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Research Paper

The benefits of nature experience: Improved affect and cognition

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HIGHLIGHTS

- Nature experience produced clear benefits for affect (e.g., decrease in anxiety and rumination).
- Nature experience produced some benefits for cognition (complex working memory span task).
- Supports the idea that exposure to natural greenspace can improve affect and cognition.

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ABSTRACT

This study investigated the impact of nature experience on affect and cognition. We randomly assigned sixty participants to a 50-min walk in either a natural or an urban environment in and around Stanford, California. Before and after their walk, participants completed a series of psychological assessments of affective and cognitive functioning. Compared to the urban walk, the nature walk resulted in affective benefits (decreased anxiety, rumination, and negative affect, and preservation of positive affect) as well as cognitive benefits (increased working memory performance). This study extends previous research by demonstrating additional benefits of nature experience on affect and cognition through assessments of anxiety, rumination, and a complex measure of working memory (operation span task). These findings further our understanding of the influence of relatively brief nature experiences on affect and cognition, and help to lay the foundation for future research on the mechanisms underlying these effects.

1. Introduction

Urbanization is progressing at a rapid rate around the globe. Over half of humanity now lives in urban areas. By 2050 this proportion is expected to exceed 70% (Heilig, 2012). This unprecedented shift from rural to urban living is associated with a significant decrease in exposure to natural environments (Skár & Krogh, 2009; Turner, Nakamura, & Dinetti, 2004). Coincident with urbanization, there is also evidence of an increase in the worldwide prevalence of mental disorders (Patel, Flisher, Hetrick, & McGorry, 2007; Whiteford et al., 2013). Growing evidence suggests that these two trends may be linked, with decreased exposure to nature causing changes in psychological functioning (Bronzaft, 2002; Hartig, Evans, Jamner, Davis, & Garling, 2003; Kaplan, 1995; Kuo & Sullivan, 2001; Lederbogen et al., 2011; Lorenc et al., 2012; Stansfeld, Haines, & Brown, 2000; Ulrich et al., 1991; for a review see Bratman, Hamilton, & Daily, 2012).

As the world urbanizes and people spend less time in regular contact with natural environments, urban planners and other public policy decision-makers are turning to research in environmental psychology to help inform them of the relationship between exposure to nature and mental health (Beil & Hanes, 2013; Bell, Greene, Fisher, & Baum, 2001; Gifford, Steg, & Reser, 2011; Hartig, Mitchell, de Vries, & Frumkin, 2014; Health Council of the Netherlands, 2004; Keniger, Gaston, Irvine, & Fuller, 2013; Parsons & Daniel, 2002; Spencer & Woolley, 2000; Taylor & Kuo, 2006; Van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012). This study aims to contribute to the literature concerned with the examination of this relationship.

1.1. Prior studies

A wide variety of research findings suggest that exposure to nature may have an impact on psychological functioning. For

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example, Leather, Pyrgas, Beale and Lawrence (1998) and Kaplan (2001) found that window views of nature from the office and home were associated with higher degrees of well-being and life satisfaction. Taylor, Kuo and Sullivan (2002) showed that among children living in urban environments, those who had everyday views of nature (e.g., a tree outside their apartment window, instead of a view of concrete) performed better on tasks that measured working memory (backward digit span, backward alphabet span), impulse inhibition (matching familiar figures task), selective attention (Stroop color-word task), and concentration (Necker Cube pattern control task). These findings suggest that greater exposure to natural environments may be associated with a range of important benefits.

Such benefits from nature exposure have now been found across a wide range of different types of contact (e.g., photographs, everyday window views, physical presence in natural environments) as assessed using a variety of different research approaches, including cross-sectional, longitudinal, and experimental designs. Benefits from nature exposure have also been observed across varying durations of exposure; from a few minutes of viewing images, to hour-long or multi-day wilderness experiences, up to life-long proximity to greenspace. The diversity of findings suggests that the impact of nature experience on psychological functioning may be both widespread and robust.

Two major theories have been proposed to explain nature's restorative benefits. They suggest that one useful way to categorize the empirical findings in the literature is to distinguish between the affective and cognitive benefits of nature experience. Each of these two theories is described briefly below, under the type of impact (affective or cognitive) with which it is most directly associated.

1.1.1. *The affective impact of nature experience*

Stress reduction theory (SRT) provides an explanation for the impact of nature experience on affect. This theory posits that natural environments have a restorative advantage over artificial environments due to the role that they played in our evolution as a species (Ulrich, 1981). More specifically, according to this view, nature scenes activate our parasympathetic nervous system in ways that reduce stress and autonomic arousal, because of our innate connection to the natural world. Particular natural landscapes (especially grasslands with clusters of trees) tended to provide human beings with "opportunities" for gain, and places of "refuge" for safety. According to Ulrich et al. (1991), viewing these types of landscapes activates our physiology in affectively beneficial ways, as we have evolved to have an innate preference for these types of environments. Ulrich's theory provides a set of testable hypotheses regarding nature's impact on the autonomic nervous system, and these have been tested via the use of physiological measurements of individuals during their exposure to various environments.

In support of SRT, viewing photographic images and videos of natural scenery has been shown to reduce skin conductance, heart rate, and other physiological indicators of stress (Gladwell et al., 2012; Laumann, Gärling & Stormark, 2003; Ulrich et al., 1991). Similarly, walking through forests and other natural landscapes reduces cortisol levels (Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2009; Tyrväinen et al., 2014). In addition to these improvements on physiological measures of stress, a 50-min walk through a natural environment can increase positive affect (Berman, Jonides, & Kaplan, 2008; Berman et al., 2012; Hartig et al., 2003). In other cross-sectional and longitudinal studies, proximity to greenspace has been shown to promote lower levels of "mental distress" and stress, as well as greater psychological well-being (General Health Questionnaire), after controlling for demographic and socioeconomic factors (Ward Thompson et al., 2012; Wells, 2000; White, Alcock, Wheeler, & Depledge, 2013). These findings suggest that exposure to nature, broadly defined, can decrease stress and increase positive affect.

If decreased exposure to nature is causing changes in mental health, one might expect the affective consequences to extend beyond stress and positive mood. For example, many psychological disorders are associated with changes in other aspects of affect, including increases in anxiety, rumination, and negative mood. Importantly, prior studies have not specifically assessed anxiety or rumination, although some have employed scales that may in part reflect changes in anxiety (e.g., Perceived Stress Scale in Ward Thompson et al., 2012). With some notable exceptions (e.g., Hartig et al., 2003; Ulrich, 1979), fewer studies have observed impacts of nature experience on negative affect. This study aims to address these gaps by examining the impacts of nature experience on these aspects of affective responding.

1.1.2. *The cognitive impact of nature experience*

Why might nature experience influence cognition? According to Attention Restoration Theory (ART), urban environments heavily tax the top-down voluntary attentional control that is required to filter relevant from irrelevant stimuli adequately. Demands from the urban environment deplete this cognitive resource, and can thereby worsen performance on tasks that rely on this focused, directed attention (Hartig, Mang, & Evans, 1991; Kaplan & Kaplan, 1989). According to ART, natural environments invoke a different sort of attention from people – a sense of "fascination," "being away," "extent," and "compatibility" – that may result in the replenishment of directed attention because they are less heavily taxed in these alternative environments. This, in turn, may lead to improved performance on tests that measure memory and attention.

Consistent with ART, Tennessen and Cimprich (1995) found that dormitory students who had views of nature through their windows performed better on tasks that require concentration (Necker Cube pattern test) than students without such views. Berto (2005) demonstrated the restorative influence of nature on sustained attention (sustained attention to response test), showing that participants who viewed nature photographs performed better on the task than those who saw images of urban environments. Similarly, walking through a natural greenspace, compared to walking through an urban environment, yields benefits for verbal working memory (backward digit span), cognitive control (executive attention component of the attention network task), and concentration (Necker Cube pattern test) (Berman et al., 2008, 2012; Hartig et al., 2003). These results suggest that exposure to nature improves performance on cognitive tasks that require directed attention.

A primary measure of working memory used in prior studies is the backward digit span task. While this task may recruit voluntary executive control to some degree, it is typically thought to reflect domain-specific storage processes (i.e., the ability to keep phonological information in short-term memory) more than domain-general executive control processes (e.g., Engle, Tuholski, Laughlin, & Conway, 1999). By contrast, *complex* span tasks, which employ a demanding concurrent task to prevent participants from simply rehearsing the items, are thought to provide a clearer assessment of voluntary control mechanisms in working memory. To our knowledge, performance on complex working memory span tasks has not been assessed after exposure to nature. Similarly, it is not yet clear whether these cognitive benefits generalize beyond verbal working memory measures to executive control over visuospatial working memory representations. Therefore, in this study we aim to broaden the examination of cognitive impacts by adding assessments of dual-task memory (operation span task) and visuospatial working memory (change detection task).

1.2. The present study

The first goal of the present study was to replicate prior research on the impact of nature experience on affect and cognition. Across the sciences, there is growing appreciation of the importance of replication (Cumming, 2011; Miguel et al., 2014; Nosek, Spies, & Motyl, 2012; Pashler & Wagenmakers, 2012; Stanley & Spence, 2014). This is particularly important in a context in which the methodologies have varied considerably across studies, and where direct replications have been scarce. To address this goal, we employed measures of affect (positive affect; Watson, Clark, & Tellegen, 1988) and cognition (backward digit span; Wechsler, 1955; executive attention portion of the attention network task; Fan, McCandliss, & Fossella, 2005) that have been previously shown to be affected by nature experience (Berman et al., 2008, 2012; Kuo & Sullivan, 2001; Taylor et al., 2002). We also used an operational definition of nature and urban experience that is similar to Berman et al. (2008) and Hartig et al. (2003), by having participants walk for 50 min in either an urban greenspace or through city streets.

The second goal of this study was to extend prior research. To gain further insight into the affective impact of nature experience, we assessed changes in anxiety (STAI; Spielberger, 1983), rumination (RRQ; Trapnell & Campbell, 1999), and negative affect (PANAS; Watson, Clark, & Tellegen, 1988). To our knowledge, the impact of nature experience on rumination and self-reported anxiety (specifically measured with STAI) has not been assessed in any previous study that does not explicitly include participants with diagnosed depression. (In a single-group design, Gonzalez, Hartig, Patil, Martinsen, and Kirkevold (2010) did find a decrease in brooding for a group of 28 depressed individuals in a nursing home who participated in gardening activities over a 12-week period.) To gain further insight into the cognitive impact of nature experience, we employed a complex span task, which prevents phonological rehearsal (operation span task; Turner & Engle, 1989). This is a dual-task memory test in which participants must solve math problems, while simultaneously storing and recalling letters from working memory. Additionally, we sought to determine whether the cognitive benefits of nature experience would generalize to a measure of visuospatial working memory (change detection task; Luck & Vogel, 1997), or if these benefits were limited to executive control over verbal working memory representations. In this way, we sought to clarify the specific impacts that directed attention replenishment may have on cognitive function. One other innovation in the present research is our assessment of self-reported feelings of connectedness to nature, which allowed us to test whether our groups (nature vs. urban) were matched on this control variable.

We tested two main hypotheses. First, we hypothesized that relative to urban experience, nature experience would decrease anxiety, rumination, and negative affect, and would increase positive affect. Second, we hypothesized that relative to urban experience, nature experience would increase verbal and visual working memory capacity, and improve performance on the executive component of an attention test. We assumed that our participants, all of whom resided in suburban or urban environments, entered the study with some degree of baseline directed attention depletion, and thus had the potential for a decrease in baseline levels of stress.

2. Methods

2.1. Participants

Seventy adults (37 female, total mean age = 24.1) from the San Francisco Bay Area with no current or past diagnosis of neurologic or psychiatric disorder were invited to participate in a study that measured affective and cognitive functioning before and after a walk. No reference was made to the type of environment they would experience during their walk. Four participants had to be eliminated due to rain on the day of the study; and another six participants were eliminated due to shuttles that were over 15 min later than their scheduled departure time. The study was aborted for these participants, without completing data collection. These exclusions were made to keep the dosage of environmental exposure as consistent as possible across participants, in terms of both duration and weather. After these exclusions, our final sample comprised sixty individuals (33 female, total mean age = 22.9). The nature group comprised thirty participants (18 female, total mean age = 22.8), and the urban group also comprised thirty participants (15 female, total mean age = 22.9). This final sample comprised 45.0% Caucasian, 23.3% Hispanic, 16.7% Asian, 1.7% biracial, and 13.4% other ethnicities.

All participants were told that they had to be physically capable of walking for approximately 120 min. The study took place over the course of 15 months, with environmental assignment spread evenly over fall, winter, spring and summer seasons, and little variation in climate across these seasons due to the geographical location of Stanford University. Each session lasted approximately 4 h. Community participants were compensated monetarily ($10/h) ($N = 16$), and student participants were compensated with research credit ($N = 44$), with an even distribution of compensation type between nature and urban groups.

2.2. Procedure

In a lab room, participants completed a battery of affect measures and cognitive tests (see Sections 2.3 and 2.4 for specific measures) that took approximately 75 min to complete. The participants then took a 15-min shuttle ride to a starting point of a 50-min walk (timed by the experimenter) in either an urban or nature environment (determined by random assignment). The nature walk took place in a park near Stanford University (known as “The Dish”) along a paved path through grassland with scattered shrubs and oak trees. The urban walk was located on a main thoroughfare through Palo Alto, a busy street with three-to four lanes in each direction and a steady stream of traffic (El Camino Real). Both walks were across fairly level ground and involved similar levels of physical exertion.

A research assistant accompanied each participant to the starting point of either the nature or urban walk. The participants were told to take ten pictures of “whatever captured their attention” during the walk. These instructions were used as a cover story to help disguise the intention behind the study, and to confirm that they complied with instructions and went on the designated walk (Fig. 1). After the walk, all participants took a 15-min shuttle ride back to the University, and were re-assessed on the same set of affect measures and cognitive tests (75 min). This allowed us to measure change within individuals from before to after each walk, and then to compare changes in affective and cognitive function between the two groups (nature vs. urban). The sequence of tests and measures was randomized for each individual, to control for order effects, but was consistent across both testing sessions for that individual. Participants were then debriefed and either paid or given course credit.

2.3. Measures of affect

To measure the affective impact of nature experience, we assessed anxiety, rumination, negative affect, and positive affect. State versions of questionnaires were used across all measurements (except rumination, which is typically assessed using different terminology, described below). Participants were asked to rate how

Fig. 1. Representative participant photos from (A) the urban walk and (B) the nature walk.

they were feeling "right now, at this moment" in each session (before and after the walk).

2.3.1. STAI

We assessed anxiety using the State-Trait Anxiety Inventory (STAI), a 20-item questionnaire in which participants rate on a 4-point scale (ranging from "not at all" to "very much so") the degree to which they currently feel a variety of items (e.g., "right now, at this moment, I feel tense"). The scale was internally consistent (α = .90). Higher means of the sum of scores indicate higher degrees of anxiety.

2.3.2. RRQ

Rumination was assessed using the Rumination-Reflection Questionnaire (RRQ). The RRQ is divided into two scales (rumination and reflection). For the purposes of this study, only the rumination scale was used, as it was a relatively brief and efficient way to measure rumination. This scale consisted of 12 items that measured ruminative tendencies (e.g., "I often reflect on episodes of my life that I should no longer concern myself with"), each rated on a 5-point Likert scale ranging from one ("strongly disagree") to five ("strongly agree"), and was internally consistent (α = .94). Higher means of the sum of scores indicate higher degrees of rumination.

2.3.3. PANAS

Positive and negative affect was assessed using the Positive and Negative Affect Schedule (PANAS). This 20-item survey is divided into a positive (10-item) scale (e.g., "interested", "active"), and a negative (10-item) scale (e.g., "distressed", "irritable"), each consisting of 5-point Likert rankings. We also included eight distractor items that were not included in analyses ("melancholy", "happy", "sad", "disappointed", "lively", "energetic", "discouraged", and "sad"). Participants were asked to assess the degree to which they currently felt each of the items, ranging from one ("very slightly or not at all") to five ("extremely"). The questionnaire used the following phrasing: "circle the answer that best describes the extent to which you are currently experiencing each of these feelings or emotions", followed by a list of items (e.g., "proud"). The scale was internally consistent (positive affect α = .93; negative affect α = .91). Higher means of the sum of scores indicate higher positive and negative affect, respectively.

2.4. Measures of cognition

To measure the cognitive impact of nature experience, we assessed verbal working memory, visuospatial working memory, and executive attention. Each of the behavioral tasks is described below. The OSPAN, change detection, and attention network test (ANT) were all administered on a laptop computer, whereas the backward digit span task was administered verbally.

2.4.1. OSPAN

The operation span task (OSPAN; Turner & Engle, 1989; Unsworth, Heitz, Schrock, & Engle, 2005) is a test of working memory that requires participants to solve math equations while simultaneously memorizing, and storing in working memory, a list of letters in serial order. A trial consists of a sequence of paired math equations and letter presentations. Each trial comprises a range of 3–7 such pairs. The complete test consists of 15 trials of varying size. Three instances of each size (i.e., 3, 4, 5, 6, or 7) are presented. The order of the trial sizes was randomized for each session. Our version was based on the automated operation span task described in Unsworth et al. (2005). Participants are presented with a math equation (the processing task), along with a solution (e.g., "(4/2) – 1 = 1") and must indicate whether the answer presented is correct or incorrect within approximately 1–2 s. The exact duration of this presentation was determined for each participant based upon his or her response time during a practice session in which the math task was practiced by itself. This is done in order to make sure that the math task is sufficiently demanding, so that it discourages phonological rehearsal of the letters. Immediately following the response, a letter is presented on the screen for 800 ms for memorization (the storage task), before the next math equation is presented. Participants had to answer at least 75% of the math equations correctly (identifying "true" or "false" solutions accurately), or their test performance was eliminated from inclusion in analysis, as this could indicate a failure to perform the dual-task element appropriately (i.e., focusing on letters only and not math; see

Unsworth et al., 2005). Due to this requirement, we had to eliminate 15 subjects (seven nature and eight urban participants), leaving 45 subjects (23 in nature group, 22 in urban group) for inclusion in this analysis. (All the statistical conclusions reported later remain the same if no participants are excluded. Similarly, the same outcomes are found if one uses a more stringent 85% threshold for math performance, as is often done with this task (e.g., Unsworth et al., 2005). Thus, the specific choice of thresholds does not influence any of our conclusions.) Participant scores were determined by summing the correctly recalled letters from only those items in which all letters were correctly recalled, including serial order. This is a common approach to scoring known as the "all-or-nothing load scoring" (ANL; Conway et al., 2005). Our version of the test was administered using MATLAB software. The test took an average of 15.9 min to administer.

2.4.2. Change detection task

The change detection task, an assessment of visuospatial working memory, was based on Luck and Vogel (1997). It consists of 3 blocks of 48 trials. Each trial begins with the presentation of an array consisting of 4 or 8 colored squares (blue, green, yellow, black, white, red) at random locations on the screen for 100 ms. This is followed by a 900 ms delay interval, in which a blank screen is presented. Following this delay, a single colored square (the probe) is presented on the screen, in the same place as one of the squares from the initial array. The color of the probe square, however, is not always the same. 50% of the time the probe square is the same color as the square it replaces. On the remaining 50% of trials, the probe square is a different color (e.g., a blue square might replace a green square). The participant must then determine whether the probe's color matches that of the corresponding square from the sample array. There is no response deadline imposed upon the participant – the probe square remains on the screen until a response is entered. Our outcome measure for this task was derived from a standard formula for calculating the capacity of working memory (Cowan, 2001; Pashler, 1998; Vogel & Machizawa, 2004). This capacity measure, K, is equal to $S(H-F)$, where S is the number of items in an array (here we used performance from the 8-item arrays), H is the hit rate, and F is the false alarm rate. Two subjects did not complete the task due to software malfunction, leaving the total number of participants for this task at 58 (30 nature and 28 urban). The task took an average of 12.5 min to administer.

2.4.3. ANT

The online version of the ANT was administered using a website (Fan, McCandliss, & Fossella, 2005; http://www.sacklerinstitute.org). For this test, participants are presented with 288 trials. Each trial begins with one of three cue types: a *centrally* presented dot (the "alert" cue, which indicates that a target is about to be presented); a dot presented in the *upper or lower half of the screen* (the "spatial" cue, which indicates where the target will be presented on the screen), or no cue at all. This is followed by a delay interval, and then the presentation of a set of arrows, in either the top or bottom part of the screen. Arrow sets were either congruent (all pointing in the same direction), or incongruent (central arrow pointing in a separate direction from flanking arrows). Participants must indicate the direction in which the center arrow is pointing. "Alerting attention" is calculated as the difference in performance (including accuracy and reaction time) between center cue and no cue trials. "Orienting attention" is calculated as the difference in performance (including accuracy and reaction time) between spatial-cue trials and center-cue trials, averaged across both congruent and incongruent arrow sets. "Executive attention" is calculated as the difference in performance (including accuracy and reaction time) between congruent and incongruent targets, averaged over all cue types. Given prior findings (Berman et al., 2008), we assessed only the last of these three aspects ("executive attention"), as it is thought to require the highest degree of top-down cognitive control (see Fan et al. (2005) for cue and arrow presentation timing details). Five subjects did not complete the task due to website malfunction, leaving the total number of participants for this task at 55 (29 nature and 26 urban). The task took an average of 15.4 min to administer.

2.4.4. Backward digit span

In each trial of this task, the experimenter reads a sequence of numbers aloud (one digit per second), and the participant is asked to repeat the numbers back in reverse order. For the first two trials, participants are given two numbers to remember (e.g., for length two: "5, 2" and "7, 4"). If the participant correctly answers at least one of the two trials correctly (i.e., they recall all the digits in the correct order), the administrator increases the length of the digit span by one, and the participant gets two trials at that new length. This continues until the participant fails to recall both trials at a particular length, or she has completed the maximum length of 8 digits. For each set correctly recalled, a participant receives one point (regardless of length). This scoring methodology is known as "all-or-nothing unit scoring" (Conway et al., 2005), and is the same method used in Berman et al. (2008). The total number of points represents the participant's score on this measure. We used a version of backward digit span that ranged from two to eight digit lengths, instead of the version that ranged from three to nine in Berman et al. (2008). The task took an average of 4.8 min to administer.

2.5. Control measure

To assess whether participants in our two conditions differed at baseline in their "connection to nature," we used the Connectedness to Nature Scale (CNS; Mayer & Frantz, 2004), a 14-item questionnaire that assesses the degree to which participants relate to the natural world by feeling a sense of oneness with nature (e.g., "I think of the natural world as a community to which I belong"); a personal identification with flora and fauna (e.g., "I often feel a kinship with animals and plants"); and a sense of equality between themselves and nature (e.g., "I recognize and appreciate the intelligence of other living organisms"). Participants rated the degree to which they agree with each item using a 5-point Likert-scale, and the scale was internally consistent ($\alpha = .86$). Higher scores indicate higher degrees of connection to nature.

3. Results

In preliminary analyses, we assessed whether there were any differences between our groups (nature walk vs. urban walk) in terms of demographics or pre-intervention performance. Groups did not differ by age, $t(55) = .02$, $p = .98$ or gender ($\chi^2(1) = .27$, $p = .60$). No differences in ethnicities were observed between groups when Caucasians were compared to all other ethnicities ($\chi^2(1) = .03$, $p = .85$). Groups did not differ with respect to connection to nature, $t(58) = .42$, $p = .67$. We also assessed whether there were group differences between any of our dependent variables at baseline (i.e., tests administered before the walk). No significant differences were observed between groups in baseline assessment for any dependent measures (all $ps > .12$). This absence of differences across all pre- measures suggests that our randomization was successful, thereby allowing us to attribute to changes in performance to our experimental manipulation (nature vs. urban exposure).

For our main analyses, we conducted 2×2 mixed factorial analyses of variance (ANOVA) on each dependent measure, with environment (nature vs. urban) as our between-groups factor, and time (before vs. after the walk) as our within-subject factor. In order

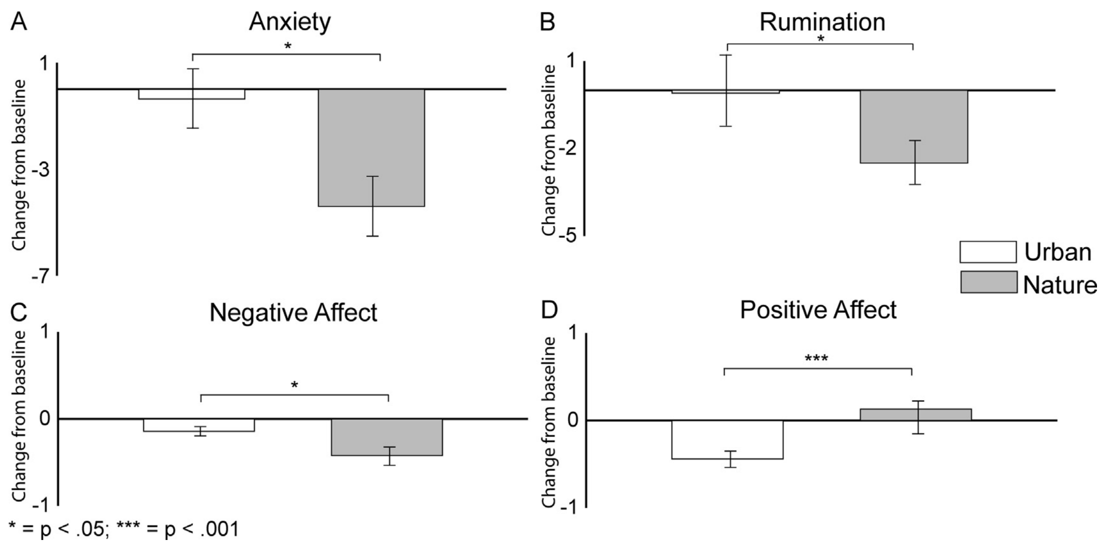

Fig. 2. Affective impact of nature experience. Difference scores are used to compare performance from before the walk to performance afterward (negative values indicate a decrease after the walk, while positive values indicate an increase). Each panel depicts these difference scores for the urban and nature groups separately on one of the four affective measures: (A) anxiety, (B) rumination, (C) negative affect, and (D) positive affect. Error bars depict standard error (SE) values.

to assess whether nature led to significantly greater benefits than walking in urban environments, we required there to be a significant interaction between environment and time. If there was a significant interaction, then we further inspected the dependent variable with planned comparisons of before and after scores within each group, to assess whether this interaction was driven by a greater change in the nature than the urban group. We also report main effects of environment and time when they are significant, but these are not critical for the primary hypotheses so they are not discussed in detail. For example, a significant effect of time could simply reflect a testing effect where participants score differently on the second administration of a measure (e.g., improvement on the OSPAN task because they've learned how to perform the task better). We provide a summary table of mean scores across all measures as supplementary material, but as we are interested solely in changes in affect and cognition that differ between the two environments, we focus here on environment × time interaction effects.

3.1. *Impact on affective functioning*

As shown in Fig. 2, participants had greater affective benefits from a nature walk than an urban walk. Compared to urban experience, nature experience led to greater decreases in anxiety, rumination, and negative affect. Nature experience also maintained positive affect, compared to the drop in positive affect that resulted from urban experience. We report statistics for each of these findings below.

For anxiety (STAI), our ANOVA yielded a main effect of time, $F(1,58) = 7.66$, $p < .01$, as well as an environment × time interaction, $F(1,58) = 5.48$, $p < .05$. As shown in Fig. 2A, follow-up tests revealed that although there was no effect of time for the urban group, $t(29) = -0.31$, *n.s.*, there was an effect of time for the nature group, $t(29) = -3.49$, $p = .002$, $d = .46$, with decreases from pre- to post-walk.

For rumination (RRQ), our ANOVA yielded a main effect of time $F(1,58) = 6.85$, $p < .05$, as well as an environment × time interaction, $F(1,58) = 5.84$, $p < .05$. As shown in Fig. 2B, follow-up tests revealed that although there was no effect of time for the urban group, $t(29) = -0.15$, *n.s.*, there was an effect of time for the nature group, $t(29) = -3.30$, $p = .002$, $d = .29$, with decreases from pre- to post-walk.

For negative affect (PANAS), our ANOVA yielded a main effect of time, $F(1,58) = 19.94$, $p < .0001$, as well as an interaction between time and environment, $F(1,58) = 5.17$, $p < .05$. As shown in Fig. 2C, follow-up tests revealed that there was an effect of time for the urban group, $t(29) = -2.58$, $p = .02$, $d = .37$, as well as effect of time for the nature group, $t(29) = -3.72$, $p = .0008$, $d = .68$. Importantly, the larger relative drop in negative affect in the nature group drove the significant interaction effect.

To examine whether changes in anxiety, rumination, and negative affect were independent effects, we tested for correlation among these change scores. These changes in the nature group in rumination, anxiety, and negative affect were not correlated (all *ps* > .18).

For positive affect (PANAS), our ANOVA yielded a marginal main effect of time, $F(1,58) = 3.80$, $p = .06$, as well as an environment × time interaction, $F(1,58) = 12.43$, $p < .001$. Interestingly, as shown in Fig. 2D, follow-up tests revealed that although there was no effect of time for the nature group, $t(29) = .91$, *n.s.*, there was an effect of time for the urban group, $t(29) = -5.35$, $p = .0001$, $d = .61$, with decreases from pre- to post-walk.

Taken together, our results support our hypothesis regarding the affective impacts of nature experience.

3.2. *Impact on cognitive functioning*

As shown in Fig. 3, participants performed better on the OSPAN task after walking in the nature than before walking in nature. No such effects were evident for the urban participants. The other cognitive tasks did not yield significant interaction effects. We report statistics for each of these findings below.

For the operation span task, our ANOVA yielded a main effect of time, $F(1,43) = 7.94$, $p < .01$, as well as an environment × time interaction, $F(1,43) = 7.85$, $p < .01$. As shown in Fig. 3A, follow-up tests revealed that although there was no effect of time for the urban group, $t(21) = -.03$, $p = .97$, *n.s.*, there was an effect of time for the nature group, $t(22) = 4.08$, $p = .0005$, $d = .67$, with increases from pre- to post-walk.

For the change detection task, our ANOVA results yielded a significant main effect of time, $F(1,56) = 4.47$, $p = .04$, and no environment × time interaction, $F(1,56) = .15$, *n.s.* (See Fig. 3B.)

For the executive attention portion of the attention network task, our ANOVA results yielded a marginal main effect of

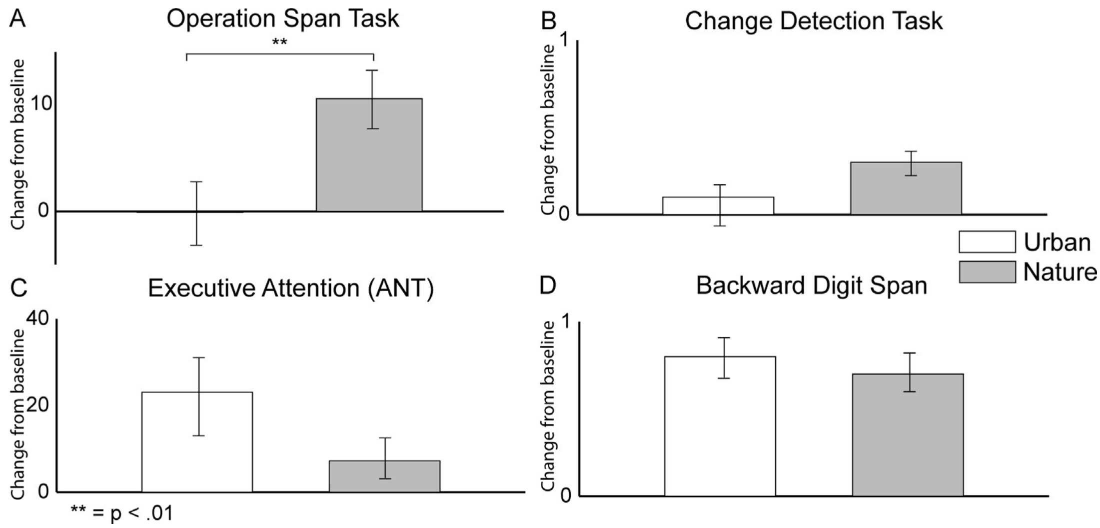

Fig. 3. Cognitive impact of nature experience. Difference scores are used to compare performance from before the walk to performance afterward (positive values indicate an increase after the walk). Each panel depicts these difference scores for the urban and nature groups separately on one of the four cognitive measures: (A) operation span task, (B) change detection task, (C) ANT, and (D) backward digit span. Error bars depict standard error (SE) values.

time, $F(1,54) = 3.11$, $p = .08$, and no environment × time interaction, $F(1,54) = .38$, *n.s.* (See Fig. 3C.)

For the backward digit span task, our ANOVA results yielded a main effect of time, $F(1,58) = 8.40$, $p < .01$, and no environment × time interaction, $F(1,58) = .04$, *n.s.* (See Fig. 3D.)

Taken together, our results show mixed support for our hypothesis regarding the cognitive impacts of nature experience.

4. Discussion

This study aimed to investigate the impact of nature experience on affect and cognition, through tests of two hypotheses. First, we hypothesized that nature experience would decrease anxiety, rumination, negative affect, and increase positive affect. Second, we hypothesized that nature experience would increase verbal and visual working memory capacity, and improve performance on an attention task. Our results strongly support our first hypothesis, while providing mixed evidence with regards to the second. When considering affect and cognition together, we believe there is clear evidence for the benefits of nature experience.

4.1. The affective impact of nature experience

In support of our first hypothesis, compared to the walk in an urban environment, the nature walk decreased anxiety, rumination, and negative affect, and maintained positive affect. These findings build upon previous studies that were motivated by theories such as Stress Reduction Theory, which demonstrated the impacts of nature experience on stress and positive affect. Our findings extend previous work by showing that relative to urban experience, nature experience leads to decreases in anxiety, rumination, and negative affect. These findings support an account of a pathway by which nature exposure may provide a "restorative" affective experience, perhaps through some process of "negative affect repair." We further explain this in our proposal for possible future directions in Section 4.3.

4.2. The cognitive impact of nature experience

Our results are mixed with respect to our second hypothesis regarding the cognitive benefits of nature experience. We found that relative to urban experience, nature experience increased verbal working memory as measured by performance on the automated operation span task. These findings are consistent with previous findings that have been motivated by theories such as Attention Restoration Theory. This evidence is compelling because complex span tasks like OSPAN have a high internal consistency, test-retest reliability, and an extensive history of use in the literature as an effective tool to assess verbal working memory, and can predict aspects of complex cognitive functioning that include advanced reasoning, problem-solving, and reading comprehension (e.g., Conway et al., 2005; Unsworth & Engle, 2007; Unsworth et al., 2005). With our findings on OSPAN, our study provides the first evidence of nature experience impacting performance on a complex test of verbal working memory. Interestingly, however, the change detection task did not produce significant differences between the groups. This test of visuospatial working memory has also not been conducted in any previous study in this literature, so our divergent results here should be investigated further in future studies.

On our other cognitive measures, we did not replicate previous findings (Berman et al., 2008, 2012; Berto, 2005). Specifically, prior research led us to expect an interaction between time and environment for the backward digit span task and the executive attention portion of the ANT task, but neither was observed. These are null findings, however, which limit the conclusions we can draw. This again underscores the importance of replication. Taken together, support for our prediction of cognitive benefits is more equivocal than what was observed among the affective measures.

4.3. Limitations and future directions

We observed compelling differences in the effects of nature versus urban experience. Specifically, we found that benefits of nature experience may lie predominantly in decreases in several aspects of negative affect and an increase in verbal working memory. Below, we discuss limitations and future directions.

Our study contrasted two conditions – one natural, one urban. One important strength of this study is the use of an urban park to assess nature exposure. That is because such parks offer the type of nature experience that is most likely to be available to many urban residents in the future. However, there are many types of natural environments, and previous research has demonstrated differences in the restorative quality of various aspects of different environments (Hartig, Korpela, Evans, & Gärling, 1997; Herzog, Maguire,

& Nebel, 2003). Thus, in future research, it will be important to examine how these benefits may vary across different types of natural environments. For our urban condition we chose the street in the area that had the highest degree of traffic, although there were some scattered bushes and trees along the sidewalk. The degrees of urbanicity and naturalness contained in urban environments vary tremendously throughout the world. Future research should much more thoroughly specify geographic (e.g., proximity to water, topography), built infrastructure (e.g., road network, buildings), biological (e.g., vegetation structure and diversity), audio (e.g., degree of traffic noise or bird song) and other key dimensions that characterize the particular urban environments chosen to contrast with natural areas.

Another notable limitation of this study is that our participants were relatively young. A recent meta-analysis by McMahan and Estes (2015) indicates that if anything, this would tend to produce a conservative estimate of true effects, as they found that effect sizes of the benefits of nature experience are larger for older versus younger participants. In future research, it will be important to examine more fully the role of this and other participant characteristics.

Due to the before-after design of the study, we were unable to assess participants' affect and cognition *during* the walk. Are these benefits observed while participants are present within the environment, or only after they leave the experience? Are the benefits apparent immediately upon arrival in the environment, or do they build across time, suggesting that longer exposure to nature could be more effective? By using tools designed for ecological momentary assessment (e.g., a mobile phone app), it might be possible and desirable in future studies to obtain this information as well. Regardless of these outcomes, however, the fact that effects were observable *after* the walk is a testament to the durability of the impacts. When considered with our relatively short duration of exposure to the environment (under an hour), it suggests that, if anything, our results are likely to be conservative estimates. Future research should focus on a within-subjects manipulation of the duration of nature experience to thoroughly examine the question of whether longer exposures to nature lead to more powerful (or longer-lasting) benefits. These studies could include physiological measurements, as well as qualitative interview methods, and assessments of the duration of effects through follow-ups, conducted days to weeks after the experiment.

This study focused primarily on demonstrating the existence of effects from nature experience. Before beginning an investigation into the causal mechanisms responsible for these effects, we had to first demonstrate that they occur. Given our results, we now formulate next steps in the exploration of possible causal mechanisms.

One direction for research on mechanisms underlying the impact of nature experience focuses on increasing adaptive forms of emotion regulation. Past research has demonstrated the effectiveness of emotion regulation strategies, including cognitive reappraisal, in reducing negative affect (Gross & John, 2003; Hemenover, Augustine, Shulman, Tran, & Barlett, 2008). Future research should investigate the potential of natural environments to encourage cognitive reappraisal, which in turn may lead to mood repair. In what Johnsen and Rydstedt (2013) have called the "emotional potential" of an environment, individuals may make active use of natural environments in the service of emotion regulation, insofar as a) they seek out places that are best-suited for providing the support needed to down-regulate negative emotions and cognitively reappraise (Hartig et al., 1997; Korpela, Hartig, Kaiser, & Fuhrer, 2001), and b) they use a choice of environment as a form of situation selection. Of course, use of the natural environment to help regulate emotion need not take place on a conscious level – individuals may seek out these places without explicit deliberation or knowledge that they service emotion regulation. Future research should more thoroughly explore the cognitive processes involved in these types of choices regarding situation selection as it applies to the environment.

A second direction for research on mechanisms underlying the impact of nature experiences focuses on decreasing maladaptive forms of emotion regulation. Frantz, Mayer, Norton, and Rock (2005) posit that nature experience may shift attention from an internal to external focus. This simple shift may be responsible for a decrease in rumination, which may in turn lead to other benefits. Nature experience may decrease rumination in participants due to an increased focus on aspects of the environment that are not directly related to narratives about the self. This may pull subjects away from a tendency to engage in negative self-descriptive patterns of thoughts, and possibly free up cognitive resources that could be observed by increased performance on memory tasks (Chambers, Lo, & Allen, 2008; Joormann & Gotlib, 2008; Whitmer & Banich, 2007). Previous research has shown that situations in which an individual focuses on an external environment may decrease the degree of self-awareness (Duval & Wicklund, 1972), a change that can be beneficial in and of itself (Leary, 2004; Leary, Adams, & Tate, 2006).

In conclusion, there are many factors that differ between natural and urban environments. It is unclear at present which of these differences accounts for the observed changes in affect and cognition. It is also unclear how to best take into account the influence that a variety of environmental covariates may have on individuals. Noise and air pollution, population density, and other elements of urban or natural environments may act as mediating factors for the impacts we observe on affect and cognitive function. There is great value in disentangling the specific components of the environment that may be related to particular impacts. As the trend of urbanization continues, it is important to understand the exact impacts of nature experience, and to build a theory upon which we may begin to understand the causal mechanisms responsible for these benefits. In much the same way as the biophysical processes of natural landscapes benefit humanity through the provision of "ecosystem services" (Daily, 1997), which purify our water, regulate our climate, and provide us with food, these landscapes may also provide us with important benefits for our mental health. We call these benefits from nature "psychological ecosystem services" (Bratman et al., 2012) and believe that clarifying these benefits – as well as the mechanisms underlying their provision – represents a crucial direction for future research.

Conflicts of interest

The authors of this manuscript do not have any direct or indirect conflicts of interest, financial or personal relationships or affiliations to disclose.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landurbplan.2015.02.005.

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