROS and SVS were administered at all three time points (T1 T2 T3).

Mood was assessed using the Positive and Negative Affect Schedule (PANAS; Watson et al. 1988) administered before (T1) and after the forest visit (T3). The scale includes 10 items representing positive (e.g. interested, excited, strong) and negative affect (e.g. distressed, scared, ashamed).

All three scales—ROS SVS and PANAS—were rated on a 7-point Likert scale (1 = not at all; 7 = extremely).

The Perceived Restorativeness Scale (PRS; Hartig et al. 1996 Hartig et al. 1997) was administered immediately after each forest visit at time point T3. The scale consists of 16 items rated on a 7-point Likert scale (1 = not at all; 7 = totally), measuring four components derived from Attention Restoration Theory (ART). For example, the fascination component includes statements like "There is much to explore and discover here"; being away is reflected in items such as "It is a place to get away from it all"; compatibility is measured with items like "Being here suits my personality"; and extent (or coherence) is assessed with items such as "It is a chaotic place".

To explore how participants perceived the different characteristics of forests, the semantic differential method was utilized. This approach captures participants' subjective impressions by contrasting pairs of opposing adjectives (Osgood 1952) (see Figure 17 in results). After each forest visit, participants were asked to rate twelve adjective pairs. Eight of these were adapted from a study by Park et al. (2011) and included the following: "Beautiful–Ugly", "Safe–Scary", "Natural–Artificial", "Interesting–Dull", "Calm–Restless", "Harmonious–Chaotic", "Pleasant–Unpleasant", and "Bright–Dark". In addition, three adjective pairs were included based on findings from previous studies: "Rich in biodiversity–Poor in biodiversity" (Carrus et al. 2015; Marselle et al. 2016), "Managed–Unmanaged" (Martens et al. 2011; Takayama et al. 2017b), and "Cheerful–Sad" (Stelzig 2000; Frick et al. 2018). The pair "Restorative–Stressful" was also added to allow comparison with the PRS results.

In addition, after each forest visit, participants were asked the question: "How suitable is this forest for your outdoor activities?" using a scale from "very well" (5) to "not at all" (1) (see Table 13 in results). Moreover, three simple open-ended questions were asked to learn more about what was liked and disliked about each forest. Participants were asked: "What did you like about this forest?", "What did you not like about this forest, or what disturbed you about this forest?", and "Did something special come to your mind about this forest?" Participants also had the opportunity to share any other thoughts at the end of the survey.

Moreover, immediately after the experiment, participants completed the Focus of Attention Scale (TFOAS) (McIntyre and Roggenbuck 1998; Tyrväinen et al. 2014). They rated, on a 7-point Likert scale (1 = not at all; 7 = completely), the extent to which their attention was directed toward each of the following six aspects: their own thoughts and emotions, other people around them, the forest environment, the task they were performing (i.e., walking), insects, and sounds other than nature (see Table 6 in results).

Environmental noise levels were measured using a Larson Davis noise dosimeter, model 706RC, and Temperature C^{o} was measured at the time point T1.

Table 5. The scales and questions participants completed during the experiment.

Before the 1. visit	**Time-point T1**	**Time-point T2**	**Time-point T3**
Gender, age, education, income etc., Childhood dwelling area, Job & education related to nature, Forest ownership, NR-6, PSS-10, DEPS	ROS, SVS, PANAS, TSK	ROS, SVS	ROS, SVS, PANAS, PRS, TFOAS Semantic differentials, Open-ended questions, How suitable the forest is for your outdoor activities?

4 RESULTS

4.1 Descriptive statistics and scale reliability

The mean sum scores and standard deviations were calculated for all psychological scales and TFOAS, with reverse-coded items taken into account in the analysis (Table 6). The reliability of restorative effect scales was found to be good according to Cronbach's α (see article I). The reliability of the PRS components, ranged from poor to acceptable for the "being away" component, and from good to excellent for both the "fascination" and "compatibility" components. For the "incoherence" component, however, reliability varied from unacceptable to acceptable which is discussed in more detailed in the article of Simkin et al. (2021). The detailed analytical steps and methods are described in the original articles.

4.2 How does forest management impact restorative effects?

In article I, changes in restoration, vitality, and emotions in forests were investigated so that each participant visited each of the four forests on different days. Differently managed forests contributed to restoration in varying ways, as observed through changes over time. The study employed a repeated measures analysis of variance (ANOVA) that included four within-subject factors: urban recreation forest, old-growth forest, mature commercial forest, and young commercial forest.

For the ROS and SVS measures, six separate models were conducted to capture all relevant contrasts with the reference categories: Urban at T1, Urban at T2, Pristine at T1, Pristine at T2, Mature at T1, and Mature at T2. For PANAS POS and PANAS NEG, three models were run using Urban at T1, Pristine at T1, and Mature at T1 as reference points. When the assumption of sphericity was violated based on Mauchly's test, the Greenhouse-Geisser correction was applied to adjust the estimates accordingly.

Neither the participants' baseline restorative effects at time point T1 nor the order in which they visited each forest differed significantly between groups.

4.2.1 The change in restoration, vitality, and emotions

No significant main effect was found for a forest site on the Restoration Outcome Scale (ROS) with $F(3, 195) = .08$, nor for the Subjective Vitality Scale (SVS) with $F(3, 195) = .18$. In contrast, the main effect of time was significant for the ROS ($F(1.42, 92.16) = 108.34$, $p < .01$) and for the SVS ($F(1.22, 79.34) = 112.58$, $p < .01$). All comparisons across the three time points—T2 vs T1, T3 vs T1, and T3 vs T2—were also statistically significant for both ROS and SVS.

The interaction effect between the Forest site and Time on ROS ($F(4.92, 320.05) = 4.37$, $p < .01$) and SVS ($F(4.75, 309.05) = 4.78$, $p < .01$) during the field experiment was significant.

Table 6. Scale statistics of psychological measures, environmental variables, and possible confounding factors in four forests during experiment. This chart is modified from original publication of Reference Simkin et al. (2020).

Forest	**Urban**		**Pristine**		**Mature**		**Young**	
Measures	Mean	SD	Mean	SD	Mean	SD	Mean	SD
At the beginning								
ROS	4.37	0.95	4.31	1.00	4.30	0.85	4.40	0.91
SVS	4.55	0.96	4.38	1.14	4.43	0.98	4.55	1.03
PANAS POS	4.15	0.88	4.05	0.94	4.04	0.82	4.11	0.82
PANAS NEG	1.85	0.71	1.86	0.70	1.85	0.70	1.83	0.69
After viewing								
ROS	4.98	0.97	4.95	0.92	4.97	0.90	5.10	0.81
SVS	5.12	0.93	5.01	0.89	5.03	1.02	5.12	0.95
After walking								
ROS	5.23	0.88	5.47	0.73	5.43	0.92	5.15	0.88
SVS	5.43	0.83	5.52	0.88	5.50	0.95	5.22	0.92
PANAS POS	4.72	0.96	5.00	0.91	4.95	0.98	4.46	0.99
PANAS NEG	1.45	0.56	1.37	0.38	1.37	0.43	1.52	0.59
Temperature, °C	14.8	4.4	15.8	4.2	15.9	5.8	15.3	4.8
Noise, dBA	55.1	2.9	50.7	4.9	48.2	3.3	50.0	3.3
Feelings and thoughts	4.80	1.41	4.41	1.35	4.88	1.38	4.88	1.14
People around me	2.76	1.20	2.45	0.95	2.67	1.26	2.65	1.05
Forest environment	5.48	0.88	5.88	0.73	5.77	0.86	5.62	0.84
The activity itself	3.61	1.16	3.61	1.18	3.42	1.30	3.56	1.44
Insects	1.55	0.86	2.17	1.26	2.17	1.34	1.98	1.20
Sound focus	3.48	1.50	4.14	1.63	3.11	1.40	3.95	1.48

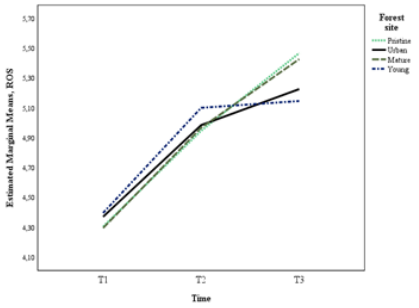
When exploring the interaction effects of ROS between the forests, it was revealed that the mature commercial forest and old-growth forest were significantly more restorative in comparison to the young commercial forest and urban recreation forest on T3 vs. T2 and T3 vs. T1 (Figure 9). Furthermore, the urban recreation forest was found to be significantly more restorative between the time points T3 and T2, compared with the young commercial forest.

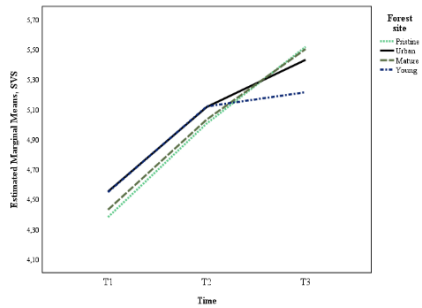
The interaction effects of SVS between the forests revealed that the mature commercial forest and old-growth forest were significantly more vitalizing in comparison to the young commercial forest on T3 vs. T2, and T3 vs. T1 (Figure 10). The urban recreation forest was perceived as significantly less vitalizing compared to the old-growth forest and the mature commercial forest on T3 vs. T2, but as equally vitalizing between T3 vs. T1. However, the urban recreation forest was perceived as significantly more vitalizing on T3 vs. T2 compared to the young commercial forest.

The Forest site ($F(3, 195) = 2.77$, $p < .05$) and Time ($F(1, 65) = 90.48$, $p < .01$) had significant main effects on positive emotions (PANAS pos) during the experiment. The interaction effect ($F(3, 195) = 11.27$, $p < .01$) was also significant, and revealed that the positive emotions were significantly higher in the old-growth forest and mature commercial forest compared to the urban recreation forest and young commercial forest and on T3 vs. T1 (Figure 11).

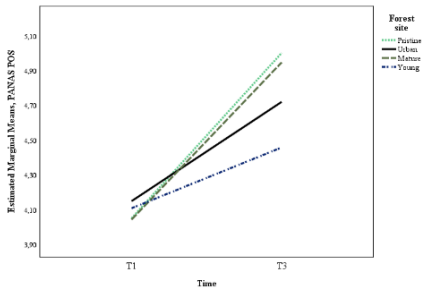
There was no significant main effect on Forest site on negative emotions (PANAS neg) ($F(3, 195) = 0.48$), but the main effect of Time was significant ($F(1, 65) = 80.86$, $p < .01$). During the experiment, the interaction effect on negative emotions was not significant ($F(2.65, 170.05) = 2.04$, $p = 0.12$) between the Forest site and Time, but there was a small effect difference between the old-growth forest and young commercial forest between T3 vs. T1 (Figure 12).

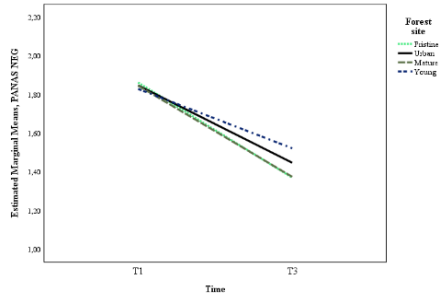
In summary, forest management influenced the restorative quality of the forests: younger forests, typical of traditional management, were the least restorative, while older forests promoted greater restoration. Interestingly, no significant difference was found between the restorative effects of the old-growth forest and the mature commercial forest. This is notable given that mature managed forests are often the most preferred in recreation studies—although such studies rarely include old-growth forests and tend to focus primarily on management preferences rather than restorative outcomes.





Figures 9 and **10**. Figure 9 represents the interaction graph for the Restoration Outcome Scale and Figure 10 the Subjective Vitality Scale. The graphs feature four lines representing different forest types, measured at three time points: T1 (before entering the forest), T2 (after sitting), and T3 (at the end of the experiment). Figures were published in the original publication of Simkin et al. (2020).





Figures 11 and **12**. Figure 11 represents the Interaction graph for PANAS positive and Figure 12 the PANAS negative: The graphs features four lines representing different forest types, measured at two time points: T1 (before entering the forest) and T3 (at the end of the experiment). Figures were published in the original publication of Simkin et al. (2020).

4.3 How do the perceived (restorative) qualities differ in differently managed forests?

Article II examined in more detail the differences between forest characteristics and their potential connection to perceived restorativeness. Differently managed forests were evaluated based on four components—being away, fascination, compatibility, and extent—that influence how restorative the environment is perceived to be, according to the Perceived Restoration Scale (PRS).

In addition to the PRS components and open-ended responses, study II also examined which forest characteristics were liked. This was investigated using a method familiar from previous research, involving comparisons of semantic adjective pairs. After visiting each forest, participants evaluated the forest, for example, by rating how beautiful they found it using the adjective pair beautiful-ugly. For example, if the forest was rated '7' on the pair ugly-beautiful, it was perceived as very beautiful. A repeated measures analysis of variance (ANOVA) was conducted using four within-subject factors, corresponding to the four forests, to assess the effects on the PRS and semantic differentials. Separate models were run for each PRS component and each semantic differential to obtain contrasts against the reference categories.

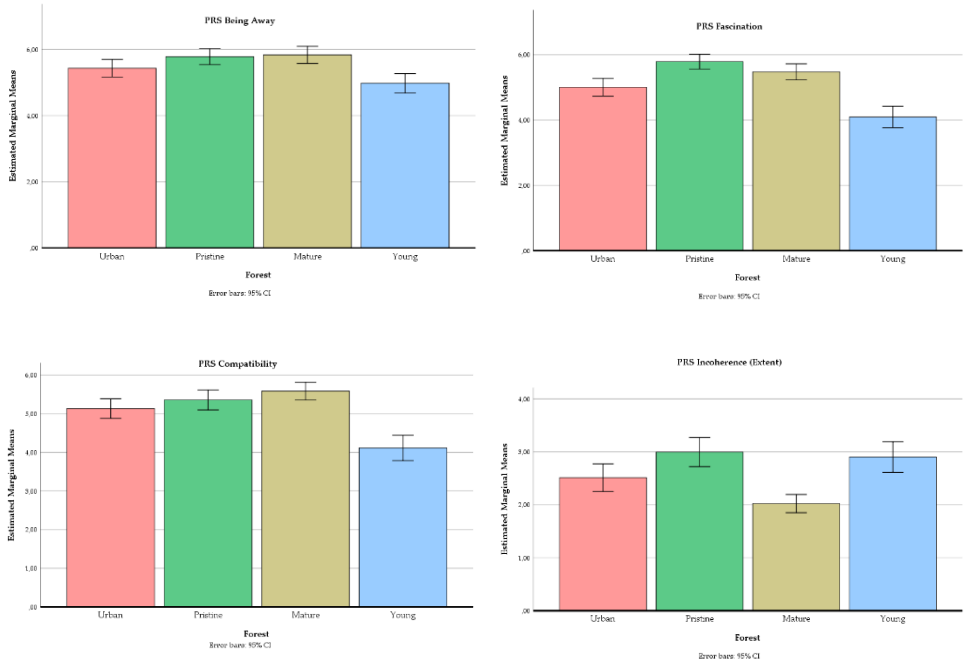
The connection of perceived restorativeness (PRS) to the semantic adjective pairs known from preference studies to be important for liking a forest was investigated with a multiple regression model. To incorporate the experience of restorativeness into the model as a single value, it was converted into a PRS score (Hietanen et al. 2007; Marselle et al. 2016). This score was calculated by summing the values of all PRS components, with the extent component using a reversed score. Four multiple regression models—one per forest —were conducted. The number of variables included in the models was limited to 13, due to the sample size (66 participants), to avoid overfitting and biased estimates, as fewer than five observations per variable is considered methodologically problematic (Metsämuuroinen 2011). Predictors were entered in three hierarchical steps to evaluate their relative contributions.

To examine more deeply the possible reasons why participants either liked or disliked the forests, these aspects were also explored through open-ended responses.

4.3.1 The four characteristics of the Perceived Restorativeness Scale (PRS)

The significant main effect was found on Forest site on the evaluation of the PRS being away ($F(2.65, 172.26) = 14.87$, $p < 0.01$), the PRS fascination ($F(2.40, 156.09) = 46.02$, $p < 0.019$, the PRS compatibility ($F(2.40, 156.00) = 33.12$, $p < 0.01$), and the PRS extent ($F(2.51, 163.22) = 16.13$, $p < 0.01$).

According to the contrasts, the feeling of being away was less strong in the urban recreation forest than in the mature commercial forest and the old-growth forest, and even weaker in the young commercial forest compared to the urban recreation forest. The old-growth forest was perceived as the most fascinating, followed by the mature commercial forest. The young commercial forest was perceived as the least fascinating. The old-growth forest was viewed as more compatible than the young commercial forest but equally compatible with the urban recreation forest. However, the mature commercial forest was perceived as more compatible than both the urban recreation forest and the young commercial forest.



Figures 13-16. The mean values of the Perceived Restorativeness Scale (PRS) for the dimensions of being away, fascination, compatibility, and extent (not reversed) were measured across the four forests at the end of the experiment. Error bars indicate 95% confidence intervals. The figures were published in reference Simkin et al. (2021).

The fourth component, the feeling of extent, was stronger in the old-growth forest and young commercial forest compared to the mature commercial forest. The urban recreation forest was perceived to have less extent than both the old-growth forest and the young commercial forest, but more extent compared to the mature commercial forest. All results are seen in following Figures 13-16.

4.3.2 The semantic differentials

The Forest site had significant main effects on the evaluation of all semantic differential adjective pairs, as seen in the Figure 17.

The semantic adjective pairs revealed several significant differences between the forests.

- The mature commercial forest and old-growth forest were perceived as more pleasant than the urban recreation and young commercial forests, with the urban recreation forest also rated higher than the young commercial forest.
- The mature commercial forest was seen as more beautiful than both the urban recreation and young commercial forests, while both the old-growth and urban recreation forests were rated more beautiful than the young commercial forest.
- The mature commercial and urban recreation forests were viewed as safer than the old-growth and young commercial forests.

- The mature commercial, old-growth, and urban recreation forests were regarded as more restorative than the young commercial forest, with the mature commercial forest being more restorative than the urban recreation forest.
- The old-growth forest was considered to have the highest biodiversity, followed by the mature commercial forest, urban recreation forest, and finally the young commercial forest, with all differences being significant.
- The young commercial forest was perceived as the least natural compared to the other three, and the urban recreation forest was less natural than the old-growth and mature commercial forests.
- The mature commercial and old-growth forests were perceived as more interesting than the urban recreation and young commercial forests, with the urban recreation forest also rated more interesting than the young commercial forest.
- The mature commercial forest was viewed as the calmest of all, while the old-growth forest was perceived as calmer than both the urban recreation and young commercial forests.
- The mature commercial forest was considered the most harmonious, followed by the old-growth and urban recreation forests, which were rated more harmonious than the young commercial forest.
- The mature commercial, old-growth, and urban recreation forests were seen as brighter compared to the young commercial forest.
- The mature commercial, old-growth, and urban recreation forests were rated more cheerful than the young commercial forest, with the mature commercial forest rated more cheerful than the old-growth forest.
- The old-growth forest was perceived as the most unmanaged, followed by the mature commercial forest, which was seen as more unmanaged than the young commercial forest.

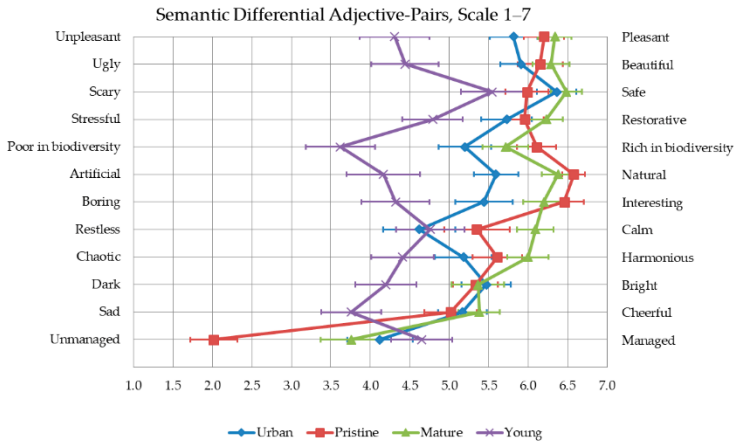


Figure 17. The average values of adjective pairs in the four different forests. Error bars indicate 95% confidence intervals. This figure was published in reference Simkin et al. (2021).

4.3.3 Participants' evaluation of site characteristics – open questions

A qualitative content analysis was applied to the open-ended responses. The most essential parts of the answers were extracted and grouped into codes based on their content. These codes were then used to identify themes that revealed meaningful patterns related to forest characteristics.

In response to the open question about what people liked in each forest, the most frequently mentioned characteristic in the old-growth forest was the presence of dead or decaying wood. In the other three forests the most liked features were the sounds of the forest and birds. Other commonly mentioned characteristics included naturalness, diversity, brightness, species richness, and details (Table 7).

Regarding the open answers to what people did not like, there were only a few negative comments about the old-growth forest and the mature commercial forest. In contrast, almost one-fifth of participants in the urban recreation forest felt there were too many other outdooring people present. In the young commercial forest, a third of the participants disliked its commercial appearance, describing it as monotonous or dull. The presence of dead and dried lower branches or logging residues was also unfavorable (Table 8). When external factors of the forest were excluded from consideration, as many as 73% of the participants mentioned some aspects they disliked in the young commercial forest, compared to 17% for the mature commercial forest, 18% for the old-growth forest, and 15% for the urban recreation forest.

A frequently mentioned disliked factor not originating from the forests themselves was airplane noise, which was noted in all three forests except the urban recreation forest, where traffic noise was the primary issue.

Some indication of what people thought about the forests can also be gained by examining the response rates. Only one participant did not respond to what they liked about the forest, and this was in the urban forest. However, the response rates for what was disliked were as follows: 92% for the old-growth forest, 86% for the urban recreation forest, 94% for the young commercial forest, and 73% for the mature commercial forest. However, this also included noise, which was, for example, mentioned by up to 64% of the participants as a disturbing factor in the old-growth forest. Thus, direct conclusions about which forests were liked or disliked cannot be drawn from the response rates.

Table 7. The proportion of the 10 most liked characteristics in the forests according to the open questions. Darker green indicates more positive responses, while darker red indicates fewer positive responses. Table is modified from the original publication of Simkin et al. (2021).

What did you like about this forest?	Urban %	Pristine %	Mature %	Young %
Dead or decaying wood	11	36	5	2
Natural	14	35	5	2
Sounds of the forest and birds	27	27	29	29
Versatile	21	27	20	3
Species richness	11	26	20	3
Bright	17	14	24	21
Fascinating/awe/details	12	24	14	3
Old/large trees	8	12	20	3
Oldness	6	18	9	0
Serene/peacefulness	11	14	12	11

Table 8. The proportion of the 10 most disliked characteristics in the forests according to the open questions. Darker red indicates more not liked responses, while stronger green indicates fewer not liked responses. Table is modified from the original publication of Simkin et al. (2021).

What did you not like about this forest, or what disturbed you about this forest?	Urban %	Pristine %	Mature %	Young %
Airplane noise	20	64	29	42
Traffic noise	47	5	6	0
Characteristics of commercial forest	0	0	3	32
Dull	3	3	3	26
Dead branches	0	0	0	20
Other people	18	2	3	2
Thinning waste	0	0	0	17
Paths	14	0	0	0
Dead or decaying wood	0	6	0	0
Gloomy spruces	3	2	5	0

4.3.4 The forest characteristics explaining perceived restorativeness (PRS)

To examine which forest characteristics explain Perceived Restorativeness (PRS), multiple regression analysis was used (see the results of step three in Table 9). The regression models were built in three hierarchical steps. In the first step, control variables (gender, age, education level, childhood living environment, and temperature) were included. The second step added nature-related variables: nature relatedness, forest familiarity, and nature-related work. Variables causing multicollinearity or lacking correlation with the outcome were excluded. In the final step, perceived forest qualities (e.g., beauty, safety, brightness, biodiversity, and management) were added based on their relevance in preference studies.

According to the model, perceived beauty was the strongest forest quality that was associated with the perceived restorativeness in all four forests. The more beautiful the participants perceived the forests, the stronger they perceived the forest was restoring (evaluated at point T3). The quality "rich in biodiversity" was associated positively to the perceived restorativeness in the old-growth forest, in the mature commercial forest and in the young commercial forest. The quality of "managed" also had a positive association with perceived restorativeness in the old-growth forest.

In summary, the three older forests had more preferred qualities than the young commercial forest. Beauty was the strongest predictor of perceived restorativeness in all forests, while perceived biodiversity supported it in all but the urban forest. The results suggest that the restorative experience is shaped by the overall character of the forest rather than by individual forest qualities alone, although these qualities also play an important role. Notably, decaying wood did not reduce perceived restorativeness, though its acceptance may vary between individuals.

Table 9. Final model (step three) of the multiple regression analyses predicting overall perceived restorativeness (PRS score) in four different forests. Table was published in the original publication of Simkin et al. (2021).

	Urban						Pristine						Mature						Young					
	B	Std. Error	Std. Beta	p	95% CI		B	Std. Error	Std. Beta	P	95% CI		B	Std. Error	Std. Beta	p	95% CI		B	Std. Error	Std. Beta	p	95% CI	
(Constant)	0.73	1.11		0.517	-1.51	2.96	0.69	0.68		0.314	-0.67	2.05	0.13	0.89		0.882	-1.64	1.91	1.91	0.98		0.057	-0.06	3.87
Temperature °C	0.01	0.02	0.06	0.582	-0.03	0.05	-0.01	0.02	-0.03	0.749	-0.05	0.03	0.02	0.01	0.20	0.041	0.00	0.05	-0.01	0.02	-0.03	0.720	-0.05	0.03
Gender: 0=men, 1=women	-0.06	0.20	-0.03	0.775	-0.47	0.35	-0.05	0.13	-0.03	0.729	-0.31	0.22	-0.23	0.15	-0.15	0.121	-0.53	0.06	0.12	0.19	0.05	0.527	-0.26	0.50
Age	0.01	0.01	0.07	0.536	-0.01	0.02	0.00	0.01	0.02	0.755	-0.01	0.01	0.01	0.01	0.11	0.216	0.00	0.02	-0.01	0.01	-0.07	0.387	-0.02	0.01
Educational level: Low=0, High=1	-0.10	0.23	-0.05	0.686	-0.56	0.37	-0.32	0.14	-0.17	0.031	-0.61	-0.03	0.13	0.16	0.08	0.426	-0.20	0.46	0.01	0.21	0.00	0.968	-0.41	0.43
Childhood environment: Countryside=0, City=1	0.07	0.25	0.03	0.790	-0.44	0.58	-0.20	0.17	-0.09	0.261	-0.54	0.15	-0.20	0.19	-0.10	0.293	-0.57	0.18	-0.13	0.24	-0.05	0.593	-0.62	0.36
Nature Relatedness. NR	0.26	0.18	0.18	0.150	-0.10	0.62	0.30	0.12	0.23	0.013	0.07	0.54	0.33	0.13	0.27	0.014	0.07	0.59	0.12	0.16	0.07	0.461	-0.20	0.44
Familiarity of outdooring in forest	-0.09	0.13	-0.08	0.523	-0.35	0.18	0.02	0.09	0.02	0.836	-0.16	0.19	0.06	0.10	0.06	0.564	-0.14	0.26	-0.02	0.12	-0.01	0.869	-0.27	0.23
Work related to nature: No=0, Yes=1	0.06	0.22	0.03	0.799	-0.39	0.51	-0.15	0.15	-0.08	0.349	-0.46	0.16	0.05	0.17	0.03	0.778	-0.29	0.38	0.09	0.23	0.04	0.697	-0.38	0.56
Beautiful	0.31	0.12	0.37	0.016	0.06	0.56	0.37	0.08	0.52	0.000	0.21	0.53	0.33	0.10	0.42	0.002	0.13	0.53	0.34	0.09	0.54	0.000	0.17	0.52
Secure	0.16	0.11	0.18	0.135	-0.05	0.37	0.03	0.07	0.04	0.641	-0.11	0.18	0.07	0.10	0.08	0.493	-0.14	0.28	0.13	0.07	0.19	0.085	-0.02	0.27
Bright-Dark	0.02	0.09	0.03	0.795	-0.16	0.20	0.00	0.06	0.01	0.939	-0.12	0.13	-0.02	0.06	-0.04	0.729	-0.15	0.10	-0.12	0.08	-0.17	0.175	-0.28	0.05
Managed	-0.04	0.06	-0.08	0.499	-0.17	0.08	0.14	0.05	0.21	0.012	0.03	0.25	-0.01	0.05	-0.03	0.780	-0.11	0.08	0.01	0.06	0.01	0.901	-0.11	0.13
Rich in biodiversity	0.13	0.08	0.20	0.106	-0.03	0.29	0.19	0.08	0.24	0.025	0.03	0.36	0.18	0.07	0.29	0.013	0.04	0.33	0.23	0.07	0.38	0.002	0.09	0.38

Note: B = regression coefficient, β = standardized regression coefficient. Step 3: Urban: R^2 adj. = 0.33 ***, Pristine: R^2 adj. = 0.68 ***, Mature: R^2 adj. = 0.52 ***, Young: R^2 adj. = 0.63 ***. R^2 = coefficient of determinations. *** Step is significant at a level of $p < 0.001$, ** at a level of $p < 0.01$, and * at a level of $p < 0.05$.

4.4 How do individual variables effect perceived restorativeness (PRS), restoration (ROS), and perceived qualities of a forest?

In article II, the research also examined whether people's sociodemographic background characteristics, such as age, gender, and childhood living environment influenced the type of forest they perceived as restorative (PRS-score). Additionally, aspects related to relationship to nature, such as nature relatedness (NR) and its relation to the perception of restoration in different forests were investigated. To determine the effets on perceived restorativeness, multiple regression analysis was used, as described in the previous section 4.3.4.

In Article III, to explore whether individuals restore differently in four forest types depending on their mental well-being state, multiple regression analysis was conducted. The models were constructed in two hierarchical steps. In the first step, control variables—gender, age, education level, childhood living environment, temperature—as well as the short Nature Relatedness Scale (NR-6), were included as previous studies have shown that these variables can influence restorative experiences. In the second step, work stress (TSK), stress (PSS-10), and risk of depression (DEPS) were added as independent variables, each tested in a separate model. The dependent variable was the change in restoration (ROS-change). Each forest type was analyzed individually, with forest type serving as the independent variable in each model.

Since the focus at this stage was not on participants' post-visit perceptions of restorativeness, the PRS variable was not included in the model. Instead, the ROS-change variable was used, as the aim was to specifically examine the change in restoration in relation to each participant's mental well-being state. To examine change in restoration, the ROS-change variable was calculated by subtracting the mean sum score at time point T1 (before the forest visit) from the mean sum score at T3 (after the forest visit), indicating the degree of restorative change.

4.4.1 Sociodemographic variables and relationship to nature

PRS-score

The study found that age and gender were not associated with perceived restorativeness (PRS) in the forests. However, a higher level of education was negatively associated with perceived restorativeness (PRS)in the old-growth forest.

There was no association between familiarity with outdoor activities and perceived restorativeness (PRS) in any of the forests. However, the final model revealed a positive association between nature relatedness and perceived restorativeness (PRS) in both the old-growth forest and the mature commercial forest. Additionally, higher temperatures were positively associated with perceived restorativeness in the mature commercial forest.

ROS-change

When exploring the potential association of individual mental state with restorative outcomes (ROS change), gender, age, educational level, childhood residency, and nature relatedness were used as control variables. Temperature was also added to the models due to its correlation with the dependent variable in some forests, with a notable association found in the young commercial forest according to the multiple regression model.

In terms of restoration outcomes, age and gender were not associated with restoration in the forests. However, higher levels of education were negatively associated with restoration in the urban recreation forest across all three multiple regression models conducted for article III (TSK, PSS-10, and DEPS). A similar negative association was found in the young commercial forest according to the DEPS model.

There was also a positive connection between nature relatedness (NR6) and restorative outcomes exclusively in the old-growth forest, according to all models (TSK, PSS, and DEPS). Although nature relatedness influenced the coefficient of determination in the TSK and DEPS models, the Sobel test (Preacher and Leonardelli 2001) indicated that nature relatedness did not mediate the effect of DEPS, TSK, or PSS-10 on restoration.

Furthermore, there was a significant negative association between urban childhood residency and restoration in the old-growth forest according to the PSS-10 and DEPS models. This means that individuals who spent their childhood in urban areas experienced less restoration in the old-growth forest compared to those who grew up in rural areas.

4.4.2 The association of participants' stress and mental state to the restorative outcome (ROS change) in different forests

There was no association between the results on the Perceived Stress Scale (PSS-10) and restorative outcomes. However, work stress (TSK) was significantly associated with the restoration in both the old-growth forest and the mature commercial forest, although the model was at the borderline of statistical significance at the mature commercial forest. The model's explanatory power in step 1 for the mature commercial forest was not significant, with an adjusted coefficient of determination (R^2) of 0.02. However, after adding the TSK variable in step 2, the explanatory power increased to an adjusted R^2 of 0.11. Therefore, work stress explained 9% of the restoration in the mature commercial forest. Correspondingly, the model's explanatory power in step 1 for the old-growth forest was an adjusted R^2 of 0.16. After adding the TSK variable in step 2, the explanatory power increased to an adjusted R^2 of 0.37. Therefore, work stress explained 21 % of the restoration in the old-growth forest. This means that these two forests, with stronger effect in old-growth forest, were more restorative for those whose current workday was more stressful compared to those who exper less stress.

When examining the link between depression risk (DEPS) and restorative outcomes, a significant result also emerged. In step 1, the model's explanatory power for the old-growth forest was an adjusted R^2 of 0.18. After adding the DEPS variable in step 2, the explanatory power increased to an adjusted R^2 of 0.24. Therefore, risk of depression explained 6% of the restoration in the old-growth forest, meaning the old-growth forest was more restorative for individuals at higher risk of depression compared to those at lower risk.

When examining the coefficient of determination in all models (PSS-10, TSK, and DEPS), only the old-growth forest showed a significant coefficient of determination as powerful as $p \leq .001$ level. In this case, the variables explained 37% of the restorative outcome in the TSK model and 24% in the DEPS model.

In summary, according to the results, nature relatedness was linked to higher restoration in both old-growth and mature commercial forests, suggesting that a personal connection to nature enhances restorative experiences, particularly in more natural settings. Moreover, natural or natural-looking older forests are the most effective in relieving stress, with genuinely old-growth forests potentially being particularly beneficial for individuals at risk of depression. Overall, the results underscore that restorative experiences are shaped not only

by forest management practices but also by individual psychological states and needs. The results described above are seen in the following Tables 10-12.

Table 10. Final models (step 2) of the multiple regression analyses predicting restoration (ROS-change) from work stress (TSK) and control variables across four different forests. The table is modified from the table in the manuscript of Simkin et al.

TSK	Urban recreation						Old-growth						Mature commercial						Young commercial					
	B	SE B	β	p	95% CI		B	SE B	β	p	95% CI		B	SE B	β	p	95% CI		B	SE B	β	p	95% CI	
(Constant)	0.42	0.91		0.65	-1.40	2.24	-0.72	0.97		0.46	-2.67	1.23	-0.26	1.04		0.80	-2.33	1.82	2.18	0.96		0.03	0.25	4.11
Temperature, °C	-0.01	0.02	-0.07	0.60	-0.05	0.03	-0.03	0.03	-0.12	0.27	-0.09	0.03	0.02	0.02	0.10	0.41	-0.02	0.06	-0.06	0.02	-0.30	0.02	-0.11	-0.01
Age	-0.01	0.01	-0.13	0.30	-0.03	0.01	0.01	0.01	0.08	0.43	-0.01	0.03	0.00	0.01	0.04	0.76	-0.02	0.03	-0.01	0.01	-0.10	0.39	-0.03	0.01
Gender 0=men, 1=women	0.30	0.21	0.18	0.15	-0.11	0.72	-0.08	0.22	-0.04	0.71	-0.52	0.36	-0.10	0.26	-0.05	0.69	-0.62	0.41	0.20	0.22	0.11	0.37	-0.24	0.65
Educational level: Other=0, Uni=1	-0.56	0.23	-0.30	0.02	-1.01	-0.10	-0.39	0.25	-0.16	0.12	-0.89	0.10	-0.30	0.28	-0.13	0.30	-0.86	0.27	-0.47	0.25	-0.23	0.07	-0.97	0.03
Childhood residency: Countryside=0, City=1	0.26	0.26	0.12	0.33	-0.27	0.78	-0.27	0.31	-0.10	0.38	-0.88	0.34	-0.25	0.33	-0.10	0.45	-0.90	0.40	0.03	0.29	0.01	0.92	-0.55	0.61
Nature Relatedness, NR-6	0.18	0.17	0.14	0.28	-0.15	0.52	0.38	0.19	0.21	0.05	-0.01	0.76	0.16	0.22	0.10	0.45	-0.27	0.59	-0.11	0.18	-0.08	0.54	-0.48	0.25
TSK	0.11	0.10	0.14	0.25	-0.08	0.31	0.43	0.10	0.50	0.00	0.24	0.62	0.31	0.12	0.34	0.01	0.08	0.54	0.18	0.11	0.21	0.09	-0.03	0.39

Note. Urban recreation: R2 adj. = .10, Old-growth: R2 adj. = .37*, Mature commercial: R2 adj. = .11*, Young commercial: R2 adj. = .14*.**

Note: ***Step is significant at a level of p ≤ .001, **at a level of p ≤ .01 level and *at a level of p ≤ .05. B = regression coefficient, standardized beta = β. R2=coefficient of determinations. CI = Confidence Intervals.

Table 11. Final models (step 2) of the multiple regression analyses predicting restoration (ROS-change) from perceived stress (PSS-10) and control variables across four different forests. The table is modified from the table in the manuscript of Simkin et al.

PSS	Urban recreation						Old-growth						Mature commercial						Young commercial					
	B	SE B	β	p	95% CI		B	SE B	β	p	95% CI		B	SE B	β	p	95% CI		B	SE B	β	p	95% CI	
(Constant)	0.29	0.98		0.77	-1.68	2.25	-0.64	1.16		0.58	-2.97	1.69	0.42	1.20		0.73	-1.99	2.82	2.20	1.02		0.04	0.16	4.24
Temperature, °C	0.00	0.02	-0.02	0.88	-0.05	0.04	-0.02	0.03	-0.08	0.52	-0.09	0.05	0.02	0.02	0.11	0.40	-0.02	0.06	-0.06	0.02	-0.31	0.01	-0.11	-0.01
Age	-0.01	0.01	-0.10	0.46	-0.03	0.01	0.01	0.01	0.05	0.67	-0.02	0.03	0.00	0.01	-0.02	0.88	-0.03	0.02	0.00	0.01	-0.05	0.69	-0.03	0.02
Gender 0=men, 1=women	0.22	0.21	0.13	0.30	-0.20	0.64	-0.12	0.25	-0.05	0.64	-0.62	0.38	-0.18	0.27	-0.09	0.52	-0.73	0.37	0.14	0.23	0.08	0.54	-0.31	0.60
Educational level: Other=0, Uni=1	-0.56	0.23	-0.30	0.02	-1.02	-0.10	-0.37	0.28	-0.15	0.19	-0.92	0.19	-0.39	0.30	-0.17	0.20	-0.99	0.21	-0.49	0.25	-0.24	0.06	-0.99	0.02
Childhood residency: Countryside=0, City=1	0.24	0.26	0.11	0.37	-0.29	0.76	-0.82	0.33	-0.30	0.02	-1.47	-0.16	-0.37	0.34	-0.14	0.29	-1.05	0.32	-0.09	0.29	-0.04	0.75	-0.66	0.48
Nature Relatedness, NR-6	0.20	0.17	0.15	0.23	-0.13	0.54	0.64	0.20	0.37	0.00	0.24	1.05	0.34	0.22	0.20	0.13	-0.10	0.77	-0.07	0.18	-0.05	0.72	-0.43	0.30
PSS-sum	0.02	0.02	0.12	0.35	-0.02	0.06	0.04	0.02	0.18	0.15	-0.01	0.08	-0.01	0.03	-0.05	0.71	-0.06	0.04	0.02	0.02	0.13	0.31	-0.02	0.07

Note. Urban recreation: R2 adj. = .09, Old-growth: R2 adj. = .19, Mature commercial: R2 adj. = .00, Young commercial: R2 adj. = .11*.**

Note: ***Step is significant at a level of p ≤ .001, **at a level of p ≤ .01 level and *at a level of p ≤ .05. B = regression coefficient, standardized beta = β. R2=coefficient of determinations. CI = Confidence Intervals.

Table 12. Final models (step 2) of the multiple regression analyses predicting restoration (ROS-change) from risk of depression (DEPS) and control variables across four different forests. The table is modified from the table in the manuscript of Simkin et al.

DEPS	Urban recreation						Old-growth						Mature commercial						Young commercial					
	B	SE B	β	p	95% CI		B	SE B	β	p	95% CI		B	SE B	β	p	95% CI		B	SE B	β	p	95% CI	
(Constant)	0.57	0.94		0.55	-1.31	2.45	-0.43	1.02		0.67	-2.47	1.61	0.31	1.11		0.78	-1.91	2.53	2.39	0.93		0.01	0.53	4.25
Temperature, °C	0.00	0.02	-0.02	0.88	-0.05	0.04	-0.03	0.03	-0.09	0.43	-0.09	0.04	0.02	0.02	0.11	0.39	-0.02	0.06	-0.06	0.02	-0.32	0.01	-0.11	-0.02
Age	-0.01	0.01	-0.12	0.32	-0.03	0.01	0.00	0.01	0.03	0.82	-0.02	0.02	0.00	0.01	-0.01	0.94	-0.02	0.02	-0.01	0.01	-0.07	0.53	-0.03	0.01
Gender 0=men, 1=women	0.24	0.21	0.14	0.27	-0.19	0.66	-0.15	0.24	-0.07	0.54	-0.63	0.33	-0.18	0.27	-0.09	0.51	-0.73	0.37	0.13	0.23	0.07	0.55	-0.32	0.58
Educational level: Other=0, Uni=1	-0.58	0.23	-0.32	0.01	-1.04	-0.12	-0.39	0.27	-0.16	0.15	-0.92	0.14	-0.38	0.30	-0.16	0.21	-0.97	0.22	-0.50	0.25	-0.25	0.05	-1.00	-0.01
Childhood residency: Countryside=0, City=1	0.23	0.27	0.11	0.40	-0.31	0.76	-0.92	0.32	-0.34	0.01	-1.56	-0.28	-0.35	0.35	-0.13	0.31	-1.05	0.34	-0.14	0.29	-0.06	0.62	-0.72	0.44
Nature Relatedness, NR-6	0.20	0.17	0.15	0.23	-0.14	0.54	0.68	0.20	0.39	0.00	0.28	1.07	0.33	0.22	0.20	0.13	-0.11	0.77	-0.05	0.18	-0.03	0.78	-0.42	0.31
DEPS	0.01	0.03	0.05	0.68	-0.04	0.07	0.07	0.03	0.28	0.02	0.01	0.13	-0.01	0.03	-0.04	0.74	-0.08	0.05	0.04	0.03	0.16	0.19	-0.02	0.09

Note. Urban recreation: R2 adj. = .08, Old-growth: R2 adj. = .24* , Mature commercial: R2 adj. = .00, Young commercial: R2 adj. = .12*.**

Note: ***Step is significant at a level of p ≤ .001, **at a level of p ≤ .01 level and *at a level of p ≤ .05. B = regression coefficient, standardized beta = β. R2=coefficient of determinations. CI = Confidence Intervals.

4.5 The linkages between preferences and restorativeness/restoration?

While participants rated the old-growth and urban recreation forests similarly on the beautiful–ugly scale, the old-growth forest was still experienced as significantly more restorative. Moreover, of the commonly preferred features in forests, the perceived beauty of the forest explained the perceived restorativeness in all forests. Additionally, perceived biodiversity richness emerged as a significant factor explaining perceived restorativeness in all models except in urban recreation forests. Conversely, no connection was found between the semantic adjective "un-managed-managed" and perceived restorativeness in managed forests. However, in the old-growth forest, a connection emerged: the more the old-growth forest was perceived as managed, the more restorative it was considered.

Immediately after each forest visit, participants were asked about the suitability of the forest for their own use with the question: "How suitable is the forest for your outdoor activities?" Based on the responses (Table 13), 60 participants found the mature commercial forest to be very or quite suitable, followed by the urban recreation forest, which 56 participants found suitable, and the old-growth forest, which 53 participants found suitable. Only 29 participants felt that the young commercial forest was suitable for them. These results were not used in the sub-publications because open-ended responses revealed that many participants interpreted the question more broadly than intended—taking into account external factors such as airplane noise or accessibility, rather than focusing on the intrinsic characteristics of the forest.

Nevertheless, the responses offer a tentative indication that comparing perceived suitability (preferences) and restoration requires caution. For instance, the urban recreation forest was rated as more suitable for outdoor activities than it was perceived as restorative—likely due to its convenient location. Despite the variation in how participants interpreted the question, the results are included in this summary to illustrate the complexity of measuring preferences and perceived well-being benefits.

In summary: Preferences generally aligned with how restorative the forests were perceived, though some discrepancies were observed. Perhaps forest in general is seen beautiful, even though it would not be so strongly restorative.

Table 13. Participants' responses to “How suitable is the forest for your outdoor activities?”

	Very well	Quite well	Neither well nor poorly	Quite poorly	Not at all	In total
Old-growth forest	22	31	5	7	1	66
Urban recreation forest	28	28	6	4	0	66
Young commercial forest	5	24	7	25	5	66
Mature commercial forest	34	26	3	3	0	66

4.6 The environmental factors during the experiment

The temperatures of the forests were similar when tested with a paired samples t-test. During the time spent in the forests, no relationship was found between the restorative effects experienced and the average temperature, according to the Pearson correlation analysis. However, there was a correlation between some components of the PRS and the average temperature on the Pearson correlation in a young commercial forest and a mature commercial forest.

The average noise levels (dBA) were significantly higher in the urban recreation forest compared to the other three forests ($p < .01$) when tested with a Kruskal–Wallis test (see Table 6). While in the forests, there was no correlation between the restorative effects or components of the PRS on average noise (dBA) on the spearman correlation.

Sound focus (other than nature) (see Table 6) captured more attention in the old-growth and young commercial forests compared to the mature commercial forest, Additionally, these sounds were more captivating in the old-growth forest compared to the urban environment.

The measurements of relative humidity varied between 29–100% in the urban recreation forest, 31–96% in the old-growth forest, 31–91% in the mature commercial forest, and 27–98% in the young commercial forest, depending on the visit day. However, the values were only indicative, as they were obtained from the measurement point located at Helsinki-Vantaa Airport, 5–15 kilometers from each forest. Therefore, a more detailed analysis could not be conducted concerning humidity variables.

5 DISCUSSION AND FUTURE STUDY RECOMMENDATIONS

Previous research suggests that while forests are generally effective for psychological restoration, a variety of factors shape both their restorative potential and people's preferences for different forest characteristics. However, there is still limited and partly inconsistent evidence on how specific forest management practices or structural features affect restorative

experiences. Further research is therefore needed to determine whether certain forest types or management approaches are particularly beneficial—especially for individuals experiencing stress or mental health challenges.

To address these gaps, this study selected two commercial forests, one recreational forest, and one forest that was as natural as possible for the experimental design. Three of the forests were older, while one—representing a young commercial forest—was approximately 40 years old. Older forests were intentionally chosen, as previous research has indicated that they are generally preferred for recreational purposes. The mature commercial forest represents a typical forest that Finns commonly encounter in their surroundings and is frequently used for recreation. The young commercial forest, selected to represent approximately 40% of the forests in southern Finland that are under 40 years old, is similarly prevalent and thus familiar to many Finns. The urban forest served primarily as a control area, but is also a highly popular recreational site. The inclusion of the old-growth forest specifically addresses a knowledge gap regarding the impacts of natural forest conditions on restoration.

This dissertation aimed to investigate, through four research questions, whether and how forest management decisions influence human experience and well-being, as discussed in the following sections.

5.1 How does forest management impact restorative effects?

This dissertation investigated the restorative effects, including perceived restorative outcomes (ROS), vitality (SVS), and positive and negative emotions (PANAS) in four forests representing different management outcomes: 1) an urban recreation forest, 2) a mature commercial forest, 3) a young commercial forest, and 4) an old-growth forest in its natural state. A repeated measures analysis of variance (ANOVA) with four within-subject factors (Urban, Pristine, Mature, and Young) was used. The findings revealed that both the mature commercial forest (managed) and the old-growth forest (natural) were the most restorative environments, while the urban recreation forest (managed) followed as the next most restorative.

Firstly, as hypothesized in Article I, all four forests in this study were significantly restorative—a result consistent with previous research showing that forests generally support psychological restoration. However, as also hypothesized, the young commercial forest was less restorative than the three older forests, although still yielding a significant restorative effect. These findings highlight how forest management practices can shape restorative outcomes.

The young commercial forest, characterized by a monotonous tree population of similar age, reflects a management choice aimed at even-aged and -sized trees for timber production. Such a forest structure would not occur if the forest were allowed to regenerate and grow naturally. If the forest regenerates and develops naturally, new seedlings typically emerge in small open spaces created by natural disturbances like storms (Kuuluvainen and Aakala 2011). Natural regeneration is also an option used in traditional commercial forests, by using shelterwood cutting for spruce-dominated forests and seed-tree cutting for pine-dominated forests. In these methods, not all large trees are removed during final harvesting; instead, some are retained to serve as seed sources (Äijälä et al. 2019). However, a more natural-looking and aesthetically valued form of commercial forest management compared to these methods is the continuous cover method, in which the regeneration occurs in small openings

created by first removing larger trees through selective harvesting (Silvennoinen et al. 2019; Koivula et al. 2020; Miina et al. 2022).

In recreational forests, managers also favor small-gap regeneration to preserve aesthetic variety and a sense of naturalness. By contrast, even-aged management generally leads to a large-scale clear-cut at the end of the rotation. If a boreal forest in Fennoscandia regenerates naturally after a disturbance like a fire, it does not develop into a managed forest structure characterized by a single species, uniform stands, or a lack of decaying wood (Aakala 2021). Thus, forest management decisions directly influence stand composition, appearance, and ecological complexity, all of which can affect a forest's perceived restorativeness.

The first article also hypothesized differences in restorative effects between the old-growth forest and the mature commercial forest; however, no significant distinction was observed. This result contrasts with a previous field experiment by Martens et al. (2010), which reported a stronger positive affect and reduced negative affect in a managed forest compared to a wild one. More recent field studies focusing on psychological outcomes, such as those by Takayama et al. (2017a, 2017b) and Saito et al. (2019), have found equal restorativeness between thinned, more open forests and unmanaged, denser forests. In contrast, Janeczko et al. (2021) observed that a natural primeval forest was more restorative than a commercially managed forest, and Saito et al. (2019) noted greater positive feelings in more natural forests for certain groups of visitors.

These inconsistencies may stem from variations in naturalness, management practices, forest developmental stage, and tree species across different study sites, as well as differences in study designs and objectives—whether they focus on the effects of recreational versus commercial forest management. Consequently, direct comparisons with the findings of this dissertation remain challenging due to the limited body of research in this area.

The findings and underlying reasons why the old-growth forest in this PhD study exhibited similar restorative effects to a mature commercial forest—despite its heterogeneous and somewhat restless appearance, which differs markedly from typical mature commercial forests—warrant further discussion and analysis. These aspects are explored in the following chapters.

Overall, the results indicating how restorative the four forests were seemed to be influenced by the types of characteristics and elements present in each forest, which was explored in article II. In addition, individual variables also affected the results, which was further explored in article III. Other features than forest characteristics or individual variables also have an impact, such as the advantages and challenges of the location; the urban recreational forest, despite being visually and structurally comparable to the mature commercial forest, demonstrated a lower restorative effect. All of these results are discussed further in upcoming paragraphs.

5.2 How do perceived (restorative) qualities differ in differently managed forests?

Previous preference studies offer insights into why the three older forests were more restorative than the young forest. All three older forests had landscape features that are typically liked, including large, mature trees, at least partly good visibility, and a relatively open stand structure with only some undergrowth. In contrast, the young commercial forest was a typically managed, even-aged forest with a monotonous structure and little variation in openness.

Moreover, besides appreciation, old trees have been noted to be one of the most important criteria for a restorative forest (Stoltz et al. 2016). Furthermore, participants had to navigate through logging residues in the young commercial forest, potentially impacting the restorative effect to some extent. However, in the old-growth forest, participants had to find their way around large amounts of decaying wood, but this did not appear to have a negative impact on the restoration in that environment. Thus, it seems that the difficulty of walking was not impacting negatively as such. Overall, the results aligns with preference studies describing the commonly appreciated forest being mature with no visible signs of forest management (e.g. Karjalainen 1996; Silvennoinen, 2017; Tyrväinen et al. 2017).

Although the urban recreation forest was nearly the same age as the mature commercial forest and managed to preserve biodiversity, it was less restorative than the other two older forests. The reasons for this were found in the open answers, where people mentioned other outdooring people, traffic, and city noise as disturbing. Additionally, 14 percent of the participants mentioned that the path network was too dense, although 12 percent of the participants particularly mentioned that they appreciated the easiness of walking in the forest, partly because of the paths. These findings align with previous research suggesting that the location of the study areas matters, as it has been suggested that forests outside cities in rural areas provide more restorative effects than urban forests (e.g. Roe and Aspinall, 2011; White et al. 2013). This may also be partly linked to familiarity, as some mentioned that the urban recreation forest was too familiar and thus did not seem to invite one on an adventure.

5.2.1 Characteristics influencing perceived forest restorativeness

Article II indicated that when certain restorative characteristics previously identified by research—such as coherence, naturalness, biodiversity, ease of walking, and brightness—were absent or diminished, other features or combinations of features appeared to compensate for them. This was in line with the two hypotheses that there are differences in restorative experiences between the forest sites and that the preferred forest qualities differ in differently managed forests. Thus, it became evident that the combined presence of different characteristics within the forests had a greater impact on how restorative the forest was perceived, rather than any individual characteristic on its own. However, according to the results of the multiple regression analysis, it seemed that certain characteristics could be very important and "stand out", even if they are relatively few in number. Thus, perceived richness in biodiversity emerged as a factor explaining restorativeness in all forests, including in the young commercial forest. All of the forests in this study were perceived as beautiful according to the semantic adjective pair "beautiful-ugly", and the perceived beauty of the forest significantly explained the perceived restorativeness in all forests. Despite the young commercial forest lacking certain characteristics that would be commonly liked, the overall perception of beauty still played a significant role in how restorative the forest was perceived.

Both the old-growth forest and the mature commercial forest, which were the most restorative forests, contained elements known from previous research to be important for the experience of restoration. Elements such as perceived biodiversity, versatility, bird sounds, and the general atmosphere of the forest contributed to the perceived equal restorative qualities of both managed commercial forests and natural old-growth forests. Naturalness, decaying wood, and brightness were also particularly valued when present, according to the open-ended answers. Perceived beauty and feelings of awe or fascination were important in both of these forests as well. However, both forests also lacked some commonly valued elements found in the other. For instance, the mature commercial forest was perceived as

easy to navigate, bright, safe, and peaceful according to semantic adjectives and open-ended answers. The old-growth forest gained appreciation for its diversity, multi-layered structure, and naturalness according to the semantic adjective pairs and open-ended answers.

Although earlier studies (Tyrväinen et al. 2003; Gundersen and Frivold 2008) indicate that dead or decaying wood is generally not preferred, it emerged as a frequently mentioned liked feature in this dissertation's open-ended responses, particularly for the old-growth forest. A considerable amount of dead wood was also retained in the mature commercial forest, but only 5% of participants cited it as a liked feature. The presence of dead or decaying wood typically indicates higher biodiversity—a factor that significantly explained perceived restorativeness in all forests except for the urban recreation forest, according to the multiple regression model.

However, the finding that deadwood was more often liked than disliked aligns with a study conducted in authentic urban forests in Helsinki, which found that decaying wood was widely accepted as a natural and desirable element of urban forest environments (Hauru et al. 2014). Moreover, previous research indicates that growing awareness of biodiversity's importance has further increased the acceptance of dead and decaying wood (Gundersen et al. 2017; Frick et al. 2018).

Upon examining the open responses, it became apparent that references to mysticism—be it fairy tales, fantasy, or trolls—occurred three times more frequently in relation to the old-growth forest than the mature commercial forest. Such emotional encounters with mystery help to break away from everyday life and enhance the experience of "being-away." Additionally, Kaplans observed that in many studies the most preferred scenes often evoke a sense of "mystery," where partially hidden information and elements within the scene attract individuals to explore further (Kaplan and Kaplan 1989).

Participants in all four forests appreciated natural sounds such as those of the forest itself and birds, yet airplane and traffic noise emerged as the most commonly disliked features. Airplane noise was particularly notable in the old-growth forest, where over 60% of participants found it bothersome; in the young commercial forest, 42% reported it as disturbing. Both of these forests experienced higher levels of overhead aircraft activity compared to the mature commercial forest and the urban recreation forest, the latter having the fewest passing airplanes.

Interestingly, despite frequent airplane noise, the old-growth forest was perceived as equally restorative as the mature commercial forest. It may have been sufficiently engaging to counteract the disturbance, as a few participants explicitly mentioned forgetting about the noise once they immersed themselves in the forest.

According to the researcher's observations, traffic noise was loudest in the urban recreation forest, where nearly half of respondents identified it as disturbing in the open-ended responses. In contrast, only one-fifth mentioned airplane noise in the same forest. Measured decibel levels confirmed that overall noise was highest in the urban forest, driven by traffic and other city sounds.

Visible signs of forest management were generally disliked; after disturbing noise, they were the second most frequently mentioned issue in the open-ended responses. Nearly all such comments referred to the young commercial forest, while only two participants mentioned signs of management as disturbing in the mature commercial forest. Additionally, more than a quarter of respondents described the young forest as boring.

Thus, it seems that the versatility of the forest contributes to the overall experience of restorativeness. If there is something intriguing to explore in the forest, the restoration process could advance further. This was evident in the fact that the restoration in the young

commercial forest no longer increased after 15 minutes from the start, according to the repeated measures of variances. When there are various elements and diversity in the forest, there is also plenty to observe, which in turn enhances attention restoration and ultimately the overall restorative effect. The significance of diversity, as in biodiversity levels, to restoration is also mentioned in the literature of the field (Wood et al. 2020; Nghiem et al. 2021). One question that arises is whether an environment can be too diverse or complex. This topic is discussed in the following section.

5.2.2 Too wild to be restorative? coherence, extent, and complexity in forest environments

According to the landscape characteristics described in the preference matrix, a coherent environment allows for an immediate understanding of how elements within the environment are connected, forming a unified whole (Tveit et al. 2012). Although the preference matrix and Attention Restoration Theory (ART) focus on different aspects of human–environment interaction, coherence still plays a role in directing attention. Within ART, the component of "extent" is critical for shaping the restorative experience. It refers to the scope and connectedness of the environment, enabling individuals to immerse themselves in the setting.

Kaplan and Kaplan (1989) discuss a trade-off between coherence and complexity. While coherence provides a sense of order and aids attention by supporting a stable mental model, complexity offers opportunities for discovery and contemplation. If an environment lacks coherence, the individual must constantly redefine their mental model, which can be mentally tiring. Ideally, a restorative environment is both rich and organized—high in complexity but also coherent. Similarly, Ulrich's Stress Recovery Theory (SRT) posits that pleasant environments are those that balance coherence and complexity (Ulrich 1983). Both theories imply that overly chaotic or overly simple environments may hinder restoration.

However, this dissertation challenges this interpretation. The perceived restorativeness of an old-growth forest was high, despite open-ended responses frequently described it as confusing or chaotic. Semantic differentials such as chaotic–harmonious also reflected this perception. Moreover, the forest was rated as high on the extent component. Yet, despite these features, the forest was still experienced as highly restorative, as indicated both by the restorative–stressful semantic differential and the temporal change in restoration. In contrast, the mature commercial forest, which had a more orderly appearance and was perceived as having a lower extent than the old-growth forest, was not considered more restorative than the old-growth forest.

These findings are important because, theoretically, the old-growth forest might lack sufficient coherence to support a stable mental model—one of the key mechanisms for restoration suggested by Kaplan (2001). Similarly, stress reduction theory does not entirely explain the strong restorative effects observed in the old-growth forest, at least not when considering all seven restorative characteristics described in the theory (Van den Bosch and Staats 2018). Although the old-growth forest met most of these characteristics, it did not align with Ulrich's (1983) criterion stating that a restorative environment should have a homogeneous and even ground surface texture that supports movement. Thus, existing theories only partially explain why the old-growth forest was so restorative.

Yet, Kaplan and Kaplan (1989) themselves noted that wilderness settings may elicit unique restorative responses that go beyond the four ART components (being away, fascination, extent, and compatibility). Participants in their wilderness studies often reported a sense of "wholeness" or "oneness" with nature. They felt deeply connected to their surroundings, leading to an intense sense of self-discovery. Overcoming challenges and fears

in the wilderness diminished feelings of helplessness and fostered a heightened sense of competence (Kaplan and Kaplan 1989). The Kaplans also suggested that the wilderness experience provided participants with a fresh perspective on their own lives, and that the mere existence of wilderness was a comforting thought. However, they acknowledged the role of confusion in this experience and the importance of having a tolerance for ambiguity.

It is crucial to recognize that simply adapting to confusion without processing it can be risky, whereas avoiding confusion altogether may hinder emotional development. Thus, the Kaplans proposed that an environment perceived as not excessively confusing—or one perceived as safe—could facilitate attention restoration. In such settings, individuals can process and make sense of any confusion they encounter.

Kaplan (2001) also emphasizes that the restorative characteristics described in ART are more "a person-environment interaction than of an environment per se." Ulrich (1983) also suggests that the inconsistent findings regarding complexity may stem from studies' inability to present a natural scene with high complexity.

Context also plays a crucial role in shaping restoration outcomes. The effectiveness of a restorative environment depends on an individual's level of need for restoration (Kaplan, 2001). Zube (1982) similarly argues that environmental experiences are shaped by cognitive processes influenced by past experiences, future expectations, and sociocultural conditioning. While natural forests may be more challenging to navigate, this may not be a barrier for everyone. In fact, according to this study, visiting a natural forest was found to be even more effective for restoration among individuals with lower moods. However, there is currently limited research on the impact of Kaplan's "single mental model" in untouched nature, warranting further investigation.

Finally, it is worth noting that Perceived Restorativeness Scale have been predominantly developed and tested in human-modified environments. The strong restorative responses observed in the old-growth forest may thus indicate that complex natural environments activate alternative or additional mechanisms of restoration not yet fully captured by existing theories. However, one possible explanation why the dissertation found that even highly complex and seemingly confusing environment was so restorative is the feeling of safety. The guided visits to the old-growth forest may have provided participants with a sense of security, allowing them to navigate and process emotions related to confusion. This raises the possibility that guided experiences in complex natural settings could be particularly beneficial in modern society, offering individuals an opportunity to engage deeply with restorative environments.

5.3 How do individual variables effect perceived restorativeness (PRS), restoration (ROS), and the perceived qualities of a forest?

5.3.1 Factors influencing perceived restorativeness and restoration: Insights from individual variables

Given that previous research indicates restorative experiences can partially depend on individual variables, this study included various background characteristics into the statistical models. According to the analyses in Articles II and III, age, gender, and childhood living environment did not influence perceived restorativeness in different forests. Similarly, there was no association between familiarity of outdooring in a forest or work related to nature and perceived restorativeness.

However, according to the results of the multiple regression model in article III, people who were born in urban areas did not restore as much in the old-growth forest compared to people who had lived their childhood in a more rural location. Perhaps the old-growth forest was experienced as too unfamiliar or exotic by more urban dwellers, a conclusion that would be supported by Adevi et al. (2012), who found that people tend to prefer the environment experienced more during their childhood. For some reason individuals with higher education levels did not perceive as strong restorativeness (PRS-score) in the old-growth forest compared to those with lower levels of education. The same connections were found with restoration (ROS-change) in the urban recreation forest and young commercial forest. While no clear explanation was identified for these results, the results showed that participants with higher educational backgrounds consistently rated their experiences lower across various survey questions, consistent with findings from previous studies (Meisenberg and Williams 2008). It is important to note, however, that the education level was on average somewhat high, for which reason the findings regarding education cannot be generalized. Therefore, further research is needed to understand the significance of education on the results.

Nature relatedness had some significant associations with how participants restored in different forests. The stronger nature relatedness explained the stronger perceived restorativeness in the old-growth forest and mature commercial forest, but stronger restoration only in the old-growth forest. The answers to these results may be found in the previous study by Davis and Gatersleben (2013), where people with higher levels of nature connectedness were found to be positively connected to awe- experience in wild nature. The awe-experience may be partly the reason why there was also a connection found between individuals at a higher risk of depression and stronger restoration only for the old-growth forest. However, it is noteworthy to mention here that nature relatedness did not mediate the effect that the risk of depression, work stress, or perceived stress had on restoration. Therefore, according to this, nature relatedness did not explain the stronger restoration for those feeling more depressed. The possible explanation of awe-effect, as well as other reasons, for the stronger restoration among individuals at higher risk of depression will be discussed next.

5.3.2 Results on the connection between stress and depression level and restoration in different types of forests

In article III, no hypotheses were formulated due to the exploratory nature of the study. The research questions focused on whether the self-evaluated perceived stress, current work stress, and risk of developing depression affected an individual's restoration in four different forests, and whether there is a difference in restorative outcomes between the four forests based on self-evaluated stress, current work stress, and risk of developing depression. There was a significant association found between the stronger restoration and higher work stress (TSK) in the old-growth forest and mature commercial forest. However, in the mature commercial forest the model was at a borderline statistical significance according to the multiple regression model. The work stress explained 9% of the variation in restoration in the mature commercial forest and 21% in the old-growth forest. Additionally, higher depression scores were associated with greater restoration in the old-growth forest, explaining 6% of the variation in restoration. Although the depression-restoration link was weaker, both this and the stronger connection between work stress and restoration in the old-growth forest highlight the need for further discussion. There was no connection between risk of depression and restoration in the mature commercial or in the other two forests.

These findings differ somewhat from earlier Swedish research (Sonntag-Öström et al. 2015), which found that patients with exhaustion disorder preferred characteristics such as an undemanding forest, brightness, openness, etc. (see chapter 1.5). However, it is also noteworthy that "stimulating" was mentioned among the preferred characteristics of these patients (Sonntag-Öström et al. 2015). The old-growth forest studied in this dissertation was partly quite demanding to walk. There was, however, brightness and openness, but it was unevenly distributed between the small openings and the dense canopies, unlike the mature commercial forest, which, due to its even-aged structure, was more uniformly open. However, the participants evaluated both forests as equally bright according to the semantic adjective pair bright-dark. On the other hand, the component "fascination" of the Perceived Restorativeness Scale was rated higher in the old-growth forest, which can be seen to represent stimulativeness. Both the mature commercial and the old-growth forest were peaceful in terms of disturbances by any other visitors, but in the old-growth forest sounds other than nature captured participants' attention significantly more than in the mature commercial forest, according to the self-evaluated 1–7 point likert scale. From the open responses it was revealed that the most disruptive noise in the old-growth forest was airplane noise. Despite the heavy airplane noise, the restoration in the old-growth forest was significant among participants with higher levels of work stress or risk of depression. The interpretation of peace or tranquility may encompass a broader range of features of the environment than just noise level or tranquility from others.

Swedish researchers have compiled a dimension model from previous studies, suggesting that the concept of a "serene" environment is important, and perhaps the most restorative among stressed individuals. They describe "social" as the opposite of "serene". The serene quality is described as an undisturbed place free from city noise and with a relative absence of other people. It is also described as natural, large, and cohesive (Stoltz and Grahn 2021a). Additionally, a serene environment should also have shelter so that one can see from their hiding place without being seen (Stoltz and Grahn 2021a). Interestingly, the authors also suggest in another study that for a serene environment a good level of maintenance is relevant: no litter, weeds, etc. (Stoltz and Grahn 2021b). They also describe it as "clear and tranquil." The description of shelter and naturalness fits well with the old-growth forest in this dissertation, but the characterization of coherence and good maintenance do not apply. The old-growth forest was not clear or maintained – quite the opposite. However, the description of the importance of good maintenance likely applies more to maintained urban parks, even though the study also included forests surrounding cities. They mention that the model created based on compiled studies is designed specifically to support land use planning in the light of "how urban greenspace qualities have been estimated historically" (Stoltz and Grahn 2021b).

Nevertheless, some studies, such as the research by Stigsdotter et al. (2017), support findings similar to those of this doctoral dissertation regarding old-growth forest. Their research suggests that a diverse environment is most optimal for restoration among individuals experiencing stress or mental illness. In addition to diverse vegetation, Stigsdotter et al. (2017) describe the ideal restorative forest as having a balance of dense, enclosed growth and more open areas. However, their experiment was conducted in an arboretum, not a natural forest. Still, such a forest resembles the typical appearance of naturally grown old-growth forests in northern regions, much like the old-growth forest studied in this dissertation. Variation in forest openness and density is, however, also common in forests managed for recreational purposes. Even in commercial forests, this structure can be present if some time has passed since the last thinning, or if trees have fallen naturally, allowing for

undergrowth to develop. The urban recreation forest in this study exhibited this kind of structure, and even the mature forest in places, where there were openings due to the fallen trees. These characteristics likely contributed to the restorative qualities of all three older forests studied. However, restoration in the urban forest was somewhat diminished by external factors, such as noise from outside the forest.

The variation between openness and enclosure seem to be important for restoration, as it reflects the qualities of "refuge" and "prospect" – concepts introduced in Appleton's (1975) theory of prospect-refuge and later incorporated into Stoltz and Grahn's dimension model (2021a). Both hiding (refuge) and observing (prospect) spaces are considered essential for evolutionary survival (Grahn and Stigsdotter 2010; Pálsdóttir et al. 2011).

All in all, a recent Japanese study (Saito et al. 2019) (see section 2.3.4) found a similar connection between depression and unmanaged forests as was found in this dissertation. However, the forest in question was not naturally grown but a plantation forest, and only 80 years old. To the best of my knowledge, no studies sufficiently similar to this dissertation have been conducted, so there are no complete points of comparison. Therefore, more research is needed on the well-being effects of natural forests. Overall, it should be noted that the aforementioned concepts are somewhat subjective and therefore difficult to compare, especially across studies conducted in different countries.

5.3.3 Why might people restore differently in different forests?

The reason why the old-growth forest appeared to be more restorative for individuals experiencing higher levels of work stress or depression may be partly explained by the three-phased restoration process outlined in the Attention Restoration Theory (ART). As detailed on chapter 2.3.1, the first phase of this process involves clearing the mind to focus on the environment. This was evident from the feedback received after the field experiment, with many participants expressing that the forest provided a much-needed break during the workweek. The second phase allows the "matters of one's mind" to be explored and heard, which was reflected in open-ended responses where participants mentioned reminiscing about childhood memories or experiencing a surge in creativity. The third phase, deep restoration, involves self-reflection, where priorities, goals, and possibilities in life become clearer (Kaplan and Kaplan 1989). This phase seems to be more pronounced, especially for some participants, in the mature commercial and old-growth forest where the higher work stress explained the restoration, and even more so in the old-growth forest where the higher work stress and greater risk of depression explained the stronger restoration. The abundant details in more natural environments seem to have helped participants relax and even experience inspiring moments, which may in turn be linked to self-reflection. In all three older forests, such details were frequently mentioned in the open-ended responses, especially in the old-growth forest, where 24% of participants highlighted them as preferred features. In comparison, the corresponding percentages were 14% in the mature commercial forest, 12% in the urban recreation forest, and only 3% in the young commercial forest. Moreover, according to a systematic review and meta-analysis of Nature-Based Mindfulness by Djernis et al. (2019), mindfulness in wild nature appeared to be more beneficial than mindfulness in more cultivated settings, emphasizing the importance of exploring the significance of different environments. Additionally, according to Perceived Restorativeness Scale, participants reported significantly more fascination in the old-growth forest compared to the other three forests. The experience of awe may have been more easily elicited in such a forest compared to managed forests that people see more often.

The “awe” experience is an emotional response when experiencing something larger than yourself of which makes the self small (Piff et al. 2015; Perlin et al. 2020). As people feeling depressed tend to think of themselves in a negative way (Tahmassian and Moghadam 2011; Davey and Harrison 2022), perhaps it was comforting that the surrounding environment (old-growth forest) was not “in order” either, but was nevertheless perceived as very beautiful. Kaplan and Talbot (1983) also discussed the connection between identification with wilderness and feelings of awe and wonder, suggesting that the experience of wilderness can evoke awe and wonder rather than feelings of control.

Despite the discussions presented in this dissertation, there may be aspects of the restorative experience in the old-growth forest that cannot be fully explained by existing theories or research findings. For instance, the potential role of factors such as microbes, phytoncides, or aromatic volatiles present in the old-growth forest in aiding the restoration of individuals with stress or depression cannot be definitively answered based on the study design and findings of this doctoral dissertation. Further interdisciplinary research, incorporating perspectives from fields such as forest sciences, biology, health sciences, and psychology, is needed to explore this aspect. As mentioned previously, exposure to microbial species found in natural environments has been shown to have a beneficial impact on human immune responses and may influence mental well-being.

5.4 The linkages between preferences and restorativeness/restoration

When preferences, i.e participants' responses to the open-ended question about the suitability of forests for themselves as well as the answers to the semantic adjective pairs, were compared with the results of perceived restorativeness and restorative effect evaluated on-site, it appears that there is a link between what people prefer in the forest and how they restore in that environment. On the other hand, the answers to the suitability were in parts different to how restorative the forests were: the mature forest and the urban recreation forest were perceived as more suitable than the old-growth forest, even though the old-growth forest was more restorative than the urban recreation forest and as restorative as the mature commercial forest. Additionally, when comparing the previous study results on forest preferences with the restoration outcomes of this dissertation, it can be concluded that the most preferred forest is not always the most restorative one. A person may feel that they prefer a certain forest for various reasons, yet another forest might be more effective in providing restoration. Additionally, a person's current psychological state—such as having had a stressful day at work or feeling down—may mean that they need a different type of forest in order to restore at that time.

This information is important when planning the management of local recreational forests, in order to ensure that they also serve as restorative environments. Traditionally, forests in many cities have been maintained in a rather tidy manner because preference studies have supported the idea that people prefer well-managed forests with minimal deadwood. In recent years, however, guidelines for managing urban recreational forests have shifted towards a more natural approach. In urban forests, proper management is however important, particularly for safety and accessibility (Saukkonen and Valkonen 2022).

Alongside forest preferences, it is essential to highlight the well-being perspective and the understanding that different people may require different types of forests for stress-relief. Given today's challenges with mental health issues, urban planning also plays a crucial role in designing areas that can not only serve all residents but also as places for relieving those

who are stressed or depressed, and in preserving areas that still are in their natural state or appear natural.

In previous preference studies perceived beauty was considered important, and this also emerged as significant in this study. According to the multiple regression model, it explained a large share of restoration in all forests, including in the young commercial forest, despite the fact that over 73% of participants mentioned some aspects they disliked in the young commercial forest. Perceived richness in biodiversity also emerged as a factor explaining restoration in all forests except the urban recreation forest, despite the fact that the young commercial forest was perceived as significantly poorer in species richness compared to other forests.

It should be remembered that quite differing issues have been studied within the forest preference study area, which affect the results of studies. If, for example, the aesthetic properties of the forest, such as perceived beauty, have been investigated, the result may be different than if the question is concerning whether the forest is suitable for oneself. However, the research question in this dissertation regarding the suitability of the forest for participants after each forest visit aligns with preference studies that indicate that mature managed forests are the most suitable, despite that the old-growth forest was found to be equally restorative in this dissertation. This supports the conclusion that preferences and restoration do not completely go hand in hand, and individual differences have their own influence.

Suitability can also be evaluated through the experiencer's current needs; does one want to just relax, or perhaps enjoy some terrain where it is just easy to walk and pick berries. Because of this, preferences as such cannot be directly compared to each other, nor to the outcome of how effective the forest or landscape is in producing well-being, such as restoration. This observation is supported by the latest field-experiment studies, according to which the respondents' impressions of the different forest environments did not appear to be accurately reflected in their well-being evaluations (Martens et al. 2010; Takayama et al. 2017b). However, since recovery from stress and relaxation are key motivations for recreational nature use (Neuvonen et al. 2022), individuals often seek out environments that fulfill these needs.

Moreover, in preference studies, which are largely conducted using photographs, the features of natural forests are more difficult to depict accurately than those of managed forests, which typically have an even-aged structure and less variability. This natural variability, characteristic of unmanaged forests, is particularly hard to capture in a single image. As Silvennoinen et al. (2022) noted, photos appear to effectively capture the features of structurally simple pine forests. However, for more complex forest stands, multiple photos or additional assessment methods are needed to provide a complete evaluation (Silvennoinen et al. 2022). A photograph is a two-dimensional representation that cannot fully capture the complexity of reality, and the visual characteristics of the subject may differ significantly from how they appear in real life (Freeman 2017; 2018). For example, when viewed in a picture, a decaying tree may appear as a disruptor of a harmonious environment, while in real nature a closer examination of it can reveal an interesting spectrum of diversity living in and on the tree. A photograph only represents a fleeting moment of an environment that is in a constant state of change (Hietaharju 2006). Although the photograph tells a lot about the environment, it also leaves a lot unsaid, and is always partly the photographer's subjective choice as an interpretable object.

Lastly, it is true that some previous research results have been able to point out that a photo inspection may be quite well in line with assessments made in the field (Stamps 1990; Sevenant and Antrop 2011; Silvennoinen et al. 2022), but the case could be different when it

comes to a natural state forest, as the objects of such inspections have mostly been managed forests, and the observers are often forest professionals (see Chapter 2.2.2 Savolainen and Kellomäki 1981; Silvennoinen et al. 2022). The accuracy of image-based assessments would probably also benefit from using videos, 3D modeling, or a virtual laboratory. Some of such laboratories allow a virtual 360-degree natural environment around the viewer, including soundscapes. Research on these methods is still quite limited. However, a recent study by Reese et al. (2022) found no significant differences in the restorative effects between on-site and virtual urban nature settings. The on-site environment, however, showed slightly stronger effects over time. This dissertation did not compare on-site results with corresponding environments using different virtual techniques, highlighting an opportunity for further research.

5.5 Validity and reliability of the results

The reliability of this dissertation was strengthened by carefully designing the experimental setups to minimize potential distractions or influencing factors, such as social interactions or emotional reactions, by asking participants to avoid talking. In addition, the physical strain, exposure to water elements, and participants' prior expectations about each visit, were eliminated as far as possible. The order of visits was randomized, with efforts made to ensure that each visit would occur in a different week. Participants were also prohibited from picking mushrooms or berries, and from using their phones, to prevent interruptions in their immersive experience of the forest. Weather conditions were also considered, and visits were canceled in cases of heavy rain or storms. All of these measures aimed to ensure that the participants had a genuine forest experience. Moreover, travel and travel time were standardized to ensure consistency across visits. The potential influence of the researcher was also controlled by having the dissertation researcher lead all visits, ensuring consistency for all participants.

On the other hand, in a natural environment it is impossible to control all potential external influences. For example, unexpected airplane noise, due to a sudden change in flight paths, disturbed the old-growth and young commercial forests more than anticipated when the forest sites were selected. On a few occasions some trash appeared in the forest, disrupting some participants' experiences. Despite providing clothing instructions each morning and offering blankets for the sitting period, several participants reported feeling cold during the visits, which might have negatively affected their experience.

The validity of the study was strengthened by selecting measures for the research design that have been widely used in the field and whose validity has been verified. Various research methods were also employed, including both quantitative and qualitative approaches, and the results were compared with each other as well as with previous literature. Additionally, having the same participants visit each forest increased the validity of the study.

There have been only a few studies conducted in authentic natural settings, because such research is costly and time-consuming. Additionally, true nature can never be fully controlled for research purposes. However, to provide the most genuine experience possible, this study was conducted in real, natural environments.

The research design can be viewed as partially following an experimental paradigm (see chapter 2.3) commonly used in studies on restorative environments. Since the aim was to investigate the potential effects of different forest environments on recovery from daily work stress, no additional stress induction was conducted immediately before the experiment.

Instead, the participants' regular workday served as the natural stressor. However, this approach did not allow for capturing participants' baseline state before the workday, which can be seen as a limitation of this study.

The study aimed to recruit participants from as diverse backgrounds as possible, in order to represent working urban residents on average. Although a range of different backgrounds was achieved, the participant profile was skewed towards higher education levels, with most being highly educated. Additionally, there were fewer men than women. The intention was also to include participants with more severe depression, but although some signed up they were unable to attend due to their condition.

6 CONCLUSIONS AND CLOSING REMARKS

Forest management significantly impacts how forest environments contribute to psychological well-being, particularly restoration. Both old-growth and mature commercial forests were found to be equally restorative, with participants valuing their rich biodiversity. The mature commercial forest, despite being managed for timber production, and the old-growth forest, despite its occasionally chaotic appearance due to the effects of bark beetles, both demonstrated substantial restorative benefits. The mature commercial forest, having surpassed its commercially optimal regeneration age, benefited from delayed harvesting, which supports biodiversity (Savilaakso et al. 2021). The older stand age likely also enhanced the forest's restorative effects, as the forest environments in older stands and their perceived biodiversity was positively associated with psychological restoration. The optimal time frame for a forest environment to maximize well-being benefits is a interesting question, particularly if the forest is managed for commercial use but also intended to support well-being and recreation. Future research should therefore investigate continuous cover forestry as a sustainable way of improving human well-being, given that it can avoid the less restorative phases associated with clear-cutting and early-stage forest growth. Nevertheless the study shows that forest management can be designed to meet both economic and well-being objectives.

External factors, such as noise, can affect the restorative experience, while perceived beauty and biodiversity also play significant roles. Although sociodemographic variables, other than education, did not systematically influence restoration outcomes, individual nature-oriented traits did. This suggests that people from different backgrounds may evaluate forests differently.

The preferences largely corresponded with how restorative the forest environments were perceived to be, but some differences also emerged. For example, no statistically significant difference was found between the urban recreation forest and the old-growth forest in the adjective pair beautiful–ugly. However, the old-growth forest was still perceived as significantly more restorative than the urban forest. This suggests that preferred forest types do not always align with those best for mental well-being.

The research also highlighted that individuals experiencing stress might benefit particularly from natural or mature managed forest environments. Results showed that higher work stress was associated with greater restoration in these forests, with natural forest being more effective at reducing stress. Additionally, individuals with a lower mood may particularly benefit from visiting natural forests, as a statistically significant association was found between risk of depression and changes in restoration only in the old-growth forest.

These findings may relate to experiencing awe in these environments, though further research is needed to confirm this. Additionally, future studies should include individuals with more severe depression, as this group was not represented in the current research, leaving the results regarding depression as preliminary.

Despite previous research often focusing on less natural or built environments, this dissertation emphasizes the importance of preserving natural habitats—particularly in urban areas where such environments, including old-growth forests, are already scarce. In these settings, access to nearby, ecologically rich forests may offer especially significant well-being benefits.

To support psychological restoration and broader human well-being, urban planning should prioritize the conservation of mature and older forests. Larger forested areas located near residential neighborhoods can better withstand recreational use while maintaining biodiversity, thus helping to prevent overcrowding and preserving ecological quality. In recreational forests, however, maintaining a natural appearance while ensuring user safety is essential for preventing hazards and enhancing the visitor experience.

While biodiversity loss is widely recognized as a threat, public and scientific discourse often centers on its consequences for non-human species. This work underscores the parallel importance of biodiversity for human health and well-being. Access to diverse and relatively undisturbed natural environments supports stress recovery and mental restoration—functions that are increasingly relevant in urbanized societies.

Forest environments hold considerable, though often underestimated, potential to alleviate psychological stress. Realizing this potential requires a broader recognition of their multidimensional value, even when these benefits may be difficult to quantify precisely. Future forest management and planning should take into account not only ecological and economic factors, but also the growing body of evidence on the human well-being benefits that forests provide.

7 DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work the author used OpenAI (2024) ChatGPT https://www.openai.com in order to improve the grammar and readability of the text. After using this tool/service, the author reviewed and edited the content as needed and take full responsibility for the content of the published article.

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