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Cognitive benefits of walking in natural versus built environments

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ABSTRACT
Leisure time physical activity can be a robust preventer of physical and mental illness. The health benefits of exercise have been well-documented, including decreased risk for obesity, diabetes, and heart disease, and increased mood, life-satisfaction and cognitive performance (An, Xiang, Yang, & Yan, 2016; Blair & Morris, 2009). Time spent outdoors is also emerging as a predictor of positive mental health, though the outcomes are often conflated with heightened levels of physical activity. This study sought to confirm the cognitive benefits of exercise in outdoor environments using established cognitive tests while measuring brainwave activity throughout the process using portable electroencephalograph (EEG) headsets. Participants completed cognitive performance tests before and after walking indoors, then again on a different session while walking outdoors. Repeated-measures analyses of variance revealed significant cognitive improvement after both walking sessions, with elevated mental restoration observed for the outdoor walking session, as measured by a Stroop Test. EEG measures revealed a significantly higher level of meditative state during the outdoor walking session, as compared to indoors. In addition, the gains in relaxed and meditative mental states were retained longer after walking outdoors. Results are discussed within the context of growing support for leisure time exposure to natural environments and outdoor prescriptions. Implications for planning, health policy, and public education are proffered in light of these findings.

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KEYWORDS
EEG; cognitive psychology; outdoor exercise; nature prescriptions

Introduction
It has long been known that physical activity can lead to increased cognitive function (Middleton, Barnes, Lui, & Yaffe, 2010). However, the environment wherein that physical activity is performed may be just as important as the act itself (Thompson Coon et al., 2011). Natural environments, as opposed to built environments, have a host of positive effects on physical and mental health, including: increased physical activity and caloric expenditure, fewer depressive symptoms, reductions in myopathy, reduced stress levels and increased feelings of accomplishment (Brussoni et al., 2015; French, Ashby, Morgan, & Rose, 2013; Grahn & Stigsdotter, 2003). By contrast, an increasingly urbanized world, with associated distractions and mental distress, may contribute to physical and mental disorders (Prince et al., 2007). Increasing screen time and decreasing outdoor time during leisure exacerbate this...
issue (Bassett, John, Conger, Fitzhugh, & Coe, 2015). A better understanding of how various environments directly impact mental well-being could provide support for policies and infrastructure that increase opportunities for routine outdoor experiences.

While previous research has documented the effects of natural environments on mental aptitude, technological advancements now provide the opportunity to understand the process whereby those outcomes are produced. Recently, portable EEG scanners have been utilized to demonstrate that green spaces reduce stress response and levels of frustration (Aspinall, Mavros, Coyne, & Roe, 2015). Given that stress causes decreased cognitive performance, it may follow that walking outdoors would be better for cognitive function than walking indoors. Numerous studies support this assertion, (Berman, Jonides, & Kaplan, 2008; Bratman, Daily, Levy, & Gross, 2015). However, there is a dearth of research combining mobile EEG technology with common cognitive tests to compare the process and effects of walking indoors versus walking outdoors on mental states. This study builds upon previous research to illustrate the influence outdoor environments have on the brain which could aid cognitive performance and mental well-being.

**Literature review**

**Leisure time physical activity**

An increase in sedentary lifestyles has led to myriad health concerns. Workplace physical activity has seen precipitous declines over the last 50 years, with 80% of modern occupations labelled as sedentary (Church et al., 2011). Given an inherent lack of choice in workplace activities, health professionals commonly focus on leisure pursuits as vehicles to healthy lifestyles. Routine leisure behaviours can influence physical and mental health as well as overall life satisfaction (Bailey, Kang, & Schmidt, 2016; Iso-Ahola, 1980). Unfortunately, residents of developed countries consistently pursue isolated, sedentary activities (e.g. television, social media) above healthier, prosocial and active opportunities (e.g. sports, visits to parks) for leisure and recreation (Bureau of Labor Statistics, 2017). Leisure time physical inactivity has been tied to a host of health concerns, including: obesity, diabetes, high blood pressure, and cardiovascular disease (An, Xiang, Yang, & Yan, 2016). Physical activity has many benefits for human health both mentally and physically. Myriad studies conclude that regular doses of physical activity influence overall health. Individuals who exercised 150 min/week at moderate intensity reduce the risk of numerous chronic diseases, preserve health and function into old age, and extend longevity (Blair & Morris, 2009).

Not only does physical activity benefit physical health but it can enhance mental health, as well. Kim et al. (2012, p. 458) states that, “… physical activity can reduce depressive symptoms in individuals diagnosed with major depression … Regular physical activity appears to be protective against anxiety disorders.” Vankim and Nelson (2013) found that college students who reported regular, vigorous physical activity were less likely to have poor mental health and perceived stress than students who did not perform vigorous activity. Running and walking have been shown to induce a relaxed state of mind, evidenced by increased alpha brain waves post workout (Schneider et al., 2009; Woo, Kim, Kim, Petruzzello, & Hatfield, 2009). Given the established benefits of physical activity for physical and mental health, this study incorporated the recommended daily dose of
light/moderate exercise (i.e. 30 min a day) into a repeated-measures design. In this way, physical activity was held constant across two differing environmental conditions.

**Natural and built environments**

While active leisure is beneficial in many ways, outcomes may also be enhanced by the environment. Numerous studies provide evidence to support the effectiveness of activities done outdoors above and beyond those performed in a built environment. Outdoor exercise has been shown to: induce greater feelings of revitalization and positive engagement, increase energy, and decrease depression, anxiety, anger, and frustration (Mitchell, 2013; Pasanen, Tyrväinen, & Korpela, 2014; Thompson Coon et al., 2011). Even when controlling for routine physical activity, time spent outdoors can enhance psychological well-being and happiness (Bailey et al., 2016). The influence of natural environments has been expounded in the Attention Restoration Theory (ART). ART maintains that urban landscapes and built environments contain distractions that exhaust the brain’s ability to focus on a task (Kaplan, 1995). Urban and built environments present a plethora of competing stimuli that render it difficult for the brain to filter out distractions. This exhaustion of top-down, voluntary attentional control renders the completion of arduous tasks requiring concentration more difficult after being in an urban landscape or indoors around other people (Berto, 2005; Kaplan, 1995). By contrast, natural environments contain fewer extraneous stimuli, allowing for a deeper state of relaxation. ART asserts that natural environments give one a sense of “being away” from the world, thereby reducing voluntary attention necessitated by urban areas, and restoring degraded attention (Berto, 2005). This influence helps one to perform better on tasks of attention after being in a natural environment.

Attention Restoration Theory has been verified through multiple studies. Taylor and Kuo (2009) found that children with ADHD performed better on a task of concentration after walking in a park compared to walking in a downtown environment. A similar study confirmed a positive influence of park space on tasks of attention for adults without ADHD (Berman et al., 2008). The influence of nature can even provide benefits indirectly. Tennessen and Cimprich (1995), for instance, found that college students having a view of nature from their dormitories performed better on tests that required excessive concentration. These findings informed our current study, the purpose of which is to illustrate the influence of outdoor versus indoor walking on cognitive performance tests. A secondary purpose was to explore the changes in mental state under testing and walking conditions in natural and built environments. This was accomplished with the use of mobile electroencephalography (EEG).

**EEG**

EEG is a technique widely used to analyze brain wave patterns in living organisms. EEG devices measure the currents created by electrochemical gradients that flow through nerve cells when excited by a stimulus (Teplan, 2002). This is accomplished by the conductive surfaces of the EEG headgear making direct contact with surface of the subject’s scalp. The brain waves recorded by the EEG can be characterized by their frequencies as a particular emotion or state of consciousness and be used to interpret the subject’s level of
stress or cognitive intensity (Teplan, 2002). EEG primarily measures the activity of the cerebral cortex due to its size and position within the brain in relation to the scalp (Teplan, 2002). This is beneficial for our study since the cerebral cortex is responsible for cognition, logical thinking, and emotional expression. Previous research has shown that natural scenery reduces stress and restores mental attention more than urban scenery (Berto, 2005; Roe, Aspinall, Mavros, & Coyne, 2013). A recent study that employed the use of mobile EMOTIV EEGs found that subjects walking in green spaces outdoors show lower levels of stress and higher levels of meditation and happiness compared to subjects walking in urban areas outdoors (Aspinall et al., 2015). For our purposes, EMOTIV EEG headsets were worn by participants as they exercised outdoors or indoors and while taking cognitive tests. The associated brainwaves were interpreted to infer the subjects’ level of focus, approach motivation, stress, relaxation, and meditative state.

**Methods**

The participants of this study included ten students (50% female, **Mean** age = 20) from a public university in the southeastern United States. Participants were recruited from health science classes that encourage research participation. No incentives were offered and there were no repercussions for declining or withdrawing early. These participants were screened to avoid complications from physical or neurocognitive disabilities.

The students selected dates of participation from a proposed schedule spanning three weeks in the mid-spring, each attending on two separate days. The participants were randomly assigned to the indoor or outdoor portion of the experiment on their first day, and the complementary portion of the experiment on their second day. For all portions of the experiment the participants were fitted with a mobile EMOTIV EEG headset to monitor their brain wave activity before partaking in any testing or walking.

To establish a baseline brainwave measure of each participant, they were first asked to relax for ten seconds with their eyes open and then repeat that with their eyes closed. The participants were then asked to complete two cognitive exams in an indoor setting at the Aquatic Recreation Center (ARC). This was the testing location for both the outdoor and indoor portions of the experiment. The first exam was the Stroop Effect Test, where participants were tasked with verbally identifying the printed colour of a word that is normally associated with another colour. The second exam, the Backward Digit Span Task (BDST), required the participants to verbally repeat a set of digits in the reverse order that they were given.

After cognitive testing, the participants assigned to the outdoor portion of the experiment walked to a nature trail on campus, and walked the entirety of this trail. The participants then walked back to the ARC with the entire route, from the ARC to the Greenway trail and back, taking thirty minutes. After this thirty-minute walk, the Stroop Effect test and the BDST were administered in the same fashion to the participants. This concluded the outdoor portion of the experiment. The indoor portion of the experiment (completed on a different day) was identical, except the participants were instead asked to walk for thirty minutes along the indoor track inside the ARC. During each walk, a researcher guided the participants by walking in front of them while simultaneously video-recording the path taken. This was done to account for any spurious activities that may have influenced brainwave data (student interactions, etc.).
Measures

Eeg
The EMOTIV headset is a brand of mobile EEG that has been utilized in various other studies (Aspinall et al., 2013; Bailey, Johann, & Kang, 2017). Emotiv headsets have been verified as comparable to high-end research EEG systems (Badcock et al., 2015). The Insight version uses five sensors to collect brainwaves from five frequencies at a rate of 128 Hz. In general, lower frequencies (Gamma = 0.5–3 Hz, Delta = 4–7 Hz) are associated with less intense brain functions such as sleep, meditation, and daydreaming. Alpha waves (8–15 Hz) indicate a relaxed brain that is ready for action. Higher frequency waves (Beta = 16–31 Hz, Gamma = 32–100 Hz) are associated with heavier mental loads (i.e. concentration, stress, etc.).

For this study, low and high pass filters removed all Delta frequencies (< 3 Hz) and Gamma frequencies above 43 Hz. This filter was employed by the hardware before converting the raw data into distinct wavelengths via Fast Fourier Transformation (FFT). Filters reduce unwanted artifacts in the data, produced by muscle movements and ambient electrical signals in the atmosphere. All data were first screened for removal of obvious artifacts, then transformed into emotional states using established formulas from previous research. Focus (i.e. concentration) was measured as the presence of high frequency waves across the frontal lobe (Coelli et al., 2015). Approach motivation (AM), or an individual’s interest and enjoyment, was measured via frontal asymmetry (Coelli et al., 2015). Higher relative activity on the left frontal cortex is associated with a more enjoyable or interesting experience, while right frontal activity indicates a desire to withdraw from the situation. Anxiety was measured as high frequency waves in the posterior cortex (Oathes et al., 2008). Relaxation was measured as relative global alpha power across all sensors (Harmon-Jones, Gable, & Peterson, 2010). Finally, meditative state was measured as the presence of more powerful lower frequency waves in the frontal cortex.

Figure 1. Smoothed data points for five mental states for a single participant session. 1)Baseline, 2)Stroop, 3)BDST, 4)Walking, 5)Stroop, 6)BDST.
(Theta) and stronger alpha waves in the posterior (Lagopoulos et al., 2009). This measure of meditative state is associated with nondirective rather than concentrative styles of meditation. Whereas concentrative meditation (e.g. Transcendental) would filter out extraneous thoughts through intense focus on a single element (e.g. sound or mantra), non-directive meditation (e.g. Mindfulness) allows thoughts to flow freely through the mind, without focusing on anything in particular. It should be noted that not all neuroscience literature agrees on EEG indicators, with various measures and labels being reported in previous research.

Given constant flux in brainwave activity, analytical approaches to this type of research vary. Figure 1 presents the overall test data for a single participant, demonstrating the amount of variation across and within each condition during the entire session.

A common approach is to EEG analysis is to select consecutive blocks of time (i.e. epochs) and measure variation between time points for each mental state (Wilson et al., 2015). The appropriate length of each epoch depends on the research questions under investigation. For this study, it was deemed appropriate to create a single epoch for each condition during the research session. Thus, a participant received a score for each mental state for the baseline (10 s of relaxed inactivity), stroop test, backward digit span task, walking, post-stroop test, and post-backward digit span task conditions. This allowed for an overall comparison of mental states over the duration of each condition for the indoor and outdoor walking sessions. While ignoring a large amount of minor variation, this provided a clearer picture of the overall influence of natural and built environments. Since brain activity varies largely across individuals, and can vary within individuals due to contextual factors (i.e. lack of sleep, time of day, etc.), all test and walking conditions were baseline-adjusted by subtracting the baseline average from each following condition (Hu et al., 2014). Thus, a negative Mean score for relaxation during the Stroop test, for example, would indicate that, on average, participants were less relaxed during the test than at baseline. The Mean for each condition was then analyzed via repeated-measures Analysis of Variance (RM ANOVA) with the natural versus built environment as a between-subjects variable.

**The Stroop Test**

The Stroop Test is a cognitive test designed to measure level of concentration. The test takes advantage of the interference caused by word meaning and the actual colour the word is printed in, which slows down the time of response. This phenomenon is commonly known as the Stroop Effect (Hanslmayr et al., 2008). The test begins with the pure Stroop Test where the participants read aloud the name of thirty colours that are printed in their respective colour (e.g. the word “green” appears in green coloured text). The time it takes for the participants to read the colours out loud is recorded. The participants then complete the interference Stroop test by reading aloud printed words of thirty colours, which are printed in a different colour than the word. The time it takes to complete this task is also recorded (in seconds). The Stroop score is calculated using the time of the pure Stroop test subtracted from the time it takes to read the interference test (MacLeod, 1991). Using this method a Stroop score was produced for every participant at four time points: (1) Pretest indoor, (2) Post test indoor, (3) Pretest outdoor, (4) Post test outdoor. The stroop test was analyzed with a RM ANOVA with time as the repeated measure and environment as a within subjects variable.
**Backward digit span test**

The BDST represented a second validated measure of concentration (Hale, Hoeppner, & Fiorello, 2002). In each trial of this task, the researcher reads a sequence of numbers aloud (one digit per second), and the participant is asked to repeat the numbers in reverse order (Bratman et al., 2015). For the first trial, participants are given two numbers to remember. If the participant correctly answers the sequence correctly (recalling all digits in the correct order), the researcher increases the length of the digit span by one number, and the participant gets one trial at the new length. This continues until the participant fails to recall both trials at a particular length, or he/she has completed the maximum length of 8 digits (Bratman et al., 2015). For each set correctly recalled, a participant receives one point (regardless of length), this is known as the “all-or-nothing unit scoring” used by Berman et al. (2008). The total number of points received by the participant will be the participant’s score on this test. Our study utilized a version of backward digit span that ranged from two to eight digits in length (Bratman et al., 2015). The BDST was analyzed with a RM ANOVA with time as the repeated measure and environment as a within subjects variable.

**Results**

**Cognitive tests**

All variables were normally distributed, excepting one score for the pure stroop test. Each individual completed the stroop test four times over the course of the study. One individual’s stroop pure test was identified as an outlier when compared with his other three pure stroop measures. This single response was replaced with the Mean of that individual’s other three stroop pure responses. Table 1 includes Mean scores and standard deviations for all participants for each test. The score for the outdoors and indoors Stroop tests are measured in seconds, with a negative score indicating that the participant and the scores for the BDST are measured as the total number of sets completed.

Participants did better on the post-Stroop test after walking indoors and after walking outdoors, indicated by a main effect for exercise in both environments ($F_{1,18} = 15.625, p = .008, \eta_p^2 = 0.331$). Additionally, the participants completed the Stroop Test 1.50 s faster after walking outside versus 0.25 s faster after walking inside. RM ANOVA revealed a significant time × environment interaction ($F_{1,18} = 8.464, p = .042, \eta_p^2 = 0.211$), confirming the additional influence of the natural environment beyond that of light exercise. The BDST demonstrated much less of an influence, with the indoor session showing no improvement and the outdoor session, only one-third of a set gain from the walking condition. There was no significant main effect for the BDST for time ($F_{1,18} = 1.767, p = .200$) nor for the time x environment interaction ($F_{1,18} = 0.000, p = 1.000$).

**Table 1.** Descriptive statistics for stroop and BDST scores.

<table>
<thead>
<tr>
<th></th>
<th>Indoors</th>
<th></th>
<th>Outdoors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Stroop Pretest</td>
<td>6.44</td>
<td>3.518</td>
<td>8.24</td>
<td>3.403</td>
</tr>
<tr>
<td>Stroop Post-test</td>
<td>6.11</td>
<td>1.661</td>
<td>6.07</td>
<td>2.536</td>
</tr>
<tr>
<td>BDST Pretest</td>
<td>4.00</td>
<td>0.471</td>
<td>3.60</td>
<td>0.516</td>
</tr>
<tr>
<td>BDST Post-test</td>
<td>4.30</td>
<td>1.059</td>
<td>3.90</td>
<td>1.370</td>
</tr>
</tbody>
</table>
Mental states

Differences in EEG-based cognitive states were assessed using a RM MANOVA, with the indoor/outdoor condition as a fixed variable. This provided insight into the change of five mental states over the duration of each session, as well as a comparison of time points across sessions. Since the only significance in objective measures was found for the Stroop test, repeated-measures analyses were conducted on the pre-Stroop test, while walking, and the post-Stroop test. All measures were baseline-adjusted, so negative means indicate a lower score during that time point than at baseline. Results for these analyses can be seen in Table 2.

Significant differences were evident in all cognitive states across three time points, with the exception of Approach Motivation (AM). This indicates that focus and stress were elevated during the Stroop tests, while meditative and relaxed states were elevated during the walk for both conditions. The outdoor walking condition also induced a higher meditative state than the indoor walking condition. Post hoc analyses helped to provide a deeper understanding of the nature of influence for each condition. A polynomial contrast applied to all cognitive states over three time points revealed a significant quadratic slope ("U" shape or inverse "U" shape) for all mental states ($p < .001$) except for AM. However, when accounting for the time x environment interaction effect, the meditative ($p = .033$) and relaxed ($p = .58$) mindsets demonstrated a linear trend, thus remaining elevated and losing significance for the quadratic slope altogether. This implies that something about the outdoor condition enabled the relaxed and meditative cognitive states to endure even through the stress-inducing post-Stroop test.

Discussion

The purpose of this study was to determine differences in cognitive performance tests after exercise in natural and built environments and assess differences in mental state that may contribute to that influence. The results indicate that participants did significantly better on the Stroop Test after walking and that the outdoor environment had an additional

<table>
<thead>
<tr>
<th>Mental State</th>
<th>Indoor Session</th>
<th>Outdoor Session</th>
<th>ANOVA (3 time points: Pre, walking, post)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Std. Deviation</td>
<td>Mean Std. Deviation</td>
<td>F  Sig  partial eta squared</td>
</tr>
<tr>
<td>Med Pre Stroop</td>
<td>0.12  0.84</td>
<td>−0.13  0.41</td>
<td>91.506 .000 .836</td>
</tr>
<tr>
<td>Med Walking</td>
<td>1.54  1.02</td>
<td>2.16  0.68</td>
<td></td>
</tr>
<tr>
<td>Med Post Stroop</td>
<td>−0.06  1.00</td>
<td>0.17  0.61</td>
<td></td>
</tr>
<tr>
<td>Relax Pre Stroop</td>
<td>−0.02  0.83</td>
<td>−0.04  0.55</td>
<td>154.109 .000 .895</td>
</tr>
<tr>
<td>Relax Walking</td>
<td>2.06  1.10</td>
<td>2.44  0.61</td>
<td></td>
</tr>
<tr>
<td>Relax Post Stroop</td>
<td>−0.17  1.01</td>
<td>0.21  0.48</td>
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</tr>
<tr>
<td>Focus Pre Stroop</td>
<td>0.03  0.22</td>
<td>0.01  0.32</td>
<td>17.274 .000 .490</td>
</tr>
<tr>
<td>Focus Walking</td>
<td>−0.20  0.30</td>
<td>−0.31  0.34</td>
<td></td>
</tr>
<tr>
<td>Focus Post Stroop</td>
<td>0.00  0.30</td>
<td>0.02  0.29</td>
<td></td>
</tr>
<tr>
<td>AM Pre Stroop</td>
<td>−0.17  1.05</td>
<td>0.20  0.73</td>
<td>187 .774 .010</td>
</tr>
<tr>
<td>AM Walking</td>
<td>0.15  0.50</td>
<td>0.08  0.54</td>
<td></td>
</tr>
<tr>
<td>AM Post Stroop</td>
<td>0.02  0.70</td>
<td>0.23  0.56</td>
<td></td>
</tr>
<tr>
<td>Anxiety Pre Stroop</td>
<td>−0.06  0.78</td>
<td>−0.11  0.80</td>
<td>27.530 .000 .605</td>
</tr>
<tr>
<td>Anxiety Walking</td>
<td>−1.19  0.60</td>
<td>−0.88  0.99</td>
<td></td>
</tr>
<tr>
<td>Anxiety Post Stroop</td>
<td>−0.08  0.38</td>
<td>−0.12  0.53</td>
<td></td>
</tr>
</tbody>
</table>
positive influence. The outdoor walking session also induced a more meditative state than the indoor session. While instructive, the results from this study should be interpreted within the context of its limitations. This study could have benefitted from a larger sample size, though EEG studies are commonly small and criteria for power and effect sizes were met. While the sample size is appropriate for the analyses used, it precludes extrapolation without confirmatory research. The testing location posed another limitation. To reduce spurious influences on performance tests, all tests were conducted in the same location and the walking condition proceeded directly from the testing location (i.e. participants did not relax during transport to the green space). Future research could incorporate a longer time frame and/or a testing location that is more centralized to varying levels of green space for comparison of multiple environments. This study did, however, produce notable results given its scope.

The two cognitive tests produced disparate results in this study. The BDST did not yield significant results for the main effect of walking, nor for the indoor or outdoor conditions. This finding is consistent with the results of Bratman et al. (2015) but at odds with that of Taylor and Kuo (2009). The latter study utilized only the BDST with no other cognitive measures, while Bratman et al. (2015) administered the BDST as the third in a battery of tests before and after a nature walk. It is possible that the effect of the walk was depleted by the other tests, thus reducing the measurable influence. To test that assertion with the data in our current study, a post hoc repeated-measures ANOVA was conducted on mental states between Stroop and BDST conditions both before and after walking. No significant differences were found for any of the five mental states measured. Future research will need to be done to determine the longevity of the impacts from walking indoors and outdoors, as well as the specific influence of natural environments on areas of the brain under load during each cognitive test.

The outdoor walking condition did significantly influence improvement in Stroop test scores. According the “selective attention” theory of the Stroop effect (Lavie, 2005), these test scores are related to the allocation of direct attention to the task at hand. Individuals who are less distracted and have more mental energy, overcome the interference of the word/colour discrepancy faster and with better accuracy. This supports the premise of Attention Restoration Theory (Kaplan, 1995), indicating that directed attention is better restored through natural environments rather than built or urban environments. Effect sizes for exercise and for the exercise x environment interaction were equal to or greater than those produced by standard ADHD medications (Swanson et al., 2004; Taylor & Kuo, 2009). Given previous similar findings, Taylor and Kuo (2009) called for the immediate implementation of nature prescriptions as part of the mental health toolkit. Standard protocols already exist for the prescription of exercise (Chen, Fredericson, Matheson, & Phillips, 2013) and consistent findings for the additional influence of natural environments are compelling. Nature prescription programmes are emerging across the country in a piecemeal fashion (c.f. http://www.outdoorsrx.org/). Given the lack of grossly negative side effects, nature prescriptions could be a viable alternative to pharmaceutical solutions.

EEG monitoring of the process provides insight into how the natural environment may influence the brain to enable better post-test performance. Meditative state (i.e. frontal theta) differed significantly across environments, remaining higher even through the post-Stroop test for outdoor walkers. The meditative state measured in
this study is consistent with that reported during nondirective meditation (Lagopoulos et al., 2009). While concentrative forms of meditation enhance high frequency bands (e.g. gamma) through focused attention on a sound or mantra, nondirective meditation (i.e. open monitoring) facilitates a free mental attitude, where any thought or sensation is allowed to pass through the consciousness without any attempt to control the content (Lagopoulos et al., 2009; Lutz, Slagter, Dunne, & Davidson, 2008). Other open-monitoring methods of meditation (e.g. mindfulness) have been shown to improve sustained attention, executive function, and visual-spatial performance for experienced meditators and those with only initial training (Moore & Malinowski, 2009; Teper & Inzlicht, 2013; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Theoretically, this occurs through the improvement of resource allocation processes, thus preparing the brain for better performance when under cognitive load (Berman et al., 2008; Malinowski, 2013). Natural environments may employ similar mechanics as nondirective meditation in regards to the stimulation of lower-frequency brainwaves. Future research will need to directly compare meditative practice with time spent in natural environments in order to confirm this assertion.

Paradoxically, the presence of theta waves has been associated with ADHD in EEG research, with a high theta/beta ratio being a leading indicator for diagnosis (Arns, Conners, & Kraemer, 2013). That an increase of theta waves in the frontal lobe would enhance performance on a task of concentration is unexpected. However, the linear trend of relaxation (i.e. alpha) and meditative states through the post-Stroop test could indicate that participants are transitioning from lower states of activity to a relaxed state that is ready for action. The ability to self-regulate mental states based on the task at hand would likely enhance performance and mental health over many contexts (Pigott, 2017). Future research can help shed light on the relationship between time spent outdoors, neuroplasticity and long-term mental health. Research has shown that time spent outdoors has a positive influence on psychological, social, and subjective well-being (Bailey et al., 2016; Mutz & Müller, 2016). It is feasible that frequent visits to natural environments can produce long-term state and/or trait-like changes to one’s disposition.

The results from this study have implications for parents, educators, urban planners and practitioners interested in facilitating health outcomes. The benefits of activity in outdoor environments can be reaped through programmed outdoor excursions or incidental daily encounters. Visitors of local parks typically report fewer visits to the doctor for chronic illness (Godbey, 2009) and outdoor-related programmes may induce a host of mental and physical benefits (Hattie, Marsh, Neill, & Richards, 1997). Positive outcomes of active outdoor leisure pursuits have been reported for decades, but we may now gain knowledge of the neural mechanisms by which these outcomes occur. There is no universal remedy for improving mental attention, but active leisure and time spent in the natural environment are viable options. Mounting evidence compels us to be intentional about logging off, unplugging, and interacting with the natural environment to protect our mental and physical health and enhance overall performance and well-being. Planners and programmers should clearly communicate the need for outdoor leisure and facilitate access to safe, open green spaces for all.
Disclosure statement

No potential conflict of interest was reported by the authors.

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