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Introducing nature at the work floor: A nature-based intervention to reduce stress and improve cognitive performance

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ABSTRACT

Background: Although a growing body of research has shown that exposure to nature has restorative effects on human health, the potential beneficial effects of nature-based interventions in the working environment are still underexplored.
Methods: We performed a randomized controlled study with a nature-based program during working hours. We enrolled employees, randomized the participants into two groups being an intervention and a control group. Twice a week for three consecutive weeks, the intervention group participated in nature-based activities for 2 h. The primary outcomes were cognitive performance, burnout assessment, salivary cortisol levels, and continuous stress levels. We performed intervention-response analyses using mixed-effects models that included random effects for each participant across the different examinations.
Results: Compared to the control group ($n = 20$), the intervention group ($n = 25$) participating in the nature-based program had a lower Burnout Assessment Tool score (−14.9% CI-16.2 to −14.3, difference; $p < 0.001$), lower salivary cortisol levels (−29.3% CI-34.7 to −25.3; $p < 0.001$) and higher visual information processing speed (7.4% CI6.9–8.0; $p < 0.001$). Selective attention of the participants that participated in the nature-based program improved during the interventions (−10.6 CI-19.6 to −6.9, $p = 0.045$), compared to the controls.
Conclusions: This study provides novel evidence that exposure to nature during work hours reduces stress and improves cognitive performance.
The trial is registered with ClinicalTrials.gov, number: NCT04111796.

1. Introduction

Work-related stress is defined as the response people may have when presented with work demands and pressures that do not align with a person's knowledge, skills, or, expectations, inhibiting one's ability to cope. Many factors are associated with work-related stress: long working hours, work overload and pressure, lack of control, lack of opportunity to participate in decision making, poor social support, and, unclear management or work role. Chronic work-related stress can lead to burnout which is a syndrome characterized by a combination of emotional exhaustion, depersonalization, and, reduced personal accomplishment(Maslach et al., 2001).

Prolonged exposure to stress can have deleterious effects for the individual, with increased risk of poor mental health, sleep disorders, cancer, cardiovascular disease, type 2 diabetes, and, premature aging (Juster et al., 2010). Work-related stress not only has an individual effect but can also negatively affect society and the workplace. According to WHO stress, depression, burnout and, anxiety results in an estimated cost to the global economy of USD 1 trillion per year through lost productivity, absenteeism and, compensation costs(Bianchi et al., 2015), with an estimated 12 billion working days lost due to mental illness every year(Kohrt et al., 2015).

Nature has restorative effects on human health and surrounding greenness is inversely associated with all-cause mortality(Rojas-Rueda

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et al., 2019). Contact with nature can lead to improved attention and cognitive functioning(Crous-Bou et al., 2020; Dadvand et al., 2015; Zijlema et al., 2017), improved mental wellbeing and, positively affect mood state(van den Berg et al., 2016). Two main theories explain the restorative effects of contact with nature (green space): the Stress Recovery Theory and the Attention Restoration Theory. The first postulates that exposure to nature results in a stress-reducing effect on humans and provides rapid short-term recovery from stress(Ulrich et al., 1991); the latter states that nature provides the particular environmental stimuli to allow restoration from mental fatigue and can restore the capacity for more attention(Kaplan 1995).

The workplace has been identified as one of the most important social contexts to address mental health problems, and promote mental health as well as wellbeing(Gritzka et al., 2020; WHO 2010). Nature-based interventions at the workplace could reduce employee stress levels and increase cognitive performance. Existing evidence of a handful of studies showed less stress-related disorders, reduced burnout scores, less long-term absenteeism and, increased work capacity(Brown et al., 2014b; Calogiuri et al., 2015; Cordoza et al., 2018; Gritzka et al., 2020; Sahlin et al., 2014; Sianoja et al., 2018). Since the effect of extensive job stress could be a major problem for the individual, the society and, the workplace, more effective methods to handle stress at work must be developed, thereby reducing employees' risk of developing serious stress-related illnesses. To our knowledge, there is no randomized controlled trial (RCT) that quantifies the effects of a nature-based intervention program during working hours for the prevention of stress. We will address this gap in knowledge by performing an RCT that evaluates self-assessed burnout, cognitive performance and, two stress parameters.

2. Methods

2.1. Recruitment

The participants in the nature-based study consisted of employees from the Province of Limburg, Belgium, spread over the various provincial managements, services and, institutions. The eligibility criterium was being an employee of the Province of Limburg, they were all invited to participate. Information about the project and invitations were e-mailed to the participants. Information was also published on the Intranet of the Province of Limburg. Participants in the intervention group partook in the nature-based intervention program and participated in the examinations. The control group only participated in the examinations. Participants provided informed consent prior to participation. The study protocol was approved by the medical ethics committee of Hasselt University, Belgium. The study population size in this intervention study took into account a sample size calculation. This was based on demonstrating the effect size in the cortisol response as reported in workers in a study by Calogiuri (Calogiuri et al., 2016), with 95% power at a significance level of 5%, two-sided α and an allocation rate of N2/N1 of 1, resulting in a size of at least 7 per group (calculated via G-power).

2.2. Randomisation and masking

After recruitment, participants were randomly assigned via a computer algorithm using the R.3.3.1 to either the control group or the intervention group. Participants and those assessing the outcomes were not blinded to group assignment.

2.3. Study population

Initially, fifty-eight individuals signed up for participation. Nine individuals were unable to participate in the project due to conflicting commitments and meetings, illness, pregnancy, or, because of the large distance to the location of the intervention and/or, the examination (Fig. 1). The total number of participants was 49, 25 individuals were assigned to the intervention group and 24 individuals were assigned to the control group. At the start of the study, 4 individuals from the control group dropped out due to illness. To check for potential selection

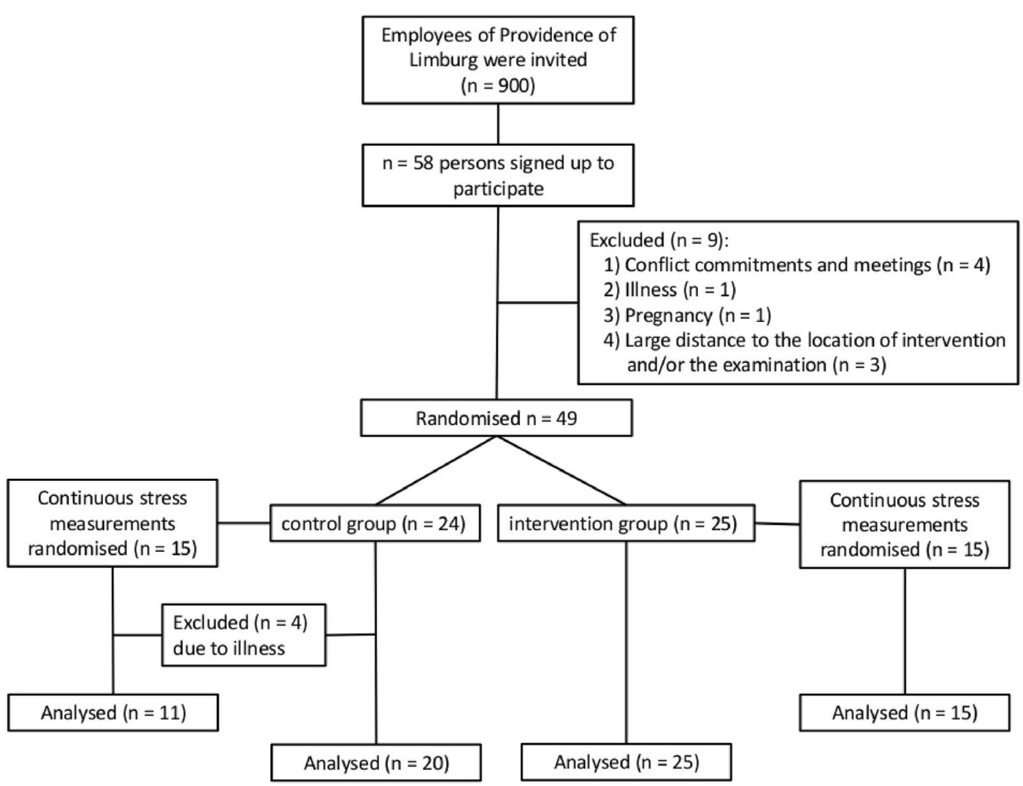

Fig. 1. Flowchart.

bias, differences between the control and intervention groups were assessed using independent t-tests. All participants worked in the same building. Data about the non-participating subjects was not available due to privacy regulations.

2.4. The nature-based intervention program

The trial is registered with ClinicalTrials.gov, number: NCT04111796. Groups limited to a maximum of eight participants each met for two 1.5 h twice a week for three consecutive weeks. The nature-based activities of 1.5 h took place during the working hours and were preceded by a 30-min stress management discussion in nature which was supervised by two qualified psychologists. The sessions took place in a green outdoor environment and their content included different methods of recognizing, dealing with, and avoiding stress at the workplace. Each intervention group carried out six different nature-based activities, in varying order: a nature walk, a nature experience walk, a workshop land art, a workshop bird feeder, a cycling tour and, an edible nature walk. In every activity, the group was accompanied by a nature guide. The intervention program was performed in a nature reserve (Domein Kiewit, Hasselt, Belgium, size 130 ha). Having a nature-based activity of 1.5 h per activity was carefully chosen after discussion with the HR-administration. The reasoning behind this length was to take into account that the program did not take into account a large proportion of the working day. The reasoning behind having an intervention of 3 weeks was based on 2 other successful studies of 2 week-interventions (Calogiuri et al., 2016; Torrente PK et al., 2016). During the intervention program, the control group did not change their work and performed their usual tasks.

2.5. Examinations

During the study, 4 examinations were organized that took place every Monday between 9:00 a.m. and 5:00 p.m. (baseline, after the 1-week intervention, after 2 weeks intervention, and, at the end after 3 weeks intervention). Before the start of the nature-based intervention program, the participants received a short questionnaire to collect information about the individual characteristics (e.g. age, sex, BMI, smoking status, …). The primary outcomes were cognitive performance, burnout assessment, salivary cortisol levels and, continuous stress levels.

2.6. Outcomes

2.6.1. Cognitive tests

A computer version of the Stroop Test (http://www.xavier-educational-software.co.uk/multistroop.shtml) and the following four tests from the Neurobehavioral Evaluation System 3 (NES3) battery were administered: Continuous Performance, Digit Span, Digit-Symbol and, Pattern Comparison(White et al., 2003).

In the Stroop Test (selective attention domain), four buttons were displayed on the screen (yellow, red, blue, and, green). During the test, the name of one of these colors appeared on the screen printed in a different color than the name. The task was to ignore the color of the printed name and to touch the button that had the same color as the name as fast as possible. Eight practice trials took place before the test, followed by 48 test trials. The mean reaction time was the average time that passed between the appearance of the name and touching the correct button.

In the Continuous Performance Test (sustained attention domain) letters were displayed on the screen, one at a time and each for approximately 200 msec. The task was to immediately respond to the letter ‘S’ by pressing the spacebar, but not to the other letters. A new letter was displayed each 1000 msec. The mean reaction time was the average time that passed between the appearance of the letter ‘S’ and pressing the spacebar.

The Digit Span Test (short-term memory domain) consisted of two parts. In the first part, the task was to reproduce a series of digits after an auditory presentation in the order of the presentation. The test started with a sequence of three digits. In case of a correct answer, a one-digit longer sequence was presented. The test continued until two consecutive incorrect answers were given. In the second part of the test, the task was to reproduce the digits in the reverse order of the presentation. The maximum number of digits that could be remembered was used as the outcome.

In the Digit Symbol Test (visual information processing speed domain), a row of 9 symbols paired with 9 digits was shown at the top of the screen. The same 9 symbols but in a different order were displayed at the bottom of the screen. During the test, 27 digits appeared consecutively on the screen. When a digit was shown, the task was to indicate as fast as possible the symbol which was paired with this digit in the row of symbols at the bottom of the screen. A new digit appeared only after the correct symbol had been indicated. The total latency time was used as the outcome.

In the Pattern Comparison Test (visual information processing speed domain), three matrices consisting of 10 x 10 blocks were shown. Two of them were identical. The task was to indicate which pattern is different from the other two patterns. The test included 25 items. The mean latency was used as the outcome.

2.6.2. Burnout assessment tool

The Burnout Assessment Tool (BAT) is a self-assessment questionnaire to measure parameters associated with burnout(de Beer et al., 2020). This self-assessment questionnaire contains 4 different subscales: exhaustion, mental distance, emotional loss of control and, cognitive loss of control. In total this questionnaire consists of 23 items, each with a 5-point scale (1 = never, 2 = rare, 3 = sometimes, 4 = often and, 5 = always). The outcome of these items resulted in a sum which is used as a score.

2.6.3. Cortisol

Cortisol is a stress hormone that is produced from cholesterol by the adrenal cortex. The production of cortisol in the body follows a circadian rhythm, i.e. the production is not the same at all times of the day. Hence, saliva collection for the measurement of cortisol occurred every week on Monday (the same day as the examinations) at 3 fixed time points (immediately after awakening, 30 min after awakening, and at 8 p.m.). Due to the cortisol awakening response, an increase in cortisol levels peaking 30–45 min after awakening in the morning, we selected the first 2 time points being after awakening and after 30 min. This response is followed by a decline over the next hours after awakening (Elder et al., 2013) and we included sampling at 8 to also include this decline in the cortisol assessment (reviewed in (Elder et al., 2013)). The saliva was collected using Salivette® Cortisol (Sarsted). The participants were asked to keep the samples in the refrigerator and take them to work at room temperature the next day where they were picked up in the morning and frozen at −20 °C. The cortisol samples were analyzed in an electrochemiluminescence immunoassay (ECLIA) by using the Cobas 8000 e602 device.

2.6.4. Continuous stress measurement

Continuous stress measurements were performed in a randomized allocated subset of the study population (n = 26). Participants were monitored for 4 weeks (1 week before the program and, during the 3 program weeks) using individually portable technology. The commercially available portable technology (BioRICS nv) consisted of a smartphone (Samsung Galaxy J1 6), and, a sports watch (Mio ALPHA 2) to measure heart rate (sport watch) and, activity (sport watch/phone). Via the 3D accelerometer of the smartphone, the activity (counts) can be quantified. The unit ‘activity counts’ represent activity that caused the acceleration signal to exceed a certain threshold and thus the acceleration was ‘counted’ as activity. When the smartphone is connected to the sports watch via Bluetooth the app can also register the heart rate (beats per minute) measured by the watch. BioRICS uses an algorithm to determine a stress level from the measured heart rate. Based on these results, a weekly average of the stress level was calculated.

2.7. Statistical analyses

Intervention-response analyses using mixed-effects models that included random effects for each participant across the different examinations were performed (SAS, version 9.3; SAS Institute Inc., Cary, NC, USA). The results of the mixed models were expressed as corrected averages (least-squares means – lsmeans) for the different outcomes in the control and intervention group at baseline, 1 week after intervention, 2 weeks after intervention, and 3 weeks after intervention examinations, respectively. The results are presented as a number for the BAT, msec for the reaction time of the Stroop Test and the Continuous Performance Test, the number of digits for the Digit Span Forward and Backward Test, msec for the total latency of the Digit-Symbol Test, and msec for the average latency of the Pattern Comparison Test, stress level for the continuous stress measurements, and, μg/dl for cortisol level. We calculated percentage differences by first calculating the difference between the beta estimate per week and the mean of the beta estimates at the baseline in both groups (control and intervention group) and then by dividing this difference by the mean of estimates at the baseline in both groups. We included an interaction term for the examination (control group and intervention group) and examination (week of measurement) as a possible difference over time per treatment group is indicative of an effect of the intervention when the intervention is progressing. We report the p-value of with the examination groups and between the examination groups.

Analyses were adjusted for *a priori* chosen covariates including age, sex, BMI, smoking (yes or no), number of sick days in the previous six months, past with doctor-diagnosed stress-related condition (yes or no). All analyses except the model for continuous stress measurements also included the covariate having had a continuous stress measurement (yes or no). Additionally, the effects of potential baseline differences were controlled for by introducing baseline levels as covariates. The cortisol models had an additional adjustment for sleep quality (based on the Pittsburg Sleep Quality Index) and, the time point of saliva collection was included as a random effect.

3. Results

In the present study, 25 people participated in the intervention group while 20 people completed the control measurements. The characteristics of the two groups were not significantly different between the intervention and control group, except for the number of days of sick leave (*p*-value for difference <0·001) and sleep quality (p-value 0.03) (Table 1). Both groups contained more women than men. The average age of the participants was 44·5 ± 9·2 years. The majority of the control and intervention group did not smoke during the study (95% and 88%, respectively). Almost half of the participants had a doctor-diagnosed stress-related condition in the past (50% and 40% for the control group and intervention group respectively). The mean of the different measurements before the start of the nature-based intervention program was comparable in both groups (Table 2).

The intervention group showed less stress compared with the control group, based on the mixed-effect models. The intervention group reported lower BAT scores by time (p-value < 0·001) and the BAT scores of the intervention and control group significantly differed over the course of the examinations. Participating in nature-based interventions was associated with a lower BAT score of 14·9% in comparison with the control group (p-value < 0·001, Table 2). An interaction effect of intervention versus examination group by examination was observed for the BAT test (p-value < 0·0001, Fig. 2A). In agreement with the self-reported stress also the mean salivary cortisol concentration of the intervention group was significantly lower when comparing the cortisol concentrations at baseline and 3 weeks after intervention. Participating in nature-based interventions was associated with a lower cortisol concentration (μg/dl) of 29·3% in comparison with the control group (p-value <0·001, Table 2). Furthermore, a significant interaction effect of the group by time was observed (p-value = 0·004, Fig. 2). Within a smaller subgroup (n = 26), a decrease in continuous stress measurement mean score during the program, assessed by portable devices, was observed in the intervention group (p < 0·001). However, no difference between the groups and no significant interaction effect of the group by time was observed (Fig. 2C).

At baseline, the mixed-effect models did not show significant differences between the cognitive performances of the 2 groups (Table 2). Over the course of the examinations, the intervention and control group showed a decrease in time (p-value <0·05) in the Stroop test, digit symbol test, and, pattern comparison test (Table 2). While the intervention group performed better in the digit span backward test (p-value 0·05), the control group did not significantly improve (p-value 0·154) during the examinations. The intervention group performed better on the digit symbol test as compared to the control group (Fig. 3E). Participating in nature-based interventions was associated with a lower latency time (msec) of 7·4% in comparison with the control group (p-value <0·001). An interaction effect of intervention versus examination group by examination was observed for the Stroop test (p-value of interaction = 0·045, Fig. 3A). There was no significant interaction effect of the group by examination for the continuous performance test, digit span forward test, digit span backward test, and, the pattern comparison test (Fig. 3).

Table 1
Population characteristics.

	Control group (n = 20)	Intervention group (n = 25)	*p*-value for difference[a]
Sex			0·08
Female	13 (65%)	20 (80%)	
Age, years	45·4 ± 7·3	43·7 ± 10·6	0·17
BMI, kg/m^2	24·8 ± 2·6	24·9 ± 3·8	0·82
Smoking status			0·23
Never smoked	13 (65%)	17 (68%)	
Ex-smoker	6 (30%)	5 (20%)	
Smoker	1 (5%)	3 (12%)	
Alcohol consumption			0·79
Never	3 (15%)	4 (16%)	
Weekly	17 (85%)	21 (84%)	
Education			0·57
High school	1 (5%)	3 (12%)	
College (max. 3 years)	5 (25%)	5 (20%)	
University (min. 4 years)	14 (70%)	17 (68%)	
Stress-related condition in past			0·11
Yes	10 (50%)	10 (40%)	
Number sick days previous six months, days*	1 ± 1·8	3·5 ± 5·5	<0·001
Sleep quality	7·7 ± 4·1	7·0 ± 3·0	0·03
Continuous stress measurements			0·84
Yes	11 (55%)	15 (60%)	

Continuous variables expressed by the mean and standard deviation (SD); categorical variables described by number and frequencies (%); Abbreviation: BMI = body mass index.

[a] Differences between control and intervention group were assessed using independent t-tests.

4. Discussion

The nature-based intervention during work hours showed i) an improvement in visual information processing speed (measured through the digit symbol test), ii) an improvement in selective attention

Table 2
Least-squares means of the mixed-effects models for the measurement in the control and intervention group at baseline, 1 week after intervention, 2 weeks after intervention, and 3 weeks after intervention examinations, respectively.

Stress	Groups	Baseline	1-week intervention	2 weeks intervention	3 weeks intervention	*p*-value (within-group)[a]	*p*-value (between groups)[b]
BAT	**Control group**	56·4 (2·2)	57·2 (2·2)	57·4 (2·2)	57·2 (2·2)	0·81	
	Intervention group	58·1 (2·1)	54·5 (2·1)[c]	51·9 (2·1)[c]	48·5 (2·1)[c]	<0·001	<0·001
Cortisol	**Control group**	0·38 (0·027)	0·38 (0·028)	0·37 (0·028)	0·35 (0·028)	0·67	
	Intervention group	0·37 (0·026)	0·36 (0·027)	0·34 (0·026)	0·24 (0·026)[c]	<0·001	<0·001
Continuous stress measurement	**Control group**	5·7 (1·7)	6·5 (1·7)	6·4 (1·6)	5·3 (1·7)	0·43	
	Intervention group	7·4 (1·5)	6·5 (1·5)[c]	6·2 (1·5)[c]	5·3 (1·5)[c]	<0·001	0·80
Cognitive tests							
Stroop test	**Control group**	1019·7 (34·5)	979·8 (34·5)[c]	992 (34·5)	971·2 (35·2)[c]	0·03	
	Intervention group	1030·5 (30·1)	1011·2 (33·4)	938·1 (33·2)[c]	917 (33·1)[c]	<0·001	0·44
Continuous performance test	**Control group**	399·6 (8)	400·6 (8)	398·1 (8)	395·8 (8)	0·87	
	Intervention group	396·4 (7·7)	394·1 (7·8)	387·6 (7·7)	389 (7·8)	0·23	0·31
Digit span forward test	**Control group**	6·7 (0·36)	7·2 (0·36)	6·9 (0·36)	6·9 (0·36)	0·75	
	Intervention group	6·7 (0·34)	6·8 (0·34)	6·9 (0·34)	7·1 (0·34)	0·37	0·63
Digit span backward test	**Control group**	5·3 (0·28)	5·9 (0·28)	5·9 (0·28)	5·9 (0·28)[c]	0·154	
	Intervention group	5·2 (0·26)	5·5 (0·26)	5·5 (0·26)	5·8 (0·26)[c]	0·05	0·60
Digit symbol test	**Control group**	95·7 (2·3)	92·7 (2·3)	90·8 (2·3)[c]	91·2 (2·3)[c]	0·02	
	Intervention group	94·5 (2·2)	89·4 (2·2)[c]	86·1 (2·2)[c]	84·2 (2·2)[c]	<0·001	<0·001
Pattern comparison test	**Control group**	3·6 (0·2)	3·3 (0·2)[c]	3·2 (0·2)[c]	3·1 (0·2)[c]	0·002	
	Intervention group	3·7 (0·19)	3·4 (0·19)	3·3 (0·19)[c]	3·2 (0·19)[c]	0·002	0·72

The values in parentheses are standard errors (SE); Abbreviation: BAT = burnout assessment tool.
Models are adjusted for age, sex, BMI, smoking, participant with continuous stress measurements, number of sick days previous six months, past with stress-related condition.
[a] *p*-value for effect per group.
[b] *p*-value for difference between groups.
[c] Difference in comparison with baseline is *p*-value $< 0{\cdot}05$.

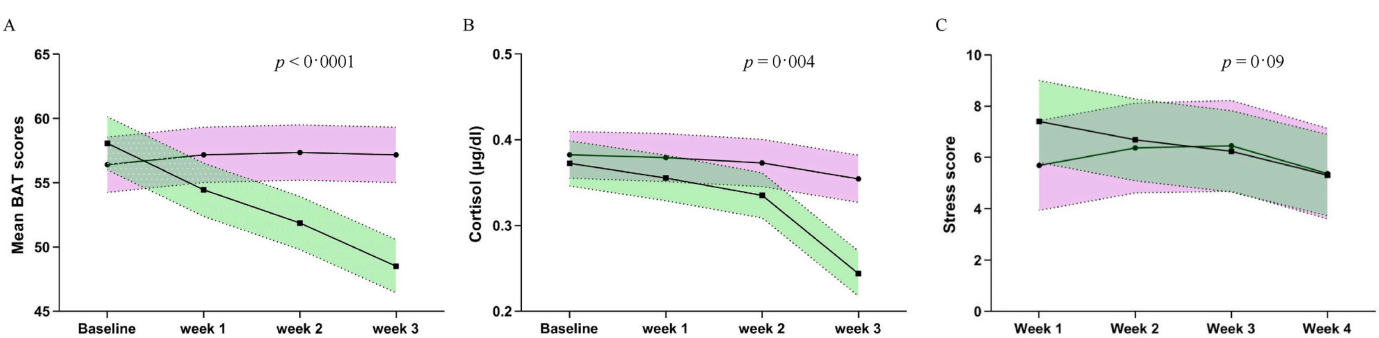

Fig. 2. Interaction plots for estimates (standard error) stress parameters versus examination and group, based on mixed-effects models; control group (circles and purple) and intervention group (squares and green); A: Burnout assessment tool (BAT), B: Cortisol, C: Continuous stress measurement; *p*-value: *p*-value of interaction between group and examination. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

(measured through the Stroop test), and, iii) a significant reduction in stress parameters, particularly self-reported stress (BAT) and, salivary cortisol concentration. Our results suggest that a nature-based program of 3 weeks during working hours may lead to a reduction in stress and better cognitive performance in employees. For the cognitive tests, our findings indicate that a nature-based program might be more important for improvements in the visual processing speed domain and the selective attention domain, than in the sustained attention and short-term memory domain.

In agreement with our study, other studies described that exposure to a green environment is associated with improved cognitive functions. The PHENOTYPE study found that living closer to a natural outdoor environment led to improved cognitive function in middle-aged people (Zijlema et al., 2017). Kuo et al. (Kuo 2001) observed less attention fatigue among residents of public housing in housing blocks with nearby nature compared to those living in housing blocks without nearby

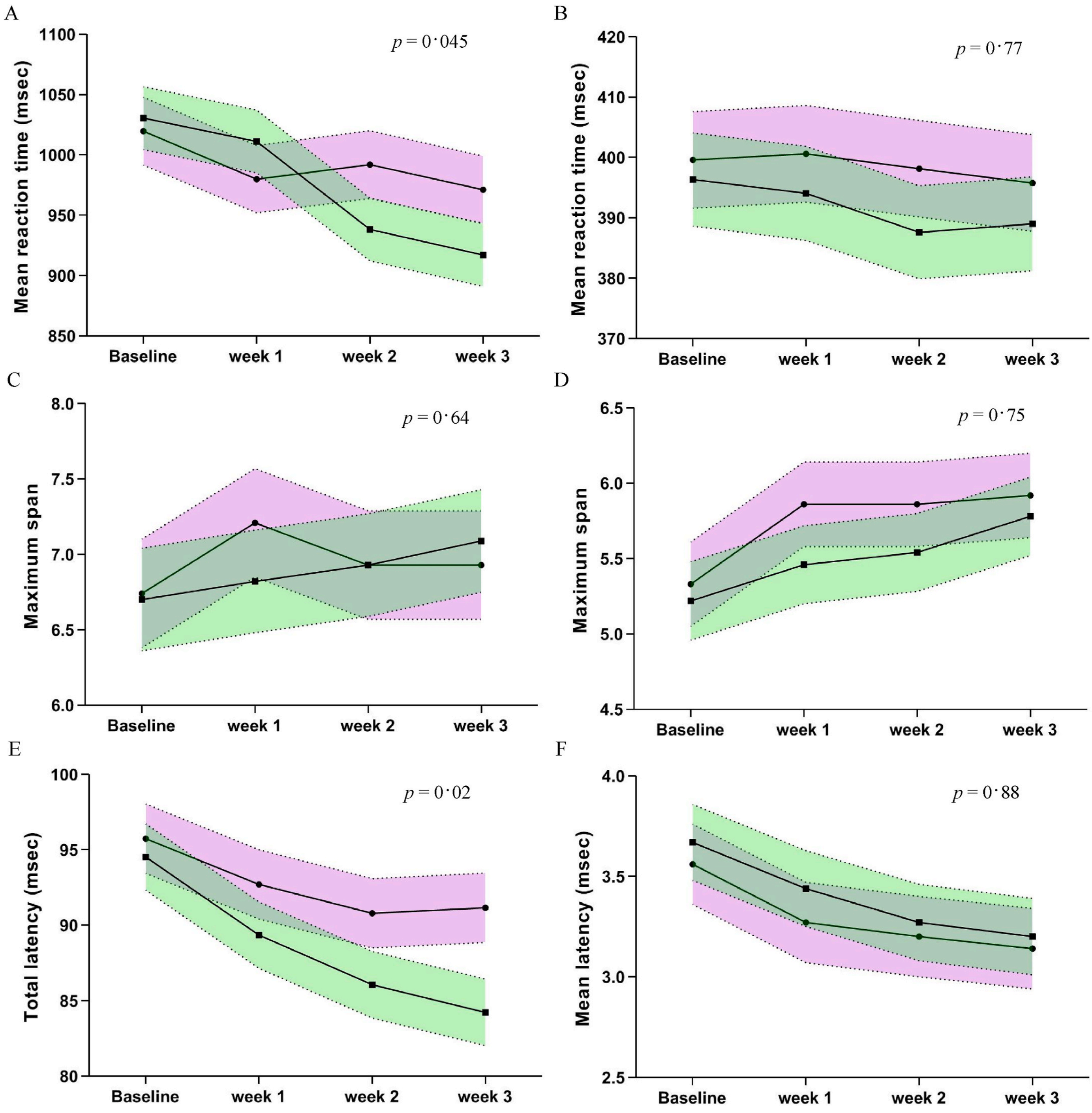

Fig. 3. Interaction plots for estimates (standard error) cognitive tests versus examination and group, based on mixed-effects models; control group (circles and purple) and intervention group (squares and green); A: Stroop test, B: Continuous performance test, C: Digit span forward test, D: Digit span backward test, E: Digit symbol test, F: Pattern comparison test; *p*-value: *p*-value of interaction between examination group and examination week. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

nature. A study in primary school children reported associations between surrounding greenness in residential, school and, commuting areas and improvements in the development of working memory and attention after 12 months(Dadvand et al., 2015). In a randomized crossover trial including 38 middle-aged people, a 30-min walk in a natural environment improved attention and restoration capacity, when compared with a similar walk in a pleasant urban environment(Gidlow et al., 2016). In contrast to these studies, other investigations could not find an association between the proportion of parks in the neighborhood and cognitive function(Clarke et al., 2012) or did not find a difference in attention between nature exposure and control groups(Hartig et al., 1991).

Here, we used cognitive tests as a proxy for cognitive performance. Many individuals perform better at cognitive function tests with repeated testing(Wesnes and Pincock 2002) hence including a control group for these tests is essential in the analyses of this study. As a learning effect is inherent to performing these cognitive tests, we could not control the learning effect in both groups but we assume that the learning effect in both groups are similar and by comparing the treatment and control groups, we strive to take the learning effect into account as much as possible. In addition, when considering the treatment effects within the intervention group, we noticed that they were not only significant but also showed a stronger association in terms of p-values compared to the control group for the Stroop test, digit span backward test and, the digit symbol test.

Our findings on the reduction of stress parameters are in agreement with other intervention studies at work. First, the participation in a 12-week nature-based stress management program with a follow-up study at 6 and 12 months resulted in a significant decrease in self-assessed burnout scores(Sahlin et al., 2014). Second, a study, in which nurses took their daily work breaks in an outside garden or the break room also reported a similar positive effect. In this crossover study, a significant improvement was demonstrated in the self-assessed burnout scores after the daily breaks in the outdoor garden when compared to the daily breaks in the break room(van den Berg et al., 2016). Third, a pilot study on including green exercise at the workplace, based on an intervention and a control group both consisting of 7 workers, showed that the nature group reported a higher potential for restoration and positive effect along with improved cortisol awakening response(Calogiuri et al., 2015). Forth, the study Walks4work showed that lunchtime walks during 8 weeks improved self-reported mental health in the nature group compared to a control group(Brown et al., 2014b). Fifth, park walks at lunchtime were related to better concentration and less fatigue in the afternoon through enjoyment(Sianoja et al., 2018).

Salivary cortisol concentrations, which show a high correlation to cortisol blood levels(Bozovic et al., 2013), are also used in other studies as a biological marker of stress and assumed to reflect physiological stress. Our results agree with other studies that found a decrease in cortisol concentration when exposed to green spaces (Calogiuri et al., 2015; Roe et al., 2013). An intervention study(Van Den Berg and Custers 2011) including 30 participants who were assigned to either an outdoor gardening intervention group or an indoor reading control group showed lower salivary cortisol concentrations in the group with outdoor gardening. A study by Kjellgren and Buhrkall(Kjellgren and Buhrkall 2010) compared cortisol concentrations before a stressful task, after a stressful task, and after 30 min of relaxation in a natural environment, and found a significant decrease between post-stress task as well as post-nature concentrations. In literature, there is mixed evidence of an association between exposure to nature and cortisol concentrations as some studies found an inverse effect (Van Den Berg and Custers 2011; Gritzka et al., 2020) while others reported no association (Beil and Hanes 2013; Detweiler et al., 2015). A possible explanation is that most studies did not measure diurnal concentration as some studies found no significant difference in cortisol concentration between pre and post-measurements. In several studies, cortisol samples were taken before and after outdoor exposure, or even during the exposure(Van Den Berg and Custers 2011).

The research hypothesis in many existing studies is that exposure to green or natural spaces can lead to stress reduction. Nature can improve recovery from stressful events by eliciting parasympathetic responses, decreased heart rate, lower blood pressure, lower skin conductance, and, reduced inflammatory markers(Bowler et al., 2010). This stress reduction, in turn, is hypothesized to carry health-promoting benefits. Exposure to scenes of natural environments could lead to faster recovery from illness(Parsons et al., 1998). Moreover, contact with nature may positively influence cardiovascular functioning(Ulrich et al., 1991), improve concentration, remedy mental fatigue(Kaplan 1995), and, improve mental wellbeing(Ulrich et al., 1991; van den Berg et al., 2016). In a longitudinal study, tracking a three-year time period between childhood and adolescence, residential industrial areas were associated with increased feelings of anger and total negative emotions(Van Aart et al., 2018). Consequently, higher residential exposure to semi-natural and forested areas was associated with increased feelings of happiness during this follow-up period(Van Aart et al., 2018).

There are several physical mechanisms through which this hypothesis may bear out. Spending time in nature may increase social contact, both planned (in the case of our study) and, unexpected, which may reduce stress. Furthermore, exposure to nature encourages people to be more physically active(Lee and Maheswaran 2011), which may lead to reduced stress and improved health.

We argue that an important strength of this study is the study design, namely a randomized controlled study. This randomized selection process facilitates the exclusion of systematic errors or bias as i) both groups contained participants who were motivated to participate in the study and, ii) because the characteristics of the two groups were comparable, the importance of other factors explaining the relationship could be avoided as much as possible. The findings were further corrected for important factors such as age, sex, BMI, etc. The selected cognitive and stress-related outcomes in this study were a combination of physiological measurements and the collection of information via standardized questionnaires. These measurements provide an objective assessment of the effect and already partially expose the working mechanism of spending time in nature. Furthermore, the use of the control group for the cognitive tests can distinguish if the findings were the result of the intervention of a possible practice effect.

Gritzka et al. (2020) identified 5 green exercise workplace intervention studies of which four implemented the intervention during the employees' lunch break (Bang et al., 2016; Brown et al., 2014a; Calogiuri et al., 2015; de Bloom et al., 2017; Gritzka et al., 2020). Only in 1 study, the green exercise was performed after completing a regular working day (Calogiuri et al., 2015). No interventions were identified that were implemented during regular working hours of employees, as is the case in our study. Planning the intervention during working hours carries the risk of underrepresentation from employees already suffering from a high workload. For these employees, participation during the working hours could be perceived as further increasing the workload, since the time spent participating in the green exercise is time that could have been spent reducing the workload. Employees already suffering from high work-related stress might however benefit disproportionately from a nature-based intervention program (Beute and de Kort 2018). Nevertheless, this study offers prospects that the efficiency and performance of employees increased, thereby supporting the hypothesis that spending time in nature does not only take away time but could also increase worker efficiency in performing tasks.

A limitation is the size of the group of participants. Although the study sample has been randomized, a small sex difference is present between the groups, nevertheless, as each person is their control this will not have biased our observations. Power calculations based on cortisol measurements indicated sufficient power for this outcome(Calogiuri et al., 2016), but we did not include multiple testing corrections. Another restriction is that the effect of the individual components being exposed to nature, stress management moment and, physical activity cannot be separated as they were integrated within our intervention program. However, it has become clear that the combination is effective and successful. A recent review from Meredith et al. (2020) concluded that 10–30 min of sitting outdoors and looking at nature has a positive effect on both biological and self-perceived markers of stress, thereby indicating that exposure to greenspace in and by itself has a positive effect (Meredith et al., 2020). The overall risk of bias due to the potential of contamination between the intervention and control group could not be prevented. Employees from both intervention and control groups worked in the same building and could discuss interventions with each other(Bang et al., 2016; Brown et al., 2014b).

In conclusion, although exposure to nature has restorative effects on human health, the translation to a work setting has been underexplored. Here, we showed that participating in a nature-based intervention during working hours lowers stress levels of employees as well as improves several aspects of their cognitive performance. These findings have important implications for enhancing employee efficiency, performance and, wellbeing. The improvement of cognitive function due to spending time in nature during workdays shows that freeing up time to go in nature will not only take time but will also generate time as workers become more efficient. These findings may promote more awareness of the importance of exposure to nature in the working environment. As a result, integration of nature based-interventions at the workplace will obtain better well-being and provides a more sustainable lifestyle.

Author contributions

SD1 and MP conceptualized the project idea. DBPC, SD1, TSN, RM and MP conceptualized the study protocol and methodology. DBPC performed the data collection and curation with help of HS. SD2 developed the burnout assessment tool. DBPC did formal data analyses with the help of MP and TN. DBPC, SD1 and MP designed the original draft. NS, HS, SD1, SD2, TSN and RM and reviewed and further edited the manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of competing interest

We declare no competing interests.

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