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Unlocking the Power of Nature: Insights from a 20-Minute Forest Visit on Well-Being

Daniela Haluza [1,*], Pauline Kersten [1], Tanja Lazic [1], Matthias Steinparzer [2] and Douglas Godbold [2,3]

[1] Department of Environmental Health, Center for Public Health, Medical University of Vienna, Kinderspitalgasse 15, 1090 Vienna, Austria
[2] Department of Ecosystem Management, Climate and Biodiversity, Institute of Forest Ecology, BOKU University, Peter-Jordan Straße 82, 1190 Vienna, Austria
[3] Department of Forest Protection and Wildlife Management, Faculty of Forestry and Wood Technology, Mendel University Brno, Zemědělská 3, 613 00 Brno, Czech Republic
* Correspondence: daniela.haluza@meduniwien.ac.at

Abstract: Recent research underscores the positive effects of nature exposure on health and well-being. Growing evidence also links biodiversity within these environments to enhanced health outcomes, as diverse ecosystems may offer a broader range of multi-sensory stimuli. This experimental field study investigated the effects on psychological and physiological outcomes linked to spending time in a forest compared to an urban environment. Sixty-six healthy participants were randomly assigned to spend 20 min in either a forest environment with alternating tree species richness in the Wienerwald near Vienna, Austria, or an urban environment. Psychological data were collected using validated scales, and saliva cortisol samples were taken before and after the intervention. Findings showed that the forest visit significantly reduced negative emotions, enhanced positive affect, and lowered cortisol levels more effectively than the exposure to the urban environment. However, increased tree diversity within the forest setting did not further amplify these benefits. These results suggest potential mental health and stress reduction benefits of forest exposure in the case of the Wienerwald, supporting the consideration of nature-based interventions in urban public health initiatives. While forest biodiversity appears to have limited additional effects, future research could further investigate its role in nature-based interventions and forest therapy practices.

Keywords: forest bathing; nature therapy; mental health; shinrin-yoku; biodiversity; Austria; environmental health; sustainability; field experiment; public health

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1. Introduction

The benefits of spending time in nature have gained widespread recognition, attracting academic and public interest worldwide [1–3]. Engaging in forest visits facilitates physical rejuvenation and regeneration, strengthens the immune system, and enhances the quality of sleep. The reduction in stress is reflected in lower pulse rate, blood pressure, and muscle tension, as well as a slowdown in brainwave activity. Additionally, forest visits are associated with decreased cortisol levels and the release of mood-enhancing hormones like serotonin and dopamine [4]. Forest bathing, which is also known as shinrin-yoku, is a traditional Japanese mindfulness practice that involves engaging all five senses to deeply immerse oneself in the forest environment [1]. According to Hansen et al. [3], forest bathing is a kind of nature therapy suitable for disease prevention and enhancing immune system functions via exposure to natural stimuli. Significant physiological outcomes include a

reduction in blood pressure and heart rate as well as enhanced high-frequency components of heart rate variability, a parameter associated with parasympathetic nervous activity [2,3]. Furthermore, forest bathing reduces salivary cortisol, a key stress marker, and has long-term benefits, including enhanced immune function through increased natural killer cells and positive effects on allergies and respiratory health [2,3].

Positive psychological effects include promoting mental well-being and alleviating symptoms of depression [5]. A meta-analysis by Kotera et al. [1] comparing twenty studies found that forest bathing interventions effectively reduced feelings of stress, anger, depression, and anxiety, with stress-related disorders being particularly positively influenced by natural environments in the short-term [1]. Moreover, psychological vigor could be improved, and mental tension was mitigated through forest stays [2]. Concerning mood, nature exposure can cause feelings of joy, affiliation, and contentment, evoking an emotionally stable state [6]. Notably, the benefits of natural environments can be enhanced when individuals feel safe in nature and forests [1,2,5,6].

While the mental health benefits of forest exposure are recognized, the effect of forest biodiversity in modulating well-being benefits remains understudied. While Wolf et al. found that videos showing four different tree species compared to monocultures seem to be associated with reduced feelings of anxiety, Johansson et al. report heightened positive affect while viewing images of forests, with medium forest biodiversity showing the greatest effect, followed by high and low forest biodiversity [7,8]. Differences in health effects between perceived and actual forest biodiversity may arise. Nghiem et al. [9], for example, investigated the connection between forest biodiversity experienced in real forests and mental well-being, showing that perceived, but not actual, biodiversity in forests increased psychological well-being mediated by the provision of higher restorative potential. Therefore, identifying the influence of various forest variables and under which circumstances they have the best possible effect in order to create optimal conditions for interventions such as forest bathing or forest therapy or other nature-based concepts is necessary [9,10].

Increasing urbanization calls for evidence-based strategies to mitigate urban stressors and promote mental health. The Wienerwald, a forest with varied biodiversity located near Vienna, Austria, provides a unique opportunity to explore how forest exposure impacts psychological and physiological health outcomes, including potential differences based on forest biodiversity. In particular, studies in diverse ecosystems could provide insights into whether specific features of a forest environment—like its biodiversity—enhance the mental health benefits observed in urban populations [11,12]. As urban areas continue to grow, integrating nature-based practices within urban planning and public health initiatives becomes increasingly vital.

This pioneering study provides the first-ever evidence comparing the psychological and physiological effects of spending time in the Wienerwald, a typical Central European mixed-forest environment, versus an urban environment. By incorporating measures such as validated psychological scales and cortisol levels, this research fills a significant gap in existing literature and supports the consideration of nature-based interventions as a practical and innovative component of urban public health strategies [13]. This targeted approach provides insights into the ways urban-proximate inhabitants engage with forest environments. These findings have the potential to inform more localized, nature-based health strategies, especially in urban areas with nearby green spaces like the Wienerwald.

2. Methods

We conducted an experimental field study to examine the influence of the forest environment and tree diversity on human affect and stress levels. This study was part of

the interdisciplinary scientific European project Dr.FOREST, which examined the interface between public health and tree diversity in peri-urban forests [14]. Forest interventions were conducted in the Wienerwald (Austria), Leipzig Auwald (Germany), and Bois de Lauzelle (Belgium), with the aim of quantifying the impacts of tree diversity on mental health and well-being. While pooled data from these sites have been published by Rozario et al. [15] and Gillerot et al. [16,17], this study presents a secondary analysis using exclusively the data from the Vienna-based sample. This single-center approach enabled a closer examination of how a specific population, i.e., individuals living in or near Vienna, fluent in German, experienced nature in a familiar forest setting, i.e., the Wienerwald.

2.1. Procedure of the Study

Data for this study was collected in an interventional study by using paper-pencil questionnaires as well as saliva samples. The study protocol was approved by the institutional Ethics Committee of the Medical University of Vienna (reference: 01509146/2021) and was conducted in accordance with the Declaration of Helsinki. The study was conducted on 10 and 11 September 2021 in the Wienerwald region, situated near the capital of Austria, Vienna. To ensure consistent light and weather conditions, participants were scheduled between 9:15 a.m. and 1:30 p.m., with each study session lasting approximately two hours. A maximum of 20 participants were assigned per time slot, which included two morning sessions (9:15 and 10:15 a.m.) and two afternoon sessions (12:30 and 1:30 p.m.). Each data collection session lasted approximately two hours, which included both the intervention time and transportation to and from the study sites.

Participants gathered at a central meeting point, located about 30 min from the urban pick-up site in Vienna. This arrangement ensured that experimental groups did not overlap at the intervention sites, despite multiple time slots being available per day. Each participant was either assigned to one of the forest conditions or the urban condition, not to both. A total of 66 volunteer participants were randomly assigned to four distinct groups, adhering to the prevailing COVID-19 regulations through antigen tests for all participants [15,16].

At the start of the study, participants gathered at a central meeting point (Figure 1a), where they were briefed about the intervention. Participants then completed the pre-intervention survey, which included demographic information and psychological assessments, and provided a baseline saliva sample (Figure 1b). Following this, participants were assigned to either a forest or urban environment for the 20-minute (min) intervention. The intervention took place in the Wienerwald area, a typical Central European mixed forest (Figure 1c), with participants assigned to designated forest patches (Figure 1e) for the exposure period. In the case of the urban control group, the intervention took place in a nearby urban area. Participants were transported in a van with semi-transparent window coverings to minimize pre-exposure to the environment (Figure 1d). Chairs were positioned before the arrival of the participants in a row with some distance between them and provided a clear view of the assigned forest or urban settings. On-site, study subjects were seated and instructed to sit quietly and observe their surroundings in a designated area within the forest or urban environment for 20 min following established protocols [1,9]. They were asked not to engage in conversation, phone use, or other distractions and to remain still and silent to allow immersion in the setting [15]. No guided mindfulness or physical exercise was involved. The passive nature of the intervention aimed to isolate the environmental effects on psychological and physiological outcomes. After the intervention, participants completed the same questionnaire as in the pre-intervention phase, supplemented with additional items on demographic data and perceived biodiversity. A second saliva sample was taken. Finally, participants were debriefed about the study's objective.



Figure 1. Pictures of intervention procedure. (**a**) Central meeting point. (**b**) Participants completing the first survey. (**c**) Wienerwald area where intervention took place. (**d**) Transportation vehicle. (**e**) Participants undertaking experiment in forest patch. (**f**) Forest patch.

The three different forest patches were selected to represent varying levels of tree species richness (1, 2, and 5 species) with assistance from local forest management agencies, thus creating low, medium, and high biodiversity levels (Figure 1f). Study sites were deemed suitable if participants could visually perceive the designated tree species richness from their seated viewpoint. The monoculture, i.e., low diversity, *Fagus sylvatica* L. (beech); medium diversity: *Fagus sylvatica* (beech), *Pseudotsuga menziesii* (Mirb.) Franco (Douglas fir); and high diversity: *Fagus sylvatica* (beech), *Carpinus betulus* L. (hornbeam), *Fraxinus excelsior* L. (European ash), *Quercus robur* L. (pedunculate oak), and *Larix decidua* Mill. (European larch). The forest patches at the three sites were all located within a two-kilometer radius. Local authorities granted access permissions for these forest areas. The urban control environment did only have minimal vegetation.

2.2. Participant Recruitment

The invitation to the interventional study was sent via personalized emails, display of posters at universities and other public places, and social media such as Facebook and WhatsApp. The participants had to fulfil inclusion criteria by answering questions in a phone screening, which included obtaining a body mass index between 18 and 30, being physically and mentally healthy, having normal or corrected-to-normal hearing and vision, and having no intake of medication affecting the central nervous system (e.g., antidepressants) or the cardiovascular system (e.g., beta-blockers).

2.3. Measures

Demographic data was gathered from the participants. Positive and negative affect was measured using the Positive and Negative Affect Schedule (PANAS) [18]. The PANAS includes 20 items: 10 items each for positive affect (PA; active, interested, excited, strong, inspired, proud, enthusiastic, alert, determined, and attentive) and negative affect (NA; distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery, and afraid). Each item was rated on a 5-point Likert scale, from 1 (very slightly, not at all) to 5 (extremely), based on participants' self-reported affective states before and after the intervention.

Physiological stress was assessed through salivary cortisol, a biomarker of hypothalamic–pituitary–adrenal (HPA) axis activity [19,20]. Cortisol samples were collected at pre- and post-intervention with a 30-min delay, accounting for HPA-driven endocrine responses [21]. Samples were stored at −20 °C immediately after collection, then thawed and centrifuged at 3000 rpm for 5 min, producing a low-viscosity supernatant. Cortisol levels were analyzed using a highly sensitive ELISA kit (Tecan—IBL International, Hamburg, Germany; catalogue number R52611), with intra- and inter-assay coefficients of variance below 11%.

2.4. Data Security and Privacy

The test subjects were informed in detail about data security, the aims of the study, and how the data would be utilized. Volunteers gave their informed consent for data collection by signing a declaration of consent before the intervention. All personal data collected was treated confidentially; names and other identifying features were replaced by alphanumeric codes and were thus anonymized. The data collection and storage were carried out via an internal server, to which the access was only available for authorized persons and was additionally password protected.

2.5. Statistical Analysis

The collected data were processed using Microsoft Excel (Seattle, WA, USA) and SPSS Statistics Version 29.0 (IBM Corp. SPSS Statistics for Windows, Armonk, NY, USA) [22]. A significance level of $\alpha = 0.05$ was employed for all statistical analyses. Descriptive statistics, including relative and absolute frequencies, mean scores, and standard deviations (SD), were utilized to analyze characteristics of the study participants and the results of the item questionnaire measuring positive and negative affect. To quantify positive and negative affect, we calculated a sum score for each subscale by summing the ratings of the ten respective items, yielding possible scores between 10 and 50. Higher scores represent a greater intensity of positive or negative affect. Internal consistency for the PANAS was evaluated through Cronbach's alpha (α). For the ten items measuring positive affect, α values were 0.862 at pre-test and 0.885 post-intervention, indicating strong reliability. For negative affect, α was 0.721 at pre-test, indicating acceptable reliability, and 0.830 post-test, reflecting solid internal consistency.

A preliminary between-subjects Analysis of Variance (ANOVA) confirmed group equivalence in pre-intervention measures, supporting the success of randomization (all

p-values ranged from 0.14 to 0.84). To examine the effects of forest exposure on affective states, paired-sample *t*-tests were used to compare pre- and post-intervention changes within each group. Between-group differences across tree diversity levels were analyzed using one-way ANOVA. Given the modest sample size and the focus on within-group and between-group comparisons rather than interaction effects, mixed ANOVAs are not reported [23]. The chosen approach offers a statistically robust and interpretable means to assess the core hypotheses of the study.

3. Results

Pre- and post-intervention data were collected from a purposive sample of voluntary participants using paper-pencil questionnaires and saliva samples to assess the targeted variables. Prior to the field experiment, a comprehensive forest inventory was conducted on each plot to capture the ecological characteristics [16]. The baseline environment consisted of an open grassy meadow, with trees positioned at least 50 m away from participants to minimize forest influence, thus providing a relatively neutral starting point for all. Approximately 25% of participants were assigned to an urban control setting, enabling comparison of their responses with those of the 75% assigned to the forest environments.

3.1. Study Participant Characteristics

A total of 66 participants took part in the study, with 48 females (72.7%), 17 males (25.8%), and one participant identifying as diverse (1.5%). The diverse participant was excluded from gender comparisons due to the small sample size. One participant did not answer an item on negative affect, leading to their exclusion from the negative affect analysis. The average age of participants was 30.3 years (SD = 10.93), ranging from 19 to 58 years. The median age was 26, dividing the group into two subgroups: 31 individuals (47%) under 26 and 35 individuals (53%) over 26 years of age.

Regarding nationality, 53 participants (80.3%) were from Austria, with the remaining 19.7% from Italy, China, Germany, Croatia, France, Lithuania, Poland, and Chile. In terms of education, 40 participants (60.6%) had completed high school or vocational training, while the remaining participants had higher academic qualifications. We randomly allocated the 66 study participants across four sites, with 49 individuals (74.2%) assigned to the low, medium, and high forest biodiversity environments and 17 participants (25.8%) to the urban control group. While 15 participants (22.7%) completed the study in the low biodiversity condition, 17 participants each (25.8%) took part in the medium and high biodiversity conditions.

3.2. Changes in Affect in Forest and Urban Environment

Table 1 presents the changes in affect before and after the intervention, comparing participants exposed to either the forest or urban environment. For positive affect, participants in the forest environment exhibited minimal change between pre- and post-intervention (mean = 30.43, SD = 5.78 to mean = 30.92, SD = 7.31). A paired sample *t*-test revealed no statistically significant difference in positive affect for the forest group ($t(48) = -0.581$, $p = 0.564$). In contrast, participants in the urban environment showed a statistically significant decrease in positive affect ($t(16) = 3.623$, $p = 0.002$), with pre-intervention scores of mean = 32.06 (SD = 10.22) decreasing to mean = 24.06 (SD = 8.89) post-intervention.

Regarding negative affect, the forest group demonstrated a statistically significant reduction in negative affect, with pre-intervention scores of mean = 13.27 (SD = 3.50) decreasing to mean = 11.71 (SD = 2.70) post-intervention ($t(47) = 3.212$, $p = 0.002$). In the urban control group, no statistically significant change in negative affect was observed, with

pre-intervention scores of mean = 11.65 (SD = 1.77) increasing to mean = 13.06 (SD = 4.10) post-intervention (t(16) = −1.301, $p = 0.212$).

Table 1. Pre- and post- affect levels in forest and urban environment.

Exposure		Pre-Intervention		Post-Intervention		p *
	n	Mean	SD	Mean	SD	
1. Positive affect						
Forest environment	49	30.43	5.78	30.92	7.31	0.564
Urban environment	17	32.06	10.22	24.06	8.89	0.002 *
2. Negative affect						
Forest environment	48	13.27	3.50	11.71	2.70	0.002 *
Urban environment	17	11.65	1.77	13.06	4.10	0.212

Notes: * p values from paired sample t-test ($p < 0.05$), SD = Standard Deviation.

3.3. Impact of Forest Biodiversity Levels on Pre- and Post-Intervention Affect

To examine the potential influence of biodiversity levels on affective states, we compared the changes in positive and negative affect before and after the forest intervention across the three biodiversity levels (Table 2). There were no statistically significant differences in changes to positive affect across the different forest conditions (F(2, 46) = 78.11, $p = 0.378$). Similarly, no statistically significant differences were observed in changes to negative affect between the biodiversity groups (F(2, 45) = 78.11, $p = 0.927$). Post-hoc comparisons using the Games-Howell test indicated no statistically significant differences in affective changes between the high, medium, and low biodiversity groups for both positive and negative affect (all p-values > 0.05).

Table 2. Comparison of effects of forest biodiversity levels on affect.

					95% Confidence Interval	
	Forest Biodiversity Levels	Mean Difference	Std. Error	p *	Lower Bound	Upper Bound
Positive affect changes	low/medium	0.52	2.26	0.971	−5.11	6.16
	medium/high	−2.71	1.77	0.293	−7.07	1.65
	low/high	−2.18	2.27	0.608	−7.85	3.48
Negative affect changes	low/medium	−0.39	1.36	0.955	−3.85	3.06
	medium/high	0.41	0.99	0.909	−2.02	2.84
	low/high	0.02	1.43	0.999	−3.58	3.61

Notes: * p values from one-way ANOVA ($p < 0.05$).

The results of the paired-samples t-tests, which analyzed changes in affect before and after the forest visit across different forest biodiversity levels, are shown in Table 3. Overall, no statistically significant changes in positive affect were observed in any of the biodiversity groups ($p > 0.05$). In the medium biodiversity condition, the mean positive affect increased from 29.29 (SD = 5.16) to 30.88 (SD = 7.14) (t(16) = −1.278, $p = 0.219$). In the low biodiversity condition, the mean positive affect increased from 31.53 (SD = 5.10) to 32.60 (SD = 7.72, t(14) = −0.565, $p = 0.581$). Conversely, in the high biodiversity condition, the mean positive affect decreased from 30.59 (SD = 6.95) to 29.47 (SD = 7.25), but this was not statistically significant (t(16) = 0.883, $p = 0.390$).

For negative affect, reductions were observed across all biodiversity levels, with the most notable decrease occurring in the medium biodiversity condition. In the medium biodiversity group, negative affect decreased statistically significantly from a mean of 13.59 (SD = 4.12) to 11.76 (SD = 2.56) (t(16) = 2.915, $p = 0.010$). In the high biodiversity condition, negative affect decreased from a mean of 12.71 (SD = 2.49) to 11.29 (SD = 1.96),

but this change did not reach statistical significance (t(16) = 1.852, p = 0.083). In the low biodiversity condition, negative affect decreased from a mean of 13.57 (SD = 3.88) to 12.14 (SD = 3.61), but this change was also not statistically significant (t(13) = 1.179, p = 0.260).

Table 3. Changes in affect comparing forest biodiversity levels (n = 48).

Forest Biodiversity Levels		Pre-Intervention		Post-Intervention		p *
	n	Mean	SD	Mean	SD	
Positive affect						
High	17	30.59	6.95	29.47	7.25	0.390
Medium	17	29.29	5.16	30.88	7.14	0.219
Low	15	31.53	5.10	32.60	7.72	0.581
Negative affect						
High	17	12.71	2.49	11.29	1.96	0.083
Medium	17	13.59	4.12	11.76	2.56	0.010 *
Low	14	13.57	3.88	12.14	3.61	0.260

Notes: * p values from paired sample t-test ($p < 0.05$), SD = Standard Deviation.

3.4. Changes in Cortisol Levels

Table 4 shows the comparison of cortisol levels in forest and urban environments, as well as across different forest biodiversity levels. Regarding the environment, a statistically significant reduction in cortisol levels was observed in the forest group (p = 0.003), with levels decreasing from a mean of 3.77 nmol/L to 2.31 nmol/L post-intervention. In contrast, the urban group showed no statistically significant change in cortisol levels (p = 0.35). When considering forest biodiversity levels, statistically significant reductions in cortisol were found only in the low biodiversity group (p = 0.04), where levels decreased from 4.58 nmol/L to 2.77 nmol/L. No statistically significant changes were observed in the high biodiversity group (p = 0.22) and the medium biodiversity group (p = 0.08).

Table 4. Cortisol levels in forest and urban environments as well as different forest diversity levels.

	Cortisol Levels (Nanomoles/Liter)				
	Pre-Intervention		Post-Intervention		p *
	Mean	SD	Mean	SD	
Condition					
(1) Environment					
Forest	3.77	4.04	2.31	1.39	0.003 *
Urban	2.49	2.65	1.99	1.35	0.35
(2) Forest diversity levels					
High	3.00	3.80	2.01	1.09	0.22
Medium	3.83	4.59	2.22	1.49	0.08
Low	4.58	3.72	2.77	1.55	0.04 *

Notes: * p values from paired sample t-test ($p < 0.05$), SD = Standard Deviation.

4. Discussion

The primary objective of this field study was to investigate the effects of a 20-min forest visit on positive and negative affect, as well as on stress hormone levels. Additionally, we explored the role of biodiversity in shaping these psychological and physiological measures [15,16]. A control group exposed to a similar intervention in an urban environment was included for comparison. Participants were randomly assigned to either the forest or the urban environment, ensuring balanced sample sizes and preventing order effects. Each participant took part in the intervention only once, which helped avoid individual carryover effects. The intervention involved seated passive exposure, with no conversation

or use of digital devices. Participants were informed in advance and monitored for compliance, and none reported falling asleep or experiencing major discomfort that would have required ending the study participation.

To assess physiological stress levels, salivary cortisol was measured before and after the intervention. Baseline samples were collected between 9:45 a.m. and 2:00 p.m., a time frame during which cortisol levels are typically declining. In line with this diurnal pattern, pre-intervention cortisol levels in our sample were at the lower end of the normal range, as described by Kirschbaum and Hellhammer [21]. The results showed a statistically significant decrease in cortisol levels within the forest group, while no such change was observed in the urban group. The observed pattern suggests that forest exposure may be associated with reductions in physiological stress; however, it warrants further investigation with larger sample sizes and interaction analyses [2,5,24].

While our primary focus was on the impact of tree diversity, the significantly lower cortisol levels observed in the low-diversity group may also reflect the increased sense of security often associated with secondary forests, such as the Vienna Woods, where visual openness and structured vegetation can create a more predictable and comfortable setting [25]. Previous research suggests that perceived safety and familiarity can modulate physiological responses to natural environments, potentially enhancing the restorative effects of forest exposure [24]. These observations align with the Savanna Hypothesis, which posits that humans have evolved to prefer open, park-like landscapes offering clear visibility and refuge opportunities, features historically associated with safety and resource availability [26]. This preference suggests that a "tidy" forest, characterized by managed vegetation and unobstructed sightlines, may enhance feelings of safety, as dense undergrowth and obstructed views in natural settings can elicit feelings of unease or fear [27]. Therefore, the lower cortisol levels observed in our low-diversity forest condition might not solely reflect biodiversity effects but also the psychological comfort derived from familiar and orderly environments. These insights underscore the importance of considering landscape structure and management in designing restorative natural spaces [28].

Notably, no statistically significant reductions were found in the medium or high biodiversity groups, indicating that higher tree diversity did not correspond with stronger cortisol reductions in this sample. These findings warrant further investigation, as they may reflect non-linear effects or be influenced by other contextual or individual factors. Prior research [19] predominantly shows cortisol reductions associated with forest visits. Our results were consistent with findings from Tyrväinen et al. [29], who also observed statistically significant cortisol declines in both natural and urban environments. However, while other studies have reported clear associations between forest exposure and decreased cortisol levels [19,20], our data did not reveal a statistically significant difference between the two settings. This suggests that factors beyond location, such as individual baseline stress, personal preferences, or even situational context, could influence cortisol responses. The biodiversity levels of forest settings may also play a role in psychological outcomes, as suggested by prior studies indicating that higher biodiversity environments promote greater psychological benefits [30]. Future research is needed to explore whether specific biodiversity features, such as species richness or canopy complexity, impact cortisol and affective responses more significantly than the mere presence of natural elements.

The Positive and Negative Affect Schedule (PANAS) is one of the most widely used tools for measuring self-reported affect [18]. Originally created as a quick and straightforward means of assessing affective states, the PANAS has shown excellent internal consistency and validity across numerous studies. Given these strengths, the PANAS was chosen for this study to evaluate affect and, indirectly, momentary well-being. Contrary to our expectations, the forest environment did not lead to a statistically significant increase

in positive affect. However, the setting might have supported the maintenance of positive emotions, as suggested in prior research, indicating that natural environments may play a protective role in emotional well-being by stabilizing mood rather than actively boosting it [6]. Yet, the pertinent literature offers mixed evidence: some studies report increased positive emotions following nature exposure, while others emphasize its stabilizing or restorative effects rather than mood enhancement [31–33]. Additionally, although nature is associated with mental health benefits such as stress reduction and psychological restoration, these effects can vary depending on personal and contextual factors such as socioeconomic status, preferences, occupation, and gender [31].

The current study provides insights into the emotional effects of brief forest exposure, as measured with the PANAS [18]. However, while this tool is well-established, it primarily captures high-arousal emotions such as excitement and alertness. Emerging research suggests that low-arousal positive affect, including states like calmness and contentment, plays a distinct and meaningful role in psychological well-being, particularly in restorative environments such as forests [34,35]. Given the nature of forest experiences, it is plausible that our findings may underestimate the broader emotional benefits, especially those related to low-arousal affective states. Future studies should address this by incorporating complementary measures that more accurately reflect the full spectrum of emotional responses to natural environments.

In our study, the control group exposed to the urban environment exhibited a statistically significant decrease in positive affect, indicating a significant reduction in positive emotions and feelings after a 20-min stay in that setting. These findings are in line with other studies comparing changes in affective state between exposure to forests and urban environments, where forest visits consistently demonstrate positive affect changes [31,33]. Current research highlights the negative impact of urban environments on mental health, with factors like overpopulation and air and noise pollution contributing to unpleasant feelings and anxiety [36]. Our study reinforces these findings by emphasizing the negative impact of urban spaces on mental health and positive mood. Our study also highlights the significance of considering the thermal conditions in Austria during the intervention days in September 2021 [15,16]. The weather was warm, and the urban environment lacked adequate shade to mitigate the heat, which potentially influenced the way participants experienced their environment during the intervention [37].

Regarding negative affect, significant changes were observed in the forest group, with a notable decrease after a 20-min forest stay. This finding confirms our hypothesis suggesting differences in affect subsequent to a forest stay, demonstrating that the forest exposure effectively reduced negative affect. These results align with existing evidence regarding the restorative effects of forest and nature exposure in humans [31,38]. The stress reduction theory proposed by Ulrich [38] suggests that exposure to nature alleviates mental distress and promotes relaxation, which aligns with our findings showing reduced negative affect after forest exposure. In contrast, the urban control group showed no change in negative affect and even experienced an increase, reinforcing the idea that urban environments exacerbate stress and anxiety, as highlighted by Bratman et al. [32].

Our study aimed to explore how forest biodiversity affects human emotions. However, we found no statistically significant difference in emotional states between the biodiversity levels in the forest environment. While existing evidence suggests that higher forest biodiversity and species richness can have greater beneficial effects on affective states and anxiety levels compared to lower biodiversity environments [7,10], our study did not support this relationship. A review by Hedin et al. [12] also noted that the effects of biodiversity on mental health and psychological well-being remain inconclusive, requiring further research to provide definitive conclusions. Our findings underscore the need for

additional studies to better understand the potential correlation between forest biodiversity and mental health.

An intriguing aspect of this topic was the contrasting impacts of actual biodiversity versus perceived biodiversity. Nghiem et al. [9] examined the impact of actual environmental biodiversity (based on tree, bird, and plant diversity and richness) on mental health. Perceived biodiversity, i.e., the richness individuals personally perceive in their surroundings, appears to have a more pronounced beneficial effect on psychological well-being [9]. Consequently, individual perceptions of biodiversity vary, and the effects of actual natural biodiversity do not uniformly affect every person in terms of mood, positive emotions, or stress reduction [9]. This discrepancy may explain why only the medium biodiversity group in our field study exhibited a noteworthy decrease in negative affect post-intervention. This effect could be due to perceived biodiversity or personal preferences for nature. Johansson et al. [8] also found that medium biodiversity elicited the highest positive emotions in study participants, providing a compelling avenue for future research on the influence of medium biodiversity in humans. This specific natural setting may be influential in affecting the emotions of many individuals.

According to Johansson et al. [8] and DeVille et al. [39], landscape and natural setting preferences vary greatly among individuals, influenced by their experiences with nature, connection to nature, psycho-physiological responses, and emotional components related to the perceived environment [6,8,39]. The changes in affect cannot be attributed to a single factor. Instead, it is likely influenced by a combination of factors, which may explain the findings in our study.

Unlike our approach, another part of the Dr.FOREST research project distinguished between actual and perceived biodiversity when examining mental health [15]. Consistent with the studies presented earlier, actual biodiversity was not a significant factor, whereas perceived biodiversity played a crucial role in various outcomes. Structural equation modeling revealed a significant negative relationship between perceived biodiversity and subjective stress and a positive association with perceived restorativeness. Perceived biodiversity also influenced short-term positive affect, mental health, and well-being. Participants who perceived the forest as more biodiverse found it more restorative, leading to better mental health and well-being. These findings suggest that even less diverse forests can be restorative, indicating that forests can be managed for different purposes while still providing therapeutic benefits.

We did not further explore thermal comfort's role in mental well-being for the Austrian dataset in the current analysis. However, the pooled data on microclimate and thermal comfort in peri-urban forests near Vienna, Leipzig, and Louvain-la-Neuve have already been published [15,16]. Our findings showed that forest areas consistently provided cooler, more stable temperatures than non-forest areas, positively impacting mental well-being indicators like positive affect and anxiety. Participants perceived forests as cooler, regardless of constant physical conditions, suggesting that psychological factors also shape thermal comfort. This indicates a synergistic effect where forests enhance both thermal comfort and mental well-being.

Limitations

While our study provides valuable insights into the effects of environmental conditions on mental well-being and physiological stress, several limitations should be considered when interpreting the results. Our participants were relatively young and well-educated, thus not representing the entire Austrian population. Additionally, our sample size was relatively small, particularly within subgroups defined by biodiversity levels. This limits the generalizability of the findings. A methodological limitation related to the limited sample

size is the employment of *t*-tests and one-way ANOVAs rather than mixed ANOVA models [23,40]. Future studies with larger samples should use more complex repeated measures models to examine potential group-by-time interactions with greater statistical power.

Although we included both psychological and physiological measures of stress, the study only assessed short-term changes [6,8,39]. The acute effects of environmental exposure may differ from longer-term effects, and future studies could benefit from a longitudinal design to examine whether these changes are sustained over time or if participants' responses to the forest or urban environments evolve with repeated exposure. Additionally, the inconsistent findings regarding the effects of varying degrees of forest biodiversity may be attributed to the influence of personal preferences, emotions, and nature-relatedness as mediating factors [6,8,39].

While the PANAS is a widely used and validated tool for assessing emotional well-being, it primarily focuses on high-arousal affective states [18]. This might have limited our ability to capture potential shifts in low-arousal positive emotions, such as calmness or contentment, which could be particularly relevant in natural settings [35]. Another limitation is the lack of a comprehensive assessment of other environmental factors that may contribute to mental well-being, such as noise levels, air quality, or social context. While we focused on the forest and urban environments, the specific characteristics of each site, such as the level of vegetation density or human activity, could have influenced participants' emotional responses and stress levels [41]. While the study aimed to assess the effects of forest biodiversity, it primarily relied on visual exposure to the environment. Other sensory inputs, such as auditory stimuli, e.g., birdsongs, were not controlled or systematically assessed, although they likely contribute to the overall experience and impact of forest bathing. Future studies should incorporate more detailed sensory measurements and potentially soundscape analysis to better capture the multisensory nature of the intervention.

Further, salivary cortisol is subject to diurnal and individual variation, affecting baseline cortisol levels [19,20]. Although participants were instructed to avoid food, caffeine, and vigorous exercise for at least 30 min prior to the experiment, and sessions were scheduled in the mid-morning to early afternoon to reduce diurnal variation, residual effects related to circadian rhythms or recent nutritional intake cannot be fully ruled out. Also, our assessment depended on baseline conditions. Participants started from a grassy meadow, which could have already engendered substantial mental well-being benefits. Lastly, while we used standardized tools for measuring mental well-being and physiological stress, participants' subjective interpretations of their environment could introduce bias [42]. Future research could further explore these subjective aspects to develop a more comprehensive understanding of how environmental factors interact to influence well-being.

5. Conclusions

This study shows that spending time in forests can support mental health. Participants who visited a forest environment experienced lower levels of perceived stress and cortisol compared to those in to urban settings. These findings support the growing evidence that nature, especially forests, can be a powerful tool for stress relief and overall well-being. Our results underscore the therapeutic potential of forest bathing as an accessible and effective intervention, with forest exposure, regardless of biodiversity levels, showing positive effects on mental health. Urban forests, like the Wienerwald, present a unique opportunity to integrate nature-based interventions into daily life, benefiting millions of inhabitants. Even modest improvements in well-being can have large-scale public health benefits, contributing to reduced healthcare costs and better quality of life for urban populations. To build on this, future large-scale studies, with diverse forest environments

and participant demographics, are crucial for further refining and expanding the potential of forests as a sustainable solution to mental health challenges.

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