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Similar cognitive benefits following nature and urban walks

Johanna Dobroschke[a*] · Julia Preisler[a] · Anna Matthießen[b] · Sandra Schumann[b] · Nico Bunzeck[c*]

[a]Student of Psychology - Cognitive Systems, Universität zu Lübeck, Lübeck, Germany
[b]Institute for Medical and Marine Biotechnology, Universität zu Lübeck, Germany
[c]Institute of Psychology I, Universität zu Lübeck, Lübeck, Germany
*Corresponding author, email: johanna.dobroschke@student.uni-luebeck.de; nico.bunzeck@uni-luebeck.de

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Abstract

Walking in nature can have a positive impact on physical health and psychological well-being but the effect on cognitive functioning remains less clear. To further investigate this relationship, 50 university students were tested in a series of cognitive tasks before and after a 15-minute walk either across an urban university campus (urban group) or a nature trail (nature group). Both groups exhibited higher test scores in the attentional task (d2-R) after walking, while only the urban group showed better working memory (Digit Span task). Neither group demonstrated higher executive functioning (Trail Making Test). The results of this pilot study suggest that taking a short walk in nature can improve specific cognitive abilities, but the effects were not superior to an urban condition. This, in turn, opens up avenues for future research.

I. Introduction

Spending time and being active in nature has a variety of benefits, ranging from improved mental well-being to increased immunological functioning, a reduction in blood pressure, and better sleep quality [1]. Some studies have demonstrated that nature walks for as little as 15 minutes can already have positive effects on mental health [2] and might even enhance cognitive functioning, especially in attention-related tasks [3].

While positive effects on health from spending time in nature can be attributed to sounds, smells, and organic compounds found especially in forests [1], it is still unclear which factors may cause enhancing effects on cognition. Attention Restoration Theory (ART, [4]) draws on different types of attentional processing, namely voluntary, goal-driven attention and involuntary, stimulus-driven attention. According to ART, reduced cognitive performance can be understood as a consequence of stress and a depletion of attentional resources that are restored by spending time in nature. The underlying idea is that "softly fascinating" stimuli of natural environments require less effortful attention allocation than other environments, allowing for a regeneration of directed attentional processes leading, in turn, to increased cognitive performance.

This present study aims to further investigate possible enhancing effects of nature walks on cognitive functioning by testing a sample of German university students before and after a 15-minute walk in either an urban (university campus) or nature setting (nature trail). It is hypothesized that i) post-walk cognitive performance will differ significantly between participants in the nature vs. urban group and ii) participants in the nature group will exhibit higher scores in the cognitive tasks post-walk than participants in the urban group.

II. Methods and materials

Participants and Design

The final sample consisted primarily of students from the University of Lübeck (n = 50), including 13 men (urban = 6, nature = 7), 38 women (urban = 19, nature = 17) and 1 participant with no gender specification, ages ranged from 18 to 33 (M = 23.4, SD = 3.69). The study took place outdoors from October 29–November 15, 2024 from 1:30 pm to 3 pm. First, participants received an instruction and signed a written consent form. Secondly, they were instructed to fill out questionnaires on demographic information such as age, gender (male, female, non-binary, no response), German degree of education (0 = no educational qualification, 1 = Hauptschulabschluss/general school-leaving certificate, 2 = mittlere Reife/intermediate school-leaving certificate, 3 = Abitur/high school diploma, 4 = Bachelor's degree, 5 = Master's degree, 6 = PhD) and transportation mode and time to the test site. Additional questionnaires assessed psychological well-being, to be reported elsewhere. Meanwhile, air quality measurement was carried out using Sensirion sensors AG SPS30 $PM_{2.5}$ (for particle matter) and SCD30 CO_2 (for CO_2 content, temperature, and humidity). Subsequently, salivary cortisol was collected from participants using cotton swabs. Following this, participants performed cognitive tasks d2-R [5], Digit Span Test [6] and Trail Making Test [7] (see below) in groups of three.

After completion, participants received fitness watches (Amazfit Bip U Pro) measuring heart rate and speed and were told to follow the test coordinator either along a nature trail (nature group) or a walk along the university campus site (urban group). Each participant completed the walk at a distance of about 10 m to the next person (max. 3 participants total). At the same time, sound measurement was carried out by the experimenter using the dB Meter Sound App for iOS. Both routes took 14-15 minutes to complete and were roughly the same length (1 km), the nature trail being about 200 m shorter. The average walking speed was 4.5 km/h and did not differ significantly between groups (M_{nature} = 4.38, SD_{nature} = 0.32, M_{urban} = 4.70, SD_{urban} = 0.15, $p > .05$). Average heart rate was 103.5 bpm, with no significant differences between groups (M_{nature} = 106, SD_{nature} = 9.13, M_{urban} = 101, SD_{urban} = 7.21, $p > .05$). Environmental measures did not differ significantly between group settings (see Table 1). Upon returning to the test site, questionnaires, salivary cortisol, and cognition tests were repeated before participants were thanked and sent home.

Cognitive performance was measured using paper-pencil versions of different tasks, namely the d2-R (attention), the Digit Span Forward (working memory) and Trail Making Test (executive functioning, TMT-A and TMT-B). In the TMT-A, participants are asked to connect numbers in ascending order. In the TMT-B, ascending numbers and letters must be connected in alternating order. For the analysis, task completion time of TMT-A (indirect measure of motor skills) is subtracted from completion time of TMT-B (indirect measure of motor skills and executive functioning) and used as a measurement of executive functioning. The Digit Span Task requires participants to repeat a series of numbers back to the test coordinator in the correct order. The longer the sequences of numbers a participant is able to repeat, the higher their score. In the d2-R, participants are shown multiple strings of letters and have to mark all instances of the letter "d" with two accompanying lines either above or below. They are given 20 seconds per line, with performance being determined by correct responses minus errors. For the analysis, we focused on the following scores: KL (based on d2-R, concentration performance), TMT-B minus TMT-A (in sec), and Digit Span Forward score (max. 16).

Table 1: Descriptive environmental data. CO_2 and $PM_{2.5}$ concentration in parts per million (ppm), air humidity (relative humidity) in %, temperature in °C, sound level in dBA. p values were calculated using Student's t-test.

Variable	Group	M (SD)	p
CO_2	Nature	228.47 (216.49)	.706
	Urban	188.96 (220.40)	
$PM_{2.5}$	Nature	76.25 (50.53)	.715
	Urban	86.42 (64.82)	
Air humidity	Nature	81.84 (7.35)	.617
	Urban	83.39 (5.41)	
Temperature	Nature	9.78 (1.82)	.344
	Urban	8.92 (1.92)	
Sound level	Nature	53.45 (3.26)	.085
	Urban	57.01 (5.28)	

Data Analysis

To analyze and visualize the data, statistical softwares Jamovi (Version 2.6, https://www.jamovi.org) and R Studio (Version 2024.09, https://www.R-project.org/) were used. An a priori analysis using G*Power (Version 3.1.9.7) for a repeated measures ANOVA comparing two groups and two time points given a medium effect size of f = 0.25 yielded a total sample size of n = 54 (critical F = 4.03). Outliers (>3 SD) were identified for each test and excluded from the respective analyses (n = 1). At one measurement point, documents were missing for the TMT, excluding further participants for this specific analysis (n = 4), one participant with a heart rate of 139 bpm during the walk was also excluded.

A 2x2 repeated measures ANOVA with between-subject factor group and within-subject factor time was

carried out for each cognitive measure, including Bayes statistics when appropriate. Age, gender, and education were added to separate ANOVAs as covariates to account for possible influences on cognitive and executive functioning [8], as were average speed, average heart rate, CO_2, air humidity, temperature and sound level during the walk.

III. Results and discussion

Trail Making Test

TMT difference scores of both groups pre- and post-walk are shown in Fig. 1. A 2x2 ANOVA on TMT difference with factors group and time revealed no significant main effect of time ($F(1, 45) = 0.72$, $p = .400$), no main effect of group ($F(1,45) = 0.12$, $p = .734$) and no interaction effect of time and group ($F(1, 45) = 0.01$, $p = .932$, $BF_{10} = 0.28$). The additional analysis with covariates (age, gender, education, heart rate, speed, CO_2, air humidity, temperature and sound level) did not reveal any significant interactions (all $p > .05$).

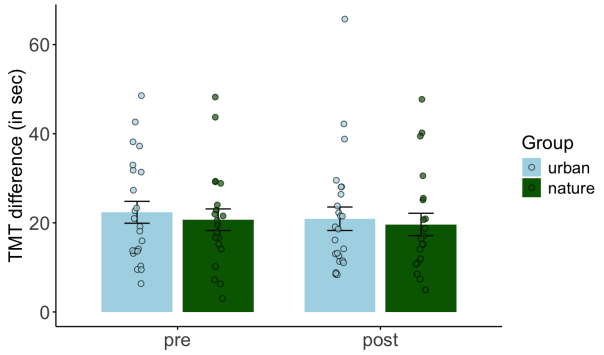

Figure 1: TMT difference (in sec) for both groups and time points.

Digit Span Forward

Digit Span Forward scores of both groups pre- and post-walk are shown in Fig. 2. A 2x2 ANOVA on Digit Span scores revealed a significant main effect of time ($F(1, 48) = 21.12$, $p < .001$) and an interaction effect of group and time ($F(1, 48) = 4.36$, $p < .05$, $BF_{10} = 1.34$), but no significant main effect of group ($F(1, 49) = 0.93$, $p = .340$). Bonferroni-adjusted post-hoc analysis revealed significantly lower scores pre-walk than post-walk ($M_{Diff} = -0.687$, $p < .001$), this time effect being significant only for the urban group ($p < .001$). Including the covariates did not reveal any significant interactions (all $p > .05$).

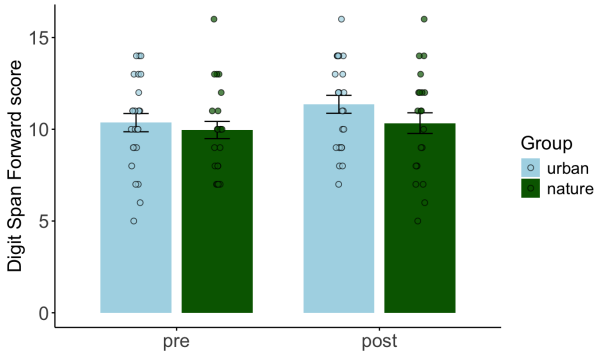

Figure 2: Mean Digit Span Forward scores for both groups and time points.

d2-R

D2-R KL sum scores pre- and post-walk are shown in Fig. 3. A 2x2 ANOVA revealed a significant main effect of time ($F(1, 47) = 118.87$, $p < .001$), but no main effect of group ($F(1, 47) = 0.12$, $p = .732$) or interaction effect of group and time ($F(1, 47) = 1.94$, $p = .170$, $BF_{10} = 0.68$). Bonferroni-adjusted post-hoc analysis revealed significantly lower scores pre-walk than post-walk ($M_{Diff} = -27.5$, $p < .001$). None of the covariates revealed any significant interactions (all $p > .05$).

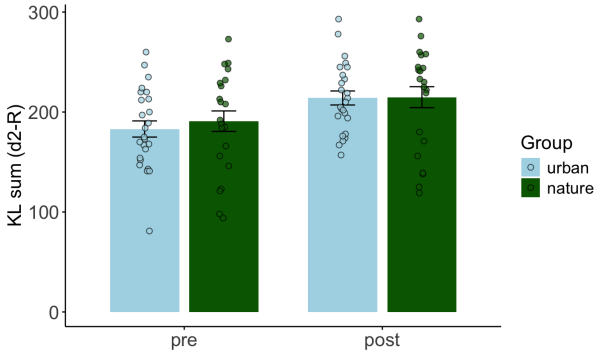

Figure 3: Mean d2-R KL sum scores for both groups and time points.

Discussion

This pilot study aimed to examine effects of nature vs. urban walks on subsequent performance in cognitive tasks. Our findings indicate that walking in either nature or urban environments can have positive effects on cognitive performance. This was true mainly for the attention task d2-R, supporting ART insofar as both walking routes might have allowed for restoration of attentional resources and improved performance to a similar extent.

Although cognitive improvements relating to atten-

tion (d2-R) could also reflect training effects, this explanation falls short regarding working memory (Digit Span) and executive functioning tasks (Trail Making Test). We did not find effects regarding working memory in the nature group, nor did we observe any improvements concerning executive functioning, raising the question of domain-specific effects of short walks on cognitive abilities that do not extend to all walking environments equally or to executive functioning altogether. This might partially explain why studies remain inconclusive about cognitive enhancements in the context of outdoor walks [9]. Such a conclusion, however, would require further testing, including a passive control group.

While these results partly suggest time-dependent performance improvements, the lack of group differences in working memory and executive functioning tasks challenges the notion of additional benefits of natural environments. However, our statistics, including BF_{10} values indicating anecdotal evidence, do not offer conclusive evidence that such effects do not exist.

This study has several strengths and limitations. Firstly, although most variables did not play a role for cognitive performance, our approach to combine physiological, psychological, and environmental measures allowed for a multidimensional perspective on the relationship between walks and cognition. Furthermore, this study took place in the span of three weeks with fairly consistent weather and testing conditions, allowing for a high level of comparability between measurement points. Likewise, the study sample was quite homogeneous in terms of age and education, limiting generalizability, but minimizing sampling errors.

Conversely, this study was conducted only once and the walk was relatively short; it is therefore reasonable to assume that longer or more frequent walks are required for the unique benefits of nature to have a noticeable effect on cognitive abilities. Secondly, while weather conditions were similar during measurements, grey skies and temperatures around 9°C may have reduced participants' cognitive performance and motivation, as questionnaires and tests were conducted outside. Moreover, the sample size approached but did not meet G*Power's recommendation of 54 participants, and the assumption of a medium effect size for nature walks on cognition could be questioned. Lastly, imbalanced gender representation and low variance in age and education in this predominantly university sample likely contributed to the lack of significant covariate effects.

IV. Conclusion

A 15-minute walk can have positive effects on certain cognitive abilities, regardless of whether it is taken in an urban or natural setting. However, this pilot study should be repeated, especially in a warmer season to rule out possible effects of temperature or a lack of "greenness". While partly in line with ART, our results open up new questions regarding domain-specific effects of walks to be addressed in future research.

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Author's statement

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration.

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