Abstract

The 'dose' of nature required for health benefits, and whether repeat visits to the same environment consistently confer health benefits, is unclear. We sought to provide proof of concept for testing this. Data were collected on repeated visits to either a natural or pleasant urban environment from 41 adults on three days, and at one follow-up assessment. Participants completed baseline profiling, then attended; three repeated visits to either an urban (*n*=17) or natural (*n*=24) environment; and a 24-hour post-exposure final session. In each environment, participants undertook a 30-minute walk at a self-directed pace. Measures included mood, cognitive function, restorative experience and salivary cortisol. Walking in both environments conferred benefits for mood, with additional improvements in restorative experience observed from visiting the natural environment. There was no change in response to visits to the natural environment over time, suggesting benefits may be consistently realized.

Keywords: nature; stress; heart-rate variability; restoration

1. Introduction

Nature exposure is consistently associated with better health (Mygind et al., 2019; Twohig-Bennett & Jones, 2018). Understanding this effect is particularly important as 54% of the world's population reside in urban areas; a number projected to reach 66% by 2050 (Nations, 2014). An increasing majority of people, therefore, have diminishing opportunities to engage with nature, with potentially detrimental health consequences. Accordingly, the 'dose' of nature required for health benefits is of interest (Shanahan et al., 2016; Shanahan, Fuller, Bush, Lin, & Gaston, 2015), which is, the quality, frequency and intensity of nature exposure required for health improvement. At least 30 minutes in a natural environment is associated with lower depression and blood pressure (Shanahan et al., 2016), and increased frequency of nature exposure is associated with greater social cohesion and physical activity (Shanahan et al., 2016). Improvements in self-esteem and mood have also been observed after just five minutes of exercise in a natural environment (Barton & Pretty, 2010).

Stress Reduction Theory (SRT) suggests that nature exposure reduces stress via psycho-physiological pathways that promote stress recovery, and diminish arousal and negative thoughts (Ulrich, 1983; Ulrich et al., 1991), and Attention Restoration Theory (ART) suggests effects are via restoration from directed attention fatigue, enabling effective cognitive performance (Kaplan & Kaplan, 1989). There is consistent support for both theories in laboratory settings, however evidence for effects on salivary cortisol, the main stress hormone, in field studies are limited and inconsistent (Bowler, Buyung-Ali, Knight, & Pullin, 2010). It is also unclear whether psycho-physiological responses to repeated visits to the same environment may be consistent, increase or diminish over time. This is important as repeated visits to easily-accessible natural environments are common, but existing research mainly concerns responses to novel environments.

We therefore addressed the following research questions: A) Does walking in a natural environment lead to better psycho-physiological outcomes than a pleasant urban environment?

B) Do effects of walking repeatedly in the same environment change over time? C) Do any effects persist to the following day?

2. Methods

2.1 Participants

Participants were forty-one adults (24 male, 17 female), who lived, worked or studied in (blinded), a medium-sized UK city (M_{age}=36.55, *SD*=14.54). 77.5% were White British and the majority were students (27.5%), in full-time work (22.5%), or part-time work (20%). Inclusion criteria were: aged ≥18 years; self-reported health of at least fair; not pregnant; no chronic medical conditions; not taking medication that could influence cortisol (Granger, Hibel, Fortunato, & Kapelewski, 2009); non-smokers; and able to undertake 30 minutes of walking. Participants were recruited via local media, University campus advertisements, and mail to residents within 1 kilometer of campus.

2.2 Design

In this between-subjects, longitudinal study, one group of participants walked in the same natural environment (country park within city) three times over three days (*n*=24), and a comparison group walked in a pleasant urban environment (quiet residential street) (*n*=17). Both locations were used in (blinded), which details criteria for environment selection. Environment was allocated as follows: participants 1-13 were randomly allocated. Because of concerns around recruitment speed, participants 14-30 were allocated to the natural environment to ensure a sufficient sample to explore effects of repeated exposure to a natural environment. The final 11 participants were allocated to the urban environment. Data was collected between June and October 2014.

2.3 Procedure

Following online screening, eligible participants attended the University at either 12:00 or 14:00, and refrained from consuming caffeine or food for 60 minutes prior. Arrival time was consistent for each participant over all data collection days. Following baseline measures at time 1 (T1) (mood, cognitive function, salivary cortisol), participants were transported to the environment (10-15 minute drive and all social interactions were kept to a minimum, with no researcher generated social interaction, although questions from the participant were responded to if they arose) and completed a 30-minute walk, accompanied by a researcher, along a pre-designated route, at a self-directed pace. During the walk, participants reported their Rate of Perceived Exertion (RPE) at five-minute intervals, with no other social interaction. Mood, cognitive function, restorative experience, and salivary cortisol were collected at the end of the walk (T2). Participants were transported back to the University and completed further measures of mood, cognitive function, and salivary cortisol (T3). This procedure was conducted on visit Days 1, 2 and 3. On Day 4, participants completed T1 measures only. Participants completed all data collection within a 14-day period, with Days 3 and 4 consecutive. Days taken to complete the study ranged from 4 to 12 (mean=7.59, SD=3.11). Environment visits were only conducted in temperate conditions and were re-arranged in the event of rain/inclement weather conditions. Despite our best efforts there was some precipitation on the visit days. Out of the 123 visit days some light/intermittent rain did occur on 20 of the days (10 green, 10 urban). The temperature was broadly similar across the three days for both groups, with a mean range between 15.53°C and 18.54°C. Although there were significant differences in temperature on Day 1 ($t(39)= 2.495$, $p=.017$) between the green (M=18.46, SD=1.61) and urban (M = 15.88, SD = 4.70) conditions and on Day 3 ($t(39)= 2.809$, $p=.008$) between the green (M=18.54, SD = 2.02) and urban (M = 15.53, SD = 4.69) conditions. All study procedures were approved by the (blinded) University Faculty Ethics Committee.

2.4 Measures

Baseline profiling. Participants self-reported: socio-demographics (age, gender, ethnicity, education and employment status); health (Ware, Kosinski, & Keller, 1996); childhood experiences of natural environments (frequency of visits: ‘Not at all’=0 to ‘Frequently’=10); and nature-relatedness (Nisbet, Zelenski, & Murphy, 2009).

Mood. We used the Brunel Mood Scale (Terry, Lane, & Fogarty, 2003) a validated, abbreviated version of the Profile of Moods States (POMS), with good internal consistency

(Cronbach's alpha=.66-.89). The Total Mood Disturbance (TMD) index was the dependent variable.

Cognitive performance. The Backward Digit Span (BDS) task was used to measure working memory (Wambach et al., 2011).

Restorative experience. We used an abbreviated version of the Restoration Outcome Scale (Korpela, Ylén, Tyrväinen, & Silvennoinen, 2008), which shows good internal consistency (Cronbach's alpha=.92), and test-retest reliability (r=.60).

Salivary Cortisol. Cortisol is a glucocorticoid stress hormone. Physical and psychological stressors promote cortisol secretion via the activation of the HPA-axis (Dickerson & Kemeny, 2004). Saliva samples were collected using synthetic swabs placed beneath the participant's tongue for two minutes. Samples were stored at -80°C until analysis (Salimetrics Ltd. High Sensitivity Salivary Cortisol Enzyme Immunoassay Kit).

We also collected Heart Rate Variability data. However, these data are not reported here given the variability in the data we observed from taking measurements in the field with active participants. The data are available on request from the corresponding author.

2.5 Statistical analysis

Demographic and health-related data were analysed to ensure baseline comparability between groups using between-subjects t-tests for mood ($t(37)=-.478$, $p=.635$), cognitive function ($t(38)=1.11$, $p=.272$), nature relatedness ($t(38)=0.94$, $p=.926$), childhood experiences ($t(38)=.919$, $p=.364$) and cortisol, ($t(38)=0.14$, $p=.890$). Cortisol concentration was natural-log transformed for parametric analysis. While there were no significant baseline differences, the mean difference did indicate baseline imbalance for mood and cognitive functioning (based on Ohly et al. (2016), therefore, we included the baseline measure (Day 1 T1) as a covariate in all analyses of mood and cognitive function.

Effects of environment. We calculated an average value for each variable at each time-point over three visit days (e.g., an average score for cortisol at T1 was calculated from the three individual scores of cortisol at T1 on visit days 1-3). For mood, cognitive function and cortisol we conducted 2x3 mixed ANOVAs with the between-subjects factor environment (urban/natural) and the within-subjects factor time (T1/T2/T3). Follow-up analysis for significant findings utilised paired contrasts. Restorative experience was assessed using a 2x3 mixed ANOVA with the between-subjects factor environment (urban/natural) and the within-subjects factor day (Day 1/2/3).

Changes during visit days. The dependent variable was within-day changes (calculated as T1-T2). Mood, cognitive functioning and cortisol data were analysed using factorial mixed 2x3 ANOVAs with the between-subjects factor environment (urban/natural) and the within-subjects factor day (Day 1/2/3). Follow-up analysis for significant findings utilised paired contrasts.

Assessing enduring effects. A one-way between-participants ANCOVA was conducted to compare post-exposure (D4,T1) mood, cognitive function and salivary cortisol: between-subjects factor was environment (urban/natural) and within-subjects factor was day (Day 1/2/3).

We conducted multiple statistical tests, therefore bonferroni corrections were applied. We considered significant results when $p<0.006$ (0.05/8 statistical tests). Missing data were excluded from pairwise analysis, which explains differing degrees of freedom. Means reported in Tables include all available data.

3. Results

3.1 Demographic Characteristics

There were no group differences in any measured demographic characteristics, nature relatedness, childhood experiences of nature, health-related variables, or days taken to complete the data collection.

3.2 Effects of environment

Table 1 presents average group values for mood, cognitive function, and cortisol at T1, T2, T3, and mean restorative experience (T2 only). There were significant group differences for restorative experience ($F_{(1,37)}$=16.68, p<.001, η^2=.21); participants in the natural environment reported higher restorative experience than the urban environment. There were no main effects of environment, nor time by environment interactions, on mood, cognitive function or salivary cortisol. There was an effect of time on mood ($F_{(1.46,40.94)}$=22.77 p<.001, η^2=.15), resulting from improvements in mood from T1 to T2 ($t_{(32)}$=3.58, p=.001) and from T1 to T3 ($t_{(35)}$=-3.16, p=.003). There was also a main effect of time on salivary cortisol ($F_{(1.36,48.86)}$=61.08, p<.001, η^2=.23), underpinned by reductions from: T1 to T2 ($t_{(39)}$=7.98 p<.001); T1 to T3 ($t_{(37)}$=8.64, p<.001); and T2 to T3, ($t_{(38)}$=4.47, p<.001).

3.3 Changes during visit days.

Within-day changes in mood, cognitive function and cortisol from T1-T2 are presented in **Table 2**. There were no effects of environment, nor day by environment interactions on mood, cognitive function or salivary cortisol. There was a main effect of Day on mood ($F_{(2,58)}$=8.41 p<.001, η^2=.10), resulting from an improvement in mood from Day 2 to Day 3 (p=.012) in both groups.

3.4 Assessing enduring effects.

Data for mood, cognitive function, and cortisol on Day 4 are displayed in **Table 3**. Measures of mood, cognitive function and salivary cortisol did not differ between groups on day 4.

4. Discussion

The data presented here are the first to compare psycho-physiological responses to repeated visits to the same natural or pleasant urban environment. There were no consistent differences between repeated walks in the two environments; both conferred benefits on mood, with additional improvements in restorative experience in the natural environment. A key finding is that participants had similar responses to walking in a natural (and urban) environment over several days. This is important, as people tend to use the same easily accessible natural environments (e.g., dog walking in the local park). Therefore, benefits of engaging with the same natural environment may be consistently realized over time, consistent with epidemiological evidence of associations between neighborhood green space and improved physical (Maas et al., 2009; Mitchell & Popham, 2007) and mental health (Barton & Rogerson, 2017).

Consistent with existing literature (Beil & Hanes, 2013; Bodin & Hartig, 2003; Gidlow et al., 2016), participants reported greater restorative experience after visiting the natural environment, however, attention restoration did not manifest as improved cognitive function, as previously reported (Bodin & Hartig, 2003; Gidlow et al., 2016), and determined by ART. A 30-minute walk may be insufficient to induce such effects, as others have observed improvements in cognitive function after 50 minutes in a natural environment (Berman, Jonides, & Kaplan, 2008; Hartig, Evans, Jamner, Davis, & Gärling, 2003), and changes in neurological activity after 90 minutes (Bratman, Hamilton, Hahn, Daily, & Gross, 2015). In contrast to SRT, we did not find superior effects of the natural environment on mood and salivary cortisol. Previous studies also report no difference in effects of walking in natural and urban environments on mood (Gidlow et al., 2016; Johansson, Hartig, & Staats, 2011; Kinnafick & Thøgersen-Ntoumani, 2014), suggesting that walking confers mental health benefits regardless of location. In studies that have demonstrated a positive effect of walking in natural environments on mood (Hartig et al., 2003; Lee et al., 2011; Tsunetsugu et al., 2013), effects may be driven by negative responses to control urban environments (Gidlow et al., 2016). Reductions in salivary cortisol were observed in both environments, and likely reflect the diurnal decline in cortisol release. A lack of environment effects on salivary cortisol have been reported elsewhere (Beil & Hanes, 2013; Gidlow et al., 2016; Lee et al., 2011). No effects persisted over a 24-hour period, consistent with existing work (Shanahan et al., 2016), suggesting that regular nature exposure is required to maintain health benefits, though the 'dose' of nature required remains unclear. Future research, with larger samples may also wish to consider how key demographic factors (e.g., nature relatedness, childhood experiences of nature), as well as in situ changes (e.g., cognitive restoration) may relate to changes in cortisol change both in relation to single, and repeated exposures to nature (Sumner & Goodenough, 2020).

Limitations include that the number of exposures was potentially insufficient to detect small, but cumulative changes over repeated exposures. We focused on immediate psycho-physiological responses, but not mechanisms that may moderate changes in health, such as physical activity and social contact (Shanahan et al., 2016). Psycho-physiological stress at T1 was low, resulting in little room for improvement, but perhaps reflective of day-to-day engagement with nature. Further, we did not note the hours sleep, nor waking time of the participants and fluctuations in these factors across participants and conditions may have affected the levels of cortisol.

5. Conclusion

Frequent engagement with pleasant and non-stressful natural (or urban) environments is associated with psycho-physiological benefits, with additional restorative experience in natural environments. Repeated visits to the same environment confers consistent benefits, however the lack of enduring effects (24-hours post-exposure) supports the need for regular exposure to maintain these benefits.

6. References

Barton, J., & Pretty, J. (2010). What is the Best Dose of Nature and Green Exercise for Improving Mental Health? A Multi-Study Analysis. *Environmental Science & Technology, 44*(10), 3947-3955. doi:10.1021/es903183r

Barton, J., & Rogerson, M. (2017). The importance of greenspace for mental health. *BJPsych international, 14*(4), 79-81. doi:10.1192/s2056474000002051

Beil, K., & Hanes, D. (2013). The influence of urban natural and built environments on physiological and psychological measures of stress--a pilot study. *Int J Environ Res Public Health, 10*(4), 1250-1267. doi:10.3390/ijerph10041250

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The Cognitive Benefits of Interacting With Nature. *Psychological Science, 19*(12), 1207-1212. doi:10.1111/j.1467-9280.2008.02225.x

Bodin, M., & Hartig, T. (2003). Does the outdoor environment matter for psychological restoration gained through running? *Psychology of Sport and Exercise, 4*(2), 141-153. doi:https://doi.org/10.1016/S1469-0292(01)00038-3

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health, 10*(1), 456. doi:10.1186/1471-2458-10-456

Bratman, G. N., Hamilton, J. P., Hahn, K. S., Daily, G. C., & Gross, J. J. (2015). Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proc Natl Acad Sci U S A, 112*(28), 8567-8572. doi:10.1073/pnas.1510459112

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychol Bull, 130*(3), 355-391. doi:10.1037/0033-2909.130.3.355

Gidlow, C. J., Jones, M. V., Hurst, G., Masterson, D., Clark-Carter, D., Tarvainen, M. P., . . . Nieuwenhuijsen, M. (2016). Where to put your best foot forward: Psycho-physiological responses to walking in natural and urban environments. *Journal of Environmental Psychology, 45*, 22-29. doi:https://doi.org/10.1016/j.jenvp.2015.11.003

Granger, D. A., Hibel, L. C., Fortunato, C. K., & Kapelewski, C. H. (2009). Medication effects on salivary cortisol: Tactics and strategy to minimize impact in behavioral and developmental science. *Psychoneuroendocrinology, 34*(10), 1437-1448. doi:10.1016/j.psyneuen.2009.06.017

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology, 23*(2), 109-123. doi:https://doi.org/10.1016/S0272-4944(02)00109-3

Johansson, M., Hartig, T., & Staats, H. (2011). Psychological Benefits of Walking: Moderation by Company and Outdoor Environment. *Applied Psychology: Health and Well-Being, 3*, 261-280. doi:10.1111/j.1758-0854.2011.01051.x

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. New York, NY, US: Cambridge University Press.

Kinnafick, F.-E., & Thøgersen-Ntoumani, C. (2014). The effect of the physical environment and levels of activity on affective states. *Journal of Environmental Psychology, 38*, 241-251. doi:https://doi.org/10.1016/j.jenvp.2014.02.007

Korpela, K. M., Ylén, M., Tyrväinen, L., & Silvennoinen, H. (2008). Determinants of restorative experiences in everyday favorite places. *Health Place, 14*(4), 636-652. doi:10.1016/j.healthplace.2007.10.008

Lee, J., Park, B. J., Tsunetsugu, Y., Ohira, T., Kagawa, T., & Miyazaki, Y. (2011). Effect of forest bathing on physiological and psychological responses in young Japanese male

subjects. *Public Health, 125*(2), 93-100. doi:https://doi.org/10.1016/j.puhe.2010.09.005
Maas, J., Verheij, R. A., de Vries, S., Spreeuwenberg, P., Schellevis, F. G., & Groenewegen, P. P. (2009). Morbidity is related to a green living environment. *Journal of Epidemiology and Community Health, 63*(12), 967-973. doi:10.1136/jech.2008.079038
Mitchell, R., & Popham, F. (2007). Greenspace, urbanity and health: relationships in England. *Journal of Epidemiology and Community Health, 61*(8), 681-683. doi:10.1136/jech.2006.053553
Mygind, L., Kjeldsted, E., Hartmeyer, R., Mygind, E., Stevenson, M. P., Quintana, D. S., & Bentsen, P. (2019). Effects of Public Green Space on Acute Psychophysiological Stress Response: A Systematic Review and Meta-Analysis of the Experimental and Quasi-Experimental Evidence. *Environment and Behavior, 0*(0), 0013916519873376. doi:10.1177/0013916519873376
Nations, U. (2014). *Trends in urbanization*.
Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2009). The Nature Relatedness Scale:Linking Individuals' Connection With Nature to Environmental Concern and Behavior. *Environment and Behavior, 41*(5), 715-740. doi:10.1177/0013916508318748
Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B, 19*(7), 305-343. doi:10.1080/10937404.2016.1196155
Shanahan, D., Bush, R., Gaston, K., Lin, B., Dean, J., Barber, E., & Fuller, R. (2016). Health Benefits from Nature Experiences Depend on Dose. *Scientific Reports, 6*(1), 28551. doi:10.1038/srep28551
Shanahan, D., Fuller, R., Bush, R., Lin, B., & Gaston, J. (2015). The Health Benefits of Urban Nature: How Much Do We Need? *BioScience, 65*(5), 476-485. doi:10.1093/biosci/biv032
Sumner, R. C., & Goodenough, A. E. (2020). A walk on the wild side: How interactions with non-companion animals might help reduce human stress. *People and Nature, 2*(2), 395-405. doi:https://doi.org/10.1002/pan3.10074
Terry, P. C., Lane, A. M., & Fogarty, G. J. (2003). Construct validity of the Profile of Mood States — Adolescents for use with adults. *Psychology of Sport and Exercise, 4*(2), 125-139. doi:https://doi.org/10.1016/S1469-0292(01)00035-8
Tsunetsugu, Y., Lee, J., Park, B.-J., Tyrväinen, L., Kagawa, T., & Miyazaki, Y. (2013). Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurements. *Landscape and Urban Planning, 113*, 90-93. doi:https://doi.org/10.1016/j.landurbplan.2013.01.014
Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environmental Research, 166*, 628-637. doi:https://doi.org/10.1016/j.envres.2018.06.030
Ulrich, R. S. (1983). Aesthetic and Affective Response to Natural Environment. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the Natural Environment* (pp. 85-125). Boston, MA: Springer US.
Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*(3), 201-230. doi:https://doi.org/10.1016/S0272-4944(05)80184-7

Wambach, D., Lamar, M., Swenson, R., Penney, D. L., Kaplan, E., & Libon, D. J. (2011). Digit Span. In J. S. Kreutzer, J. DeLuca, & B. Caplan (Eds.), *Encyclopedia of Clinical Neuropsychology* (pp. 844-849). New York, NY: Springer New York.

Ware, J., Kosinski, M. M., & Keller, S. (1996). A 12-Item Short-Form Health Survey: Construction of Scales and Preliminary Tests of Reliability and Validity. *Medical care, 34*, 220-233. doi:10.2307/3766749

Tables

Table 1. Overall Environmental Effects: Average scores of psychological and salivary cortisol variables at T1, T2 and T3

	Green Mean (SD)			Urban Mean (SD)		
	T1	T2	T3	T1	T2	T3
Mood (TMD)	-3.80 (7.64)	-4.85 (6.24)	-3.77 (6.55)	-2.24 (5.88)	-4.96 (4.06)	-4.33 (3.94)
Cognitive Function	7.03 (2.52)	7.07 (2.73)	7.75 (2.86)	6.31 (2.57)	6.46 (2.46)	6.63 (2.31)
Restoration		5.27 (0.62)*			4.17 (1.06)*	
Cortisol (nmol/l)	1.63 (0.56)	1.20 (0.43)	1.03 (0.41)	1.59 (0.41)	1.22 (0.39)	1.13 (0.37)

* p <.006

Table 2. Changes in mood, cognitive function and cortisol from T1 to T2 by environment.

	Green *M (SD)*			Urban *M (SD)*		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Mood (TMD)	2.63 (7.73)	1.26 (4.85)	3.74 (4.07)	3.64 (7.83)	1.14 (3.69)	4.14 (6.92)
Cognitive Function	-0.13 (1.66)	-0.30 (1.43)	0.22 (2.02)	-1.13 (1.54)	0.38 (1.50)	0.56 (1.41)
Cortisol (nmol/l)	0.11 (1.58)	0.08 (1.15)	0.07 (0.08)	0.07 (0.09)	0.06 (0.06)	0.05 (0.07)

Table 3. Mood, cognitive functioning and salivary cortisol variables on Day 4 T1 by environment.

	Green *M (SD)*	Urban *M (SD)*
Mood (TMD)	-4.04 (6.09)	-3.86 (4.85)
Cognitive Function	7.88 (3.18)	6.89 (2.99)
Cortisol (nmol/l)	1.41 (0.44)	1.50 (0.66)