SEX DIFFERENCES IN THE RESTORATIVE IMPACT OF NATURE ON ATTENTION IN YOUNGER AND OLDER ADULTS

A Thesis

by

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ABSTRACT

Attention Restoration Theory (ART) posits that spending time in nature allows direct attention capacity to be restored which leads to improvements in concentration and working memory performance. Previous research has neglected individual differences in sex and age that may impact the restorative effect. To evaluate these effects, 200 younger adults were be randomly assigned into ‘nature’, ‘not-nature/urban’, ‘control’ restoration groups. In addition, a small pilot study of older adults, ages 65+, were assigned to nature and urban groups. All groups completed series of questionnaires including general demographics, mood, and exposure to nature in their home environment. All groups completed a sustained attention and working memory task before and after a 12 minute exposure to either nature, urban, or control stimuli. An eye tracker was used measure visual attention to the stimuli during exposure. Results showed no evidence of a restoration effect in the younger or older group. Emerging evidence for sex differences in the reception of natural and urban images are discussed, as well as limitations and directions for future research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

In an increasingly urbanized world, the natural environment is becoming more and more difficult to access. This may be problematic as a growing body of research suggests that exposure to natural environments has a beneficial effect on human cognition (Bertram & Rehdanz, 2015; Hartig, Mitchell, de Vries, & Frumkin, 2014; Olafsdottir et al., 2020; Swanwick, Dunnett, & Wololley, 2003). However, the mechanism underlying the ability of nature to benefit cognitive performance is not entirely understood.

One theory as to why people may benefit from nature is based on the premise that humans are evolutionarily predisposed to be calmed by exposure to nature (Ulrich et al, 1991). Sometimes called Psycho-Evolutionary Theory or Stress Reduction Theory, this theory proposes that exposure to nature increases a sense of well-being and decreases physiological arousal, thereby increasing or restoring performance on cognitive tasks. Early research on stress reduction theory supports the hypothesis that exposure to nature decreases physiological arousal, indicated by metrics such as heart rate and blood pressure (Ulrich, 1981; Bodin & Hartig, 2003; and more recently, cortisol levels (Olafsdottir et al., 2020) . However, other researchers have found that exposure to nature benefits cognitive performance even when there is no change in physiological arousal, suggesting the beneficial effects of nature on cognition may be mediated by another mechanism (Sahlin et al., 2016).

An alternative explanation for the beneficial effect of exposure to natural environments on cognition is the Attention Restoration Theory (ART) (Kaplan, 1995). In this framework, directed attention is considered a resource required for problem solving, navigating, and other higher order tasks associated with executive functioning, whereas indirect attention is involuntary and associated with basic, bottom-up cognitive tasks like alerting and orienting to stimuli. Additionally, directed attention can be fatigued, as demonstrated by research that shows decreased performance on attentional tasks over longer durations (Boksem, Meijman, & Lorist, 2005; Smilek, Carriere, & Cheyne, 2010). According to ART, nature has a 'soft fascination' that captures indirect attention rather than directed attention, allowing fatigued directed attention facilities to become restored. Recent research suggests that this could be in part to the low 'mental bandwidth' nature takes up in one's mental processing capacity (Basu, Duvall, & Kaplan, 2019), in contrast to being just inherently fascinating.

The proposed distinction between direct and indirect attention is consistent with research on brain structure and function. Orienting attention (or indirect attention, using Kaplan's terminology) is associated with a ventral attention network, which is comprised of the temporopariteal junction (TPJ) and the ventral frontal cortex (VFC) and are typically activated when stimuli occur unexpectedly. Meanwhile top-down functions of attention (or directed attention) are associated with activation of a dorsal network of attention which is comprised of the intraparietal sulcus (IPS) and frontal eye fields (FEF) which are activated when attention is overtly oriented in visual space (Petersen & Posner, 2012; Vossel, Geng, & Fink, 2014). These two systems work in tandem depending on what the task at hand demands. For instance, during top-down guided visual search tasks, activity in the TPJ (ventral; indirect attention) is suppressed by signals that originate in the dorsal system (directed attention) (DiQuattro & Geng, 2011).

1.1. Evidence Supporting ART

Natural stimuli that have been successfully used to induce a restoration effect vary from images of natural environments on a computer screen (Gamble, Howard, & Howard, 2014), to a walk in an urban park (Berman, Jonides, & Kaplan, 2008), to immersion in the woods the countryside (Hartig, Evans, Jamner, Davis, & Gärling, 2003). Similarly the duration of exposure to nature that produces an effect ranges from as little as 10 minutes (Berman et al., 2008) to several hours (Bodin & Hartig, 2003). Additionally, many different attention related tasks, such as Digit Span Forwards and Backwards tasks, Necker Cube Pattern Control (NCPC), and the Search and Memory (SMT) task have been used as outcome measures of the effect. The results of a recent meta-analysis of controlled studies of ART indicate that across this research, using a variety of study methods, exposure to nature has a restorative impact on attention (for review see Ohly et al., 2016).

Attention fatigue has been demonstrated to impact other areas of executive function including impulse control, working memory, problem solving, and emotion regulation (Awh, Vogel, & Oh, 2006; Hunt & Lansman, 1986; Schmeichel, 2007; Vonasch, Vohs, Pocheptsova Ghosh, & Baumeister, 2017).Therefore, it is not surprising that a nature restoration effect has been demonstrated on other areas of executive control. For instance, researchers found exposure to photos of nature increased the amount of persistence during a frustrating task (Chow & Lau, 2015). Given the potential impact of attention on other areas of executive function, the restoration of this finite resource may provide an avenue for improving cognitive function across multiple areas.

1.2 Criticisms of ART Research

Although the wide variety of tests demonstrated to show an ART effect is somewhat exciting, due to the promising impact nature can have across cognition, it is also problematic. In recent years there has been considerable criticism on the lack of construct validity within the ART field (Joye & Dewitte, 2018). Kaplan's premise of 'directed attention' has been generalized to a wide variety of tasks, unsurprisingly, as directed attention is needed for a large swath of executive function. This leaves researchers with a wide variety of cognitive tasks, many of which having already been demonstrated to show an effect (see Ohly, 2016), to choose from.

For instance, in Ohly's 2016 meta-analysis concluded the two tasks that showed the most promise for capturing effects of attention restoration were Digit Span Backwards- which is also a measure of working memory, and Trail Making B Task- which is also a measure of cognitive flexibility. Both tasks need directed attention, but have different implications for the generalizability of results to everyday life (Stevenson, Schilhab, & Bentsen, 2018) and demonstrate poor discriminant validity for a whatever portion of executive function the idea of 'directed attention' is meant to capture. In order for the field to advance, the construct of directed attention needs to be operationalized (Joye & Dewitte, 2018).

In addition to problems of the construct validity, issues with methodology have been also discussed. In a 2017 letter to the editor, Hartig makes the important distinction that in order to measure restoration, a need for restoration, or fatigue, must be induced. Many studied purportedly trying to capture the attention restoration effect only measured attention performance after exposure to nature, and make no effort to fatigue the participants into having a need for restoration beyond the varied experiences the participants may have had prior to participating in the experiments. This includes the only study that looked at adults over the age of 65 as well as many of the in-vivo exposure studies (Gamble et al., 2014). Hartig and others argue that in order to capture a restoration, fatigue needs to both be induced and demonstrated (Hartig & Jahncke, 2017; Stevenson et al., 2018).

1.3. Sex and other individual differences

As research in the ART grows, more focus is being directed towards groups that may benefit from attention restoration such as children with ADHD, older adults, and depressed adults (Gamble et al., 2014; Gonzalez, Hartig, Patil, Martinsen, & Kirkevold, 2010; Kuo, 2008). Another factor that may impact whether adults see cognitive benefits from exposure to nature is sex or gender of the individual.

Previous ART research rarely offers an analysis of sex differences, and when done, produces contradicting results. For instance, in a study on the impact of nature exposure on stress Beil & Hanes (2013) found preliminary evidence that women show greater increases in subjective stress in urban environments compared to men as well as greater decreases in stress in natural environments. Conversely, other studies have shown benefits to exposure to greenspace for men but not for women (Richardson & Mitchell, 2010) or have found no sex differences (Olafsdottir et al., 2020). These conflicting findings on sex differences are seen when the outcome variables are related to mood, cognition, health and psychopathology (Bolte, Nanninga, Dandolo, & Study, 2019; Bos, van der Meulen, Wichers, & Jeronimus, 2016) and in adults and children (Stevenson, Dewhurst, Schilhab, & Bentsen, 2019).

The differences observed between men and women may be related to the differing ways in which they interact with the environment. For example, in a study on leisure time and mortality, gardening was associated with longer life for men but not for women, even while controlling for other health factors (Agahi & Parker, 2008). Men and women may also differ on whether they perceive greenspace as restorative based on their perceptions of safety (Ho et al., 2005). In addition, women appear to be more sensitive to the aesthetic quality of nature than men (MacBride-Stewart, Gong, & Antell, 2016). The impact of gender on the mechanism, strength, and overall impact of nature's restorative effect is largely unknown. These differences may have implications for the application of ART research in interventions meant to improve attention.

Another individual difference factor rarely considered in the previous ART literature is the impact of age. Aging is associated with diminished performance of several areas of executive function including mental processing speed, episodic memory, and task switching (Hoyer & Verhaeghen, 2006; Craik & Salthouse, 2008; Dorbath, Hasselhorn, & Titz, 2011; Wasylyshyn & Sliwinski, 2011). Compared with younger adults, older adults have decreased performance on tasks of attentional control (Kray, Eppinger, & Mecklinger, 2005). If the underlying mechanism of older adult's diminished performance on tasks of attentional control is the fatigue of directed attention resources, then the restoration of those resources should lead to increased performance on attention related tasks.

Previous research on children with Attention Deficit Hyperactive Disorder (ADHD) show that populations with diminished attentional control benefit from exposure to nature. For instance, children demonstrate increased performance on cognitive tasks completed in the woods compared to tasks completed in a built, artificial environment (Van den Berg & Van den Berg, 2011). Likewise, children with ADHD performed better on a concentration task after a twenty minute walk in a park compared to children who went on a twenty minute walk in an urban setting (Faber-Taylor and Kuo, 2009). It could well be the case that the dismissed attentional control seen in older adults, as a normal part of aging, has an entirely different underlying mechanism that will preclude older adults from experiencing attention restoration after exposure to nature. However, many resources are already being used to enhance the quality and access to greenspace in older adult's lives, and thus it is an important area for study to better inform those efforts (Navarrete-Hernandez & Laffan, 2019).

Although research on the impact of nature exposure on older adults is limited, recent study comparing on ART in older and younger adults found that older adults' performance on an attentional task showed a larger pre- to post-test improvement in attention compare to the younger adult's pre to post-test improvement in attention after exposure to photos of a natural environment (Gamble et al., 2014). This finding is the first to suggest that older adult's capacity for attention restoration may be greater than younger adults. However, sex differences were not discussed. This is problematic as sex and aging interact in social, biological, cognitive and behavioral spheres and there is already budding evidence that exposure to nature may have a different impact on sexes as they age (Bos et al., 2016).

1.4. Current study

The purpose of this study is to compare the impact of exposure to nature on attention between men and women, and begin to look at how those difference may change as men and women age. As summarized above, the existence or absence of sex differences in the restorative impact of nature has yet to be established. Further, very little is known about the differences in impact of exposure to the natural environment men and women or within a more advanced aged population. It is possible that the decrease in attentional capacity may preclude older adults from benefiting from a restoration effect in nature. After a certain point in cognitive decline a natural environment's restoration impact on attentional capacity may be too small to make up for the loss in executive function due to aging. However, it is also a possible that the restorative effect of nature could have a greater impact older adult's attention compared to younger adults because their attentional capacity may be more sensitive to factors that deplete directed attention capacity.

To provide a stronger test of this hypothesis in across sex an experimental design was used to measure the effects on attention between sexes. In addition, a small pilot sample of older adults are included to begin to explore the possible different impact on nature on older adult cognitive performance. It is hypothesized that exposure to nature will restore attention in both age groups, but that the effect will be stronger in older adults. A loading or fatiguing task is included to induce the need for cognitive restoration. In addition, a Tobi X60 eye tracker to measure the visual attention paid to the stimuli during the exposure. The inclusion of eye-tracking allows comparisons of the visual effort it takes to attend to different stimuli. Finally, the study improved upon previous designs by including measures of individual characteristics such as gender, affect, and access to nature outside of the experiment that may influence responses to natural scenes.

2. METHOD

2.1. Participants

The younger adult population in this study included 200 undergraduate students from Texas A&M University, recruited from the Psychology Department's SONA Subject Pool. Sample size was set following a power analysis was conducted with alpha set to .05, following recommendations by Cohen, (1992) based on data from a previously published study that compared performance on the Digit Span Backwards task as a measure of attention after exposure to urban images compared to performance after exposure to nature images (Gamble et al., 2014), which found moderate effect size (Cohen's *d*=.67). However, subsequently published meta-analyses have reported that studies that use measures of working memory tasks such as digit span backward have typically shown effect sizes in the small to medium range (Stevenson et al., 2018).

The age of younger adult participants ranged from 18 years to 27 years (*M*=19.09, *SD*=1.09). The sample contained 94 men and102 women. The student participants were compensated for participation with course credit.

In addition, 20 older adults were recruited from the community surrounding Texas A&M University for pilot testing. Their ages ranged from 65 years to 92 years (*M*=72.2, *SD*=6.66) and were made up of 9 men and 11 women. The older adult, community participants were paid $20 to participate in the study.

2.2. Measures

2.2.1. Demographic Questionnaire

A demographics questionnaire documented age, gender, level of education, employment status and race. Additionally, several questions about the participant's access to nature in their home environment as well as their previous exposure to nature the day of testing were be asked to control for nature exposure outside of the lab setting.

2.2.2. Mini Mental State Examination (MMSE)

Due to the heavy cognitive load required to complete this study, older adults were screened for cognitive impairment using the Mini Mental State Examination (MMSE). The MMSE is a brief assessment of cognitive impairment composed of 10 questions designed to assess memory and orientation to person, time and place.

2.2.3. Beck Depression Inventory-II (BDI-II)

Depression was assessed to control for the possibility of broader mood dysfunction distorting nature exposure's impact on mood. The Beck Depression Inventory (BDI-II) is a 21 item questionnaire that assesses the cognitive, affective, and physical symptoms of depression (Beck AT, Steer RA, 1988). Normative data collected on the BDI-II demonstrates that it is appropriate to use with both the younger adults in the student sample and older adults (Segal, Coolidge, Cahill, & O'Riley, 2008).

2.2.4. Positive and Negative Affect Schedule (PANAS)

The impact of test stimuli on mood was measured using the Positive and Negative Affect Schedule (PANAS), a 20 item measure of mood states that asks participants to rate 20 different emotions on 5 point Likert scale (D. Watson, Clark, & Tellegen, 1988). These ratings can be complied into two subscales, positive affect and negative affect. Instructions asked participants to consider their mood in the current moment.

2.2.5. Continuous Performance Task

The continuous performance task is a commonly used measure of sustained attention and vigilance. The PEBL Continuous Performance Task (P-CPT or CPT) is a 14 minute long computer task in which participants are asked to attend to a series of letters presented one at a time on a computer screen. The participants must hit the space bar as each new letter is presented, unless the letter is an ‘x’, in which case they must inhibit the space bar hitting response. This measure was included as a measure of sustained attention as well as a means to induce fatigue prior to the presentation of the natural, urban, or control stimuli to address problems of previous research, discussed above. The number of omission errors (CPT-O), in which participants are presented with the target stimuli and fail to press the space bar, is included as an outcome measure of sustained attention, with greater omission errors indicating worse performance in sustained attention. The Psychology Experimental Building Language (PEBL) is a platform available to experimenters for free (Mueller & Piper, 2014). The P-CPT is designed to be comparable to the more widely used C-CPT and has been shown to have test-retest reliability (Piper, Mueller, Talebzadeh, & Ki, 2016) .

2.2.6 Digit Span Backwards Task

The digit span backwards (DSB) task is an attention task that is sensitive to the attention restoration effect (Ohly et al., 2016). Participants will be presented with a series of numbers and asked to repeat the numbers in the reverse order that they were presented in. The amount of numbers in each series is repeated twice, and increases until the participant is unable to remember report two series in a row accurately. The combination of remembering the numbers and mentally reversing the order that they are presented tests both working memory, attention capacity, and concentration (Ostrosky-Solís & Lozano, 2006). The DSB was given both as a baseline and outcome measure for the purpose of this experiment, with different digits in the pre- and post- tests to limit practice effects.

2.2.7. Test Stimuli: Natural vs Urban Environments

Younger adult participants were randomly assigned to one of three experimental conditions: natural scenes, urban scenes, or crosshair scenes (control). Due to the anticipated small sample of older adults, older adults were only sorted into the natural and urban scenes groups. Each condition consists of 50 images presented on a computer monitor. Each image is presented for 15 seconds for a total exposure time of 12.5 minutes. Natural scenes and urban scenes are photographs selected from a google image search based on subjective aesthetic quality and image resolution. An eye-tracking device, Tobii X60, will provide measures of visual attention such as the number of fixations and duration of fixations during the presentation of the visual stimuli.

2.3 Procedure

Participants were tested individually in a session lasting 45 minutes. After providing informed signed consent, older adults were screened for cognitive impairment using the MMSE. No older adults in the sample scored below the cut-off score of 24, and all participated in the study. After being consented all participants completed the baseline measures of the PANAS and the DSB. Next, all participants completed the first CPT. Older adults were randomly assigned to the ‘natural’ or ‘urban’ exposure groups, and younger adults were randomly assigned to one of the three experimental conditions: natural, urban, or control. Participants in each experimental condition were seated in front of a computer and completed a 9-point visual calibration sequence for the presentation of the environment stimuli and concurrent eye-tracking. Following successful calibration, they were instructed to watch the images on the monitor in any way they wish. After finishing the experimental task, participants completed the DSB, the PANAS, and the CPT a second time and the questionnaire battery (Demographic sheet and BDI-

II). The questionnaires and demographic information were collected at the end to control for expectancies during the experimental exposure. See Figure 1 for visual representation of the experimental design.

3. RESULTS

3.1. Pretest differences and Test Selection

The participants in both age groups primarily identified as White or Caucasian (*n*=134). As expected, the student sample had all completed high school and some college course work. Interestingly, 11 of the 20 older adults in the sample had completed a post-graduate degree, most likely due to recruitment efforts in close proximity to Texas A&M University and the use of the university's list serve for recruitment purposes. Older adults were screened for cognitive impairment prior to participation in the study using the Mini Mental State Examination (MMSE) and all scored above the cut-off for cognitive impairment (*M*=28.45, *SD*=1.54).

There were no significant differences between the Nature, Urban, or Control experimental exposure groups prior to experimental exposure, see Tables 1 and 2. Younger adults did not significantly differ in demographic variables such as age or level of education, nor did the younger adults differ in pre-test levels of positive affect (PANAS), negative affect (PANAS), or depression (BDI-II), or in pre-test levels of attention measured by Digit Span Backwards or CPT performance. See Table 1 for group means on relevant variables. Likewise, older adults in the nature and urban conditions in the pilot study did not differ on demographic variables, pretest mood measure, depression, or pretest attention measures.

Outliers greater than 3 standard deviations above or below the mean were adjusted to one standard deviation above or below the mean to reduce the influence of outliers on the dataset without deleting data points. Cohen's *d* is reported to compare the effect size of differences within sex (Cohen, 1992). Hedges' *g* is also reported to make comparisons to recent meta-analysis that primarily used Hedges' *g* as a measure of effect size and to limit bias in smaller sample sizes (Hedges, 1981).

One of the criticism highlighted by Hartig's 2017 editorial is many previous work's failure to control for baseline differences. Stevenson et al (2018) further emphasizes that much of the previous research on ART has relied on the analysis of change scores from pre- to post- test, rather than ANCOVA, with the baseline measure as a covariate. Stevenson notes that ANCOVA is generally recommended for randomized treatment studies, such as the current study. With this criticism in mind, ANVOCAS are primarily used in this section to examine the differences between the treatment groups and sex on the Eye-tracking variables, post-test attention measures and post-test mood measures, using the pre-test measures of attention and mood as covariates.

3.2. Younger Adults Eye-tracking

Eye tracking was included both as an exposure check, to see if participants were attending the visual stimuli as expected, as well as a novel contribution in whether the differences in how urban versus natural scenes are viewed. For the purpose of this study two variables were extracted: the average number of fixations across all 50 slides in the group, "number of fixations" and the average duration of the fixations across all 50 slides "average fixation duration". The number of fixations is a commonly used metric in eye tracking research used to demonstrate the visual attention to given areas of a visual stimuli, with greater number of fixations indicating more visual interest and sustained attention. The average fixation duration demonstrates greater cognitive effort (Rayner, 1998).

The quality of the eye-tracking data is also considered during the analysis. During the calibration sequence, prior to exposure to the stimuli, participants complete a 9 point calibration sequence in iMotions, the eye-tracking software. Only after completing this calibration can participants continue through the task with the eye-tracking enabled. Across the younger and older adult samples, the calibration sequence failed on 5 participants- indicating that the eye tracker would not be able to trace their eye movements. These participants still participated in the presentation of the stimuli but no eye-tracking data was collected and thus they are excluded from the eye-tracking portion of the analysis.

In addition, throughout the eye tracking procedure the eye tracker records the percentage time captured, or the proportion of time the eye tracker is able to detect the eyes of the participant to the amount of time the eye tracker cannot detect the participants eyes, due to blinking, looking away, turning the head, or other disruptions in data collection. This is referred to as the *robustness* of the data. Robustness has been shown to impact common dependent variables such as the average number of fixations, used in this analysis (Wass, Forssman, & Leppänen, 2014).

As such, less robust data, where the eye-tracking device picks up the eyes less than 75% of the time in which the stimuli are presented, was excluded from portions of the eye-tracking analysis (*n*=15). This cutoff is in keeping with the iMotions software's data collection recommendations, which classifies cases with less than 75% gaze tracked as 'poor'. In the collected data, an independent samples t-test comparing the number of fixations of cases with less than 75% of the gaze tracked (*M*=17.54, *SD*=5.67), 'poor' cases, compared to those with greater than 75% tracked (*M*=27.54, *SD*=8.59), 'good' cases ,showed significant differences between the two groups on number of fixations, $t_{(213)}=-6.151$, $p<.0$. This finding demonstrates that the poor quality of the eye tracking results in lower number of fixations and should thus cases with low eye-tracking quality (*n*=15) should be excluded from the analysis for number of fixations. These 15 cases did not significantly differ from the rest of the sample on any demographic variable, including sex (7 men, 8 women) and were dispersed across all 3 experimental conditions (*n*=5 for each condition, natural, urban and control groups).

However, the average fixation duration, our second eye tracking variable, averages across all of the recorded fixations, and thus should not be impacted by the percentage of time tracked- i.e., the failure to pick up the gaze results in no data, and the average duration of the recorded gaze points is not impacted. An independent samples t-test comparing the average fixation duration between the 'poor' quality, or less the 75% gaze tracked, group (*M*= 310.58, *SD*=109.53), to the 'good' quality group, or greater that 75% gaze tracked, group shows (*M*=339.32, *SD*=149.62) no significant difference, $t_{(213)}$= -1.01, *p*>.05 between the two groups, and therefore the 'poor' quality cases were included in the following analysis of fixation duration.

3.2.1 Number of Fixations

The number of fixations did not correlate with outcome attention measures of Digit Span Backwards (DSB) $r_{(190)}$=.004, p>.05, which was true both within the men *r*(91)=-.001, p>.05 and within the women r(99)=.017, p>.05. Likewise, number of fixations did not correlated with Continuous Performance task omission errors (CPT-O) $r_{(185)}$=-.043, *p*>.05, both within men r(88)=-.090, p>.05 and within women r(95)=-.050, p>.05, see Table 3 for *r* values.

A 2 x 3 analysis of covariance (ANCOVA) of the interaction of sex and condition on number of fixations was conducted, controlling for the quality of the eye-tracking data using the percentage of time the eye-tracker could track the participant's eyes. There was no interaction between experimental condition and sex, nor was there a main effect of sex. There was a statistically significant main effect of experimental group, *F*(2,159)=96.572, *p*<.001, partial η2 = .584).

Pairwise comparisons, with p-values set to .05 and using the Bonferroni correction, were done as follow up tests. Adjusted marginal mean number of fixations in the control group (adjusted *M*=17.91) were significantly lower than the Urban group (adjusted *M*=30.26) with a statistically significant mean difference of -12.109 fixations, 95% CI [-14.449, 9.769], $p<.001$. The control group also had significantly lower fixations than the nature group (adjusted *M*=30.017) with a statistically significant mean difference of -13.081 fixations, 95% CI[-15.654, -10.508], p<.001. The urban and nature groups did not significantly differ from each other, mean different of 1.021 fixations, 95% CI [-3.483, 1.332], $p>.05$. There were no significant pairwise comparisons between men and women within any of the three conditions.

In summary, participants in the control group had significantly less fixations compared to those in the nature or urban groups. In addition, the men and women in the sample did not significantly differ from each other on the number of fixations regardless of the experimental condition they were in.

3.2.2. Average Fixation Duration

The average fixation duration did not significantly correlate with either of the outcome measures for attention for the whole sample, the Digit Span Backwards (DSB), $r(190)=-.008$, $p>.05$ which remains the case within the men and the women. Likewise, the average fixation duration did not related to the Continuous Performance Task- Omissions (CPT-O), $r(183)=-.107$, $p>.05$, which remains true within men and within women.

A 2 x 3 analysis of covariance (ANCOVA) of the interaction of sex and condition on average fixation duration was conducted, controlling for the quality of the eye-tracking data using the percentage of time the eye-tracker could track the participant's eyes. There was a statistically significant interaction between experimental condition and sex when controlling for the quality of the eye-tracking data, $F(2,183)=5.18$, $p<.01$, partial $\eta2=.05$. Follow up simple main effects test demonstrate that there was only a significant difference between men and women on the average fixation duration within the control group, $F(1,183)=8.48$, $p<.01$, partial $\eta 2= .044$) and not within the urban $F(1,183)=1.68$, $p>.05$, partial $\eta 2= .009$ or natural $F(1,183)=0.44$, $p>,05$, partial $\eta 2= .002$ exposure groups.

Within the control group, the adjusted mean for the average fixation duration for women (adjusted $M=542.33$) was significantly higher than the adjusted mean duration for men (adjusted $M=469.85$), mean difference of 72.483 milliseconds, 95% CI [23.376, 121.591] $p<.05$, adjusted for multiple comparisons using the Bonferroni correction. These findings show the control group women's average fixation duration was longer than the men, suggesting women exerted more cognitive effort within the control group than the men. Pairwise comparisons show no significant differences between men and women within the nature group (Mean difference of 15.93 milliseconds, $SE=25.304$, 95% CI[-34.05, 65.90], $p>.05$, or within the urban group (mean difference 24.58 milliseconds, $SE=26.22$. 95% CI [-27.212, 76.363], $p>.05$.

In addition to the simple main effects described above, there were also significant main effect of condition. The participants in the control group (adjusted $M=506.01$, $SE=12.64$) had significantly longer mean duration of fixations compared to the natural group (adjusted $M=272.94$, $SE=11.77$); mean difference of 233.15, $SE=17.35$, $p<.001$, 95% CI [191.25, 275.05] and urban group (adjusted $M=270.83$, $SE=12.21$, mean difference 235.27, $SE=17.79$, $p<.001$, 95% CI 192.27, 278.26], across both sexes.

In summary, the participants in the control group had significantly longer fixation durations than the participants in the nature or urban groups. In addition, within the control group there were significant sex differences- women had significantly longer average fixation durations than the men.

3.2.3. Exploring Trends within Sex

The trends *within* sex were examined for the eye-tracking variables, number of fixation and average duration. The younger adult men had nearly the same number of fixations in the natural group (*M*=32.15, *SD*=4.32) compared to the men in the urban group (*M*=32.17, S*D*=6.23; *Cohen's d* = 0.003.) However, the women in the urban condition (*M*=33.16, *SD*=6.26) had a slightly higher average fixation count than the women in the natural condition (*M*=30.59, *SD*=6.88; *Cohen's d* =0.39).

The men in the urban group (*M*= 302.33, *SD*=70.89) had longer durations of fixations compared to the men in the natural group (*M*=280.98, *SD*=35.62; *Cohen's d* =.38). In contrast, women in the natural group (*M*=266.70, *SD*=46.40) had longer fixation durations than the women in the urban group (*M*=262.93, *SD*=36.16, *Cohen's d* = 0.09).

In summary, the men and women in the sample had different trends within the nature and urban groups, such that women had more fixations, but shorter duration fixations, in the urban group compared to the natural group and men had the same number of fixations in each group but longer durations in the urban group, however these differences were small and insignificant.

3.3.Younger Adults Mood

Negative affect, measured by the PANAS-Negative affect scale, is not related to either of the attention measures. Positive affect, measured by the PANAS Positive affect scale, is also not related to either attention measure when looking at the whole sample (see Table 3). Within women, however, posttest performance on the DSB had a small, negative relationship with positive affect, $r(99)=-.282$, $p<.01$.

A 2 x 3 between-subjects multivariate analysis of covariance (MANCOVA) was conducted to examine the impact of sex and experimental condition on post-test negative affect and positive affect, controlling for depression (BDI-II). There was not a statistically significant interaction between sex and experimental group on positive affect, $F(2,162)=.647$, $p>.05$, partial $\eta2=.008$, or on negative affect, $F(2,162)=.863$, *p*>,05, partial $\eta2 =.008$. Nor was there a significant main effect of sex for either negative or positive affect.

There was, however, a statistically significant main effect of condition for positive affect $F(2, 162)=5.21$, $p=.006$, partial $\eta2=.06$, but not for negative affect, $F(2,162)=1.23$, $p>.05$, partial $\eta2=.015$. Pairwise comparisons using the Bonferroni correction were conducted to compare the participants in the different conditions on positive affect. The adjusted for depression marginal means for positive affect in the younger adults in the natural group (*M*=24.41, *SE*=1.05) and the control group, (*M*=19.72, *SE*=1.04) had a statistically significant mean difference of 4.686, 95% CI[1.659, 6.56], p<.01 indicating that the natural condition resulted in higher positive affect compared to the control condition. There was not a statistically significant mean difference in positive affect between those in the natural group and the urban group (adjusted *M*= 22.57, *SE*=.729) with a mean difference of 1.699, *SE*=1.038, 95%CI[-.812, 4.210], p>.05 or between the urban and control groups, mean difference of -.244, *SE*=.402, 95%CI[-1.229,.719] p>.05).

The difference in positive affect between the participants exposed to natural images (*M*=23.70, *SD*=7.96) and those exposed to urban images (*M*=22.80, *SD*=8.59) were not significant, and had a small effect size (*Cohen's d*=0.108, *Hedges' g*=0.108). Similarly, the difference in negative affect between those exposed to natural images (*M*=12.17, *SD*=2.63) and those exposed to urban images (*M*=12.11, *SD*=2.16) were not significant and had a small effect size (*Cohen's d*=0.02, *Hedge's g*=0.02). Though there was a statistically significant difference in the negative affect between those who looked at the natural images and the control images (*M*=12.79, *SD*=2.86), the effect size was small (*Cohen's d*= 0.22, *Hedges' g*= 0.22)

In summary, participants in the natural condition had higher post-test scores of positive affect compared to participants in the control condition. However participants in the nature, urban, and control groups did not differ in their post-test negative affect. Additionally, the men did not significantly differ from the women, regardless of their experimental group, on either positive or negative affect.

3.3.1 Exploring Trends within Sex.

Within sex there were small differences in positive affect for men, but not women. Men had greater positive affect in the natural group (*M*=25.26, *SD*=7.05) compared to the men in the urban group (*M*=23.21, *SD*=7.31; *Cohen's d* = 0.28) and women functionally the same positive affect in the natural group (*M*=23.26, *SD*=7.57) compared to women in the urban group (*M*=22.96, *SD*=9.78; *Cohen's d* = 0.03). Males had nearly the same negative affect in the natural (*M*=12.40, *SD*=3.22 and the urban group (*M*=12.27, *SD*=2.17; *Cohen's d* = 0.05.), similarly the women had nearly the same negative affect in the natural (*M*=12.04, *SD*=2.21) compared to the urban group (*M*=11.92, *SD*=2.23; *Cohen's d* = 0.05).

These trends demonstrate the for the most part, the group condition did not have different impacts on positive and negative affect within men or within women with the exception that men within the natural group had slightly higher positive affect than the men within the urban group. This difference, however, is not statistically significant and has a small effect size.

3.4.Younger Adults Attention – The Attention Restoration Hypothesis

3.4.1. Digit Span Backwards.

Posttest performance on the digit span backwards test of attention was not significantly related to the number of omissions individual's made on the continuous performance task, our other outcome measure for attention, $r(185)=-.185$, $p>.05$., within just the younger men $r(89)=-.122$, $p>.05$, and within the younger women $r(96)=.024$, $p>.05$

Within the younger adult sample, a two-way between subject analysis of covariance (ANCOVA) was conducted to examine the impact of sex and nature exposure on Digit Span Backwards task, controlling for pretest performance on the task. There was not a statistically significant two-way interaction between sex and experimental condition while controlling for pretest performance, $F(2,185)=2.371$, $p=.096$, partial $\eta2=.024$. In addition, there was no main effect of condition or sex. Excluding the control condition, there is no difference between the participants in the natural (M=9.30, SD=2.67) and urban conditions (M=9.21, SD=1.93) (*Cohen's d*= 0.03; *Hedge's g*=0.03). This indicates that the participants in the nature, urban, and control conditions did not significantly differ from each other on their posttest Digit Span Backwards performance. In addition, the men and women in the sample did not significantly differ from each other on posttest Digit Span Backwards performance regardless of condition.

3.4.2. Trends within Sex.

Secondary analysis the trends within men and women differ from one another. Although women perform better on the digit span backwards after being exposed to the urban condition (M=9.30, SD=1.54) compared to the natural condition (M=8.69, SD=2.43; *Cohen's d* =0.299), men perform better in the natural condition (M=10.00, SD=2.81) than in the urban condition (M=9.13, SD=2.27; *Cohen's d* =0.341). In summary, although women perform better on this attention task in the urban condition compared to the nature condition, men tend to perform better in the nature compared to the urban, with effect sizes in the small range.

3.4.3. Continuous Performance Task- Omissions.

Posttest performance on the Continuous Performance task number of omissions was not related to positive affect, $r(181)=.051$, $p>.05$, which remains true within men $r(86)=.031$, $p>.05$, and within women $r(95)=.014$, $p>.05$. There is a significant correlation between CPT-O and negative affect, $r(181)=.172$, $p<.05$, however there is not a significant relationship when you break it down by just within women, $r(95)=.124$, $p>.05$, or just within the men $r(86)=.175$, $p>.05$.

Next, a two-way between subjects analysis of covariance (ANCOVA) was conducted to examine the impact of sex and nature exposure on the number of omissions on the continuous performance task (CPT), controlling with pretest performance on the same task. There was not a significant interaction between sex and condition on the number of omissions, $F(2,178)=0.457$, $p>.05$, partial $\eta 2=.005$. There was no main effect of condition on performance on the CPT. There was, however, a significant main effect of sex $F(1,178)=7.40$, $p<.05$, $\eta 2=0.40$.

The main effect of sex showed a statistically significant difference in the adjusted marginal mean number of omissions for men (adjusted M= 5.909) and women (adjusted M=4.704), demonstrating that across conditions on average men made more omission errors than women with a mean difference of 1.38, SE=.51, CI[.378, 2.374], $p<.05$. These findings indicate that the participants in the nature, urban, and control conditions did not significantly differ from one another. However, across all conditions men (M=6.08, SD=4.84) made more errors of omission on the CPT than women (M=4.34, SD=3.38; *Cohen's d*=0.41).

3.4.4. Trends within Sex.

Within men, there is no difference in the amount of omission errors made on the posttest CPT between the natural and urban groups. Men in the natural condition (M=6.61, SD=4.38), performed nearly the same as men in the urban condition (*M*=6.45, *SD*=5.16, *Cohen's d* = 0.03). Within women, those in the natural condition (*M*=3.91, *SD*=3.26) made less omission errors than those in the urban condition (*M*=5.29, *SD*=3.87, *Cohen's d* = 0.38), though the effect size is small.

In summary, the men in the natural and urban groups did not have differ in the amount of omission errors the made. In contrast, the women made less omission errors in the natural condition than in the urban condition, with a small effect size.

3.5 Older Adults Eye-tracking

20 older adults were run in a pilot test for this purposes of this study. Due to anticipated lower sample size, older adults were randomly sorted into only the two experimental conditions, the nature exposure and the urban exposure, in order to increase power in the experimental conditions and to make comparisons in effect size to comparable groups in previous research. As expected, there are two few individuals in each group for significant differences to emerge- however trends are examined.

In the same manner as the younger adults, the eye tracking differences were examined controlling for eye tracking quality and excluding cases where the eye tracker picked up the eyes less than 75% of the time (*n*=3).

3.5.1. Number of Fixations

In keeping with the younger adults sample, the older adults number of fixations did not significantly correlate with either attention outcome measure, DSB $r(19)=.028$, $p>.05$, or CPT-O $r(19)=-.170$, $p>.05$. This was also true of the older adult men for DSB $r(8)=.506$, $p>.05$ and the CPT-O $r(8)=.000$, $p>.05$. However, for the older adult women, though there was no relationship with the CPT-O $r(11)=.195$, $p>.05$, there was a significant correlation between their number of fixations and their DSB performance, $r(11)=-.635$, $p<.05$.

A 2 x 2 ANCOVA was used to look at the effects of condition and sex on the eye tracking metrics. There is no significant interaction between sex and condition on number of fixations ($F(1,11)=.039$, $p>.05$, partial η2=.004, and no significant main effect of sex $F(1,11)=.053$, $p>.05$, partial η2==.005 or main effect of condition $F(1,11)=.092$, $p>.05$, partial η2=.008. The older adults in the natural and urban conditions did not significantly differ from one another on the number of fixations. In addition, the older adult men and women did not differ from each other on the number of fixations regardless of the experimental condition they were in.

3.5.2. Average Fixation Duration

Within the older adult sample, average fixation duration did not have a significant relationship with any of the mood or attention outcome variables (see Table 3).

A 2 x 2 ANCOVA examining the impact of sex and condition on the average fixation duration found no significant interaction $F(1,11)=.478$, $p>.05$, partial η2 =.041, no main effect of sex $F(1,11)=.232$, $p>.05$, partial η2=.021, and no main effect of condition, $F(1,11)=.491$, P>.05, partial η2=.021. In summary, older adult men and older adult women do not differ from each other on the average fixation duration, and those in the natural and urban conditions do not differ from each other on their average fixation duration.

3.5.3. Trends within Sex.

For number of fixations, older adult men in the urban condition (*M*=25.99, *SD*=13.36) had a greater number of fixations compared to the natural condition (*M*=18.76, *SD*=.622; *Cohen's d*=.76), in contrast to the younger adults men who had functionally equivalent fixations in both groups. The older adult women in the urban condition (*M*=27.28, *SD*=9.23) had more fixations compared to the older adult women in the natural condition (*M*=25.62, *SD*=4.90; *Cohen's d*=0.22), similar to the younger adult women.

For fixation duration, the trends within each sex were that the men in the urban condition (*M*=218.18, *SD*=33.92) tended to have longer durations than the older adult men in the natural condition (*M*=198.755, *SD*=19.61; *Cohen's d* =0.70) similar to the younger men in the undergraduate sample. Likewise, the older adult women in the urban condition (*M*=246.53, *SD*=63.05) had longer durations than older adult women in the natural condition (*M*=215.56, *SD*=19.49; *Cohen's d* = 0.71.) This is in contrast to the undergraduate women that had longer durations in the natural condition compared to the urban condition.

3.6. Older Adults Mood

There is a significant correlation between posttest positive affect and performance on the DSB, $r(18)=-.507$, $p<.05$. This relationship is not significant within only the men or only the women of the sample. In addition, there is not a significant relationship with negative affect. See Table 4.

A 2 x 2 between subjects MANCOVA was conducted to examine the impact of sex and experimental condition on negative and positive affect, controlling for pre-test differences and depression. This is the same analysis that was done on the younger adults, but significantly underpowered due to the small sample of older adults.

There was no significant interaction between sex and experimental group on positive $F(1,11)=.801$, $p>.05$, partial $\eta 2= .068$ or negative affect $F(1,11)=.017$, $p>.05$, partial $\eta 2=.002$, similar to the younger adults. There were also no main effects of sex or condition on either positive or negative affect unlike the younger adult sample which had a main effect of condition on positive affect. The difference in negative affect between older adults in the nature condition (*M*=10.87, *SD*=1.72) and in the urban condition (*M*=11.27, *SD*=2.41)was not significant with small effect size (*Cohen's d*=0.19; *Hedges' g*=0.19) The difference in positive affect between the older adults in the nature condition (*M*=33.75, *SD*=7.88) and the urban condition (*M*=36.81, *SD*=7.17) was not significant, with moderate effect size (*Cohen's d*=0.41, *Hedges' g*=0.41), with the older adults in the urban condition having greater positive affect.

3.6.1. Trends within Sex.

The negative affect did not differ between older adult men in the natural condition (*M*=10.50, *SD*=.07) and the older men in the urban condition (*M*=10.00, *SD*=.00; Cohen's *d*= 10.10). The positive affect was slightly higher in the men in the natural condition (*M*=40.4, *SD*=12.02) compared to the men in the urban condition (*M*=38.33, *SD*=7.05; *Cohen's d*= 0.19).

The negative affect also did not differ for the older adult women in the natural condition (*M*=10.2, *SD*=.44) from the women in the urban condition (*M*=12.80, *SD*=3.03; *Cohen's d*= 1.20). However, for positive affect women in the urban condition (*M*=35.00, *SD*=7.14) reported greater positive affect than the women in the natural condition (*M*=31.40, *SD*=6.50; *Cohen's d*=0.52). In summary, although negative affect did not differ within sex for the older adults, older men in the natural condition had more positive affect than men in the natural. In contrast, women in the urban condition had more positive affect than women in the natural condition.

3.7. Older Adults Attention – The Attention Restoration Hypothesis

3.7.1. Digit Span Backwards

A 2 x 2 ANCOVA on the effect of sex and condition on DSB performance in older adults, controlling for pretest performance, showed no significant interaction between sex and experimental condition $F(1, 14)$ =2.058, $p>.05$, partial η2==.128 no significant main effects of sex *F*(1,14)=4.45, *p*>.05, partial η2= .031, or condition F(1,14)=.559, *p*>.05 partial η2= .025. The older adults exposed to natural images did not differ in their posttest DSB performance compared to the older adults exposed to urban images. In addition, the men and women did not significantly differ from each other on DSB performance. Though the differences are not statistically significant, comparison of means suggests that the participants in the natural condition (*M*=10.38, *SD*=1.41) scored higher than those in the urban condition (*M*=9.45, *SD*=3.01) (*Cohen's d*=0.39; *Hedges' g*=0.37).

3.7.2. Trends within Sex.

However, the mean scores trended in the same direction as the younger adults sample, though they were not statistically significant, with men (*M*=10.33, *SD*=1.53) in the natural group performing better than the men in the urban group (M=8.20, SD=3.56; *Cohen's d* = 0.79). Women in the urban (*M*=10.50, *SD*=2.258) group performed virtually the same as the women in the natural group (*M*=10.40, *SD*=1.517; *Cohen's d* =0.051). For both the younger and older adults, men perform better on the posttest DSB in the natural group compared to men in the urban group. Although the reverse was shown for women in the younger adult group, the women in the older adult natural and urban groups did not differ on posttest DSB performance.

3.7.3. Continuous Performance Task – Omissions

The number of omission errors older adults made on the CPT did not have a significant relationship with any of the other outcome variables, see table 3 for relevant *r* values.

Similar to the younger adults, on the number of omissions on the CPT, there was no significant interaction between sex and experimental condition *F*(1,15)=.103, *p*>.05, partial η2= .007, nor was there a main effect of condition, *F*(1,15)=.000, *p*>.05, partial η2= 0, but there was a significant main effect of sex *F*(1,15)=4.852, *p*=.044, partial η2=.244. Pairwise comparisons adjusted for Bonferroni show a mean difference of 5.528, *p*<.05, CI [1.79, 10.876]. This main effect was in the same direction as the younger adults with men having more omissions adjusted for pretest performance (adjusted *M*=6.681, *SE*=1.74) than the women (adjusted *M*=1.153, *SE*=1.51) within the older adults. Experimental condition does not impact the number of omissions on the CPT in older adults. However, older adult men (*M*=6.58, *SD*=5.91) make significantly more omission errors that older adult women (*M*=1.18, *SD*=1.40; *Cohen's d*=1.26, *Hedge's g*=1.32).

3.7.4. Trends within Sex.

Looking within each sex, the trends went the same direction as the younger adults. The older adult men made more omission errors in the natural condition (*M*=7.00, *SD*=3.646) than in the urban condition (*M*=6.37, 7.286; *Cohen's d* =0.12), and women made more omission errors within the urban (*M*=1.50, *SD*=1.6545) condition compared to the natural (*M*=.80, *SD*= 1.095; *Cohen's d* = 0.50). In summary, the older adult men made more omission errors in the natural condition compared to the urban condition, and older adult women made more omission errors in the urban condition compared to the natural condition.

4. DISCUSSION

The purpose of the current study was to examine the sex differences within the attention restoration effect - or the propensity for better attention performance after exposure to nature, or nature images, compared to exposure to urban environments, or urban images (Kaplan, 1995). In addition, this research also hoped to further explore the impact of exposure to nature on mood and to expand the population studied to an older population that may have more to gain from a restoration effect than more commonly studied undergraduate students. In order to evaluate this effect, 200 undergraduate students from Texas A&M (92 men, 101 women, 7 other) were randomly sorted into one of three experimental groups, where they were presented with images of nature, urban environments, or a control for 12 minutes. Likewise, 20 older adults (9 men, 11 women) were sorted into two experimental groups and were presented with nature or urban images.

All participants across both age groups completed pre exposure and post exposure measures of affect using the Positive and Negative Affect Schedule (PANAS), as well as pre- and post-test measure of attention including the Continuous Performance Task-Omissions (CPT-O) and Digit Span Backwards (DSB). Pre-test measures of attention were included to address the previous criticism that being unable to control for pretest differences is a weakness of much of Attention Restoration Theory (ART) research (Hartig & Jahncke, 2017). Other strengths of the present study include the large sample size of younger adults, the novel control condition, the inclusion of two attention tasks to deplete pre-exposure attention, as well as eye-tracking as a measure of visual attention.

Despite the relatively rigorous experimental design, comparisons between experimental conditions showed an unexpected lack of restoration effect on measures of attention. Most notably, there were no differences in post-test attention performance, as measured by the DSB and CPT-O, between participants exposed to nature images compared to participants exposed to urban or control images in the younger adults The absence of the attention restoration effect is noteworthy given that the DSB has demonstrated the restoration effect in the past, with effect sizes in the small to moderate range (Ohly et al., 2016; Stevenson et al., 2018). Previous work has demonstrated that the effect size of attention restoration is largest in experimental designs where attention is depleted prior to the exposure to nature (estimated pooled *Hedge's g*=.307). (Stevenson et al., 2018). For that reasons, in the present study, participants completed the continuous performance task, which requires a long period of sustained attention, prior to the experimental nature exposure. Despite this design consideration, the difference in attention performance between those who were exposed to natural images compared to those exposed to urban images was negligible in the younger adults (*Hedge's g*=0.03).

The results of the present research are consistent with previous studies that found no restorative effects of nature on attention, e.g. Ohly, Stevenson. In addition, the present study found no evidence consistent with a positive effect of nature on mood (Olafsdottir et al., 2020). However, previous research on the impact of exposure to nature on mood has been mixed (Berman et al., 2008, 2012; Gidlow et al., 2016). Younger adults in the exposure to nature group had greater positive affect post-exposure compared to those in the control group (*Cohen's d*=0.56). However there was no difference in affect between those who looked at nature images compared to those who looked at urban images, consistent with previous research (Berman et al., 2008; Chow & Lau, 2015).

Measures of attention using eye-tracking were included as previous work has suggested that there may be a difference between *how* urban environments and nature environments are viewed. Photographs of nature are associated with lower number of fixations than photographs of urban scenes, consistent with Kaplan's hypothesis of nature producing 'soft fascination' (Berto, Massaccesi, & Pasini, 2008; Kaplan, 1995; Valtchanov & Ellard, 2015a). In contrast, our results did not demonstrate any significant differences in the average number of fixations between participants looking at natural images compared to participants looking at urban images. In addition, our study did not find any differences in the duration of the fixations between urban and natural environments. However, the novel control condition differed from the other two conditions in that those in the control, across men and women, younger and older samples, had longer durations and less fixations than the other two stimuli.

The finding that the control images of a cross hair on an empty screen produced less fixations and longer durations in comparison to the other two conditions is not entirely surprising, as the cross hair provides a single place for the gaze to rest on the screen, unlike relatively more complex images of urban and natural environments. It does, however, contrast to previous assertions that a lower number of fixations indicate a lower cognitive load (Grant & Spivey, 2003; Ikehara & Crosby, 2005). Should that have been the case, we might have seen better performance on post task measure of attention for those in the control group, who had significantly lower number of fixations- but we did not.

Duration, often a signal of cognitive processing (Irwin, 2004), was also longer in the control group compared to both the urban and nature groups. It is possible that focusing on the cross hair in the control condition took more effortful control compared to the natural and urban conditions, though the participants were instructed to look at the screen and not specifically to focus on the cross hair. But if so, this greater cognitive effort was not reflected in the posttest performance on the Digit span backwards or CPT omissions, as the participants in the control condition were not significantly different from natural or urban exposed groups on posttest measures of attention despite the significant differences in the group on both of the eye tracking variables.

In fact, the only significant difference between the control group and the other two groups outside of eye-tracking was less positive affect in the control group compared to the nature group. This impact of condition on positive affect is similar to the pattern shown in the duration of the fixations, or cognitive effort- in sum, those in the control group had fewer fixations, longer duration of fixations, and less positive affect in comparisons to the other two groups. The low interest images that require less fixations resulted in lower positive affect, this finding is consistent with the idea that it is not the simply the reduction of image complexity, or mental bandwidth (Basu et al., 2019), that contributes to greater positive affect, but rather, nature's 'soft fascination' may have a mood effect. However, much like directed attention, soft fascination has not been operationalized within the ART field and was not measured in the present study, so this explanation remains speculative.

The differences in the control group compared to the nature group provide evidence that should the content of the photos vary widely enough, a difference will be reflected in the eye-tracking data. The present study did not detect a restoration effect nor did it find differences in eye tracking measures between the nature and urban groups. This could perhaps be an issue with the nature and urban stimuli used in this research. In order to control for anticipated known differences in eye tracking due to presence of words/reading in images and fixations on faces, urban images without writing and without people were selected. This is unlike real exposure to urban environments, which contain billboards, road signage, store signage, etc., as well as many more people than may be expected in natural environments. The erasure of these real world differences in this study decreases the external validity of the exposure groups and may contribute to the lack of differences in both the eye-tracking measures and the attention restoration theory outcome measures of attention and mood.

Further analysis such as gaze-path analysis to look at the content of the photos (Nordh, Hagerhall, & Holmqvist, 2013) or the use of machine learning to examine individual differences in gaze path, such as recent research that has used gaze-path analysis to distinguish expert's from novice's eye patterns completing mammographic screenings (Alamudun, Yoon, Hudson, Morin-ducote, & Hammond, 2017), are possible avenues to explore in the future, but beyond the scope of the current study.

4.1. Sex differences

Men and women did not differ in age, race and education or their reports of prior nature exposure. Nor were there sex differences in the attention restoration outcome variables of the eye-tracking, mood, and attention. There are two exceptions to these general findings - first, men made more omission errors on the CPT than the women in both the younger adult (*Cohen's d*=0.41), consistent with prior evidence that men typically make more omission errors than women on this task (Conners, Epstein, Angold, & Klaric, 2003). Second, men had significantly shorter fixation durations within the control group in the younger adults. Both of these findings suggest that the men greater difficulty with prolonged sustained attention compared to the women. However, any such difference was not reflected in post-test DSB scores, consistent with previous research that has not found sex differences in working memory tasks (Grégoire & Linden, 2007; Kaufman, 2007).

The lack of generalization between the two attention-related measures may be due to the differences in cognitive skills or resources needed to successfully perform digit span backwards versus the continuous performance tasks. Although both use effortful, directed attention- which this study aimed to deplete then restore-the DSB utilizes working memory, where the participants must actively manipulate information that they hold in working memory. The continuous performance task, in contrast, involves prolonged sustained attention in which participant must inhibit their space-bar-pressing habit when they alert to the letter ‘X’. Similar to the CPT, the control experimental condition involved long dwell times on a single fixed point- it is therefore not surprising that the men in the sample had both more omission errors and shorter duration of fixations, suggesting more trouble with sustained attention in both tasks which did not generalize to the short DSB task.

Overall, there was no evidence for the attention restoration effect in the present research. However, whereas men in the nature condition performed best on the DSB task compared to men in the urban condition, women in the nature condition performed worst on the DSB compared to women in the urban conditions. Women the nature condition produced worst performance on the DSB, lowest fixation count, longest fixation durations compared to women in the urban condition. Men in the natural condition had better DSB performance, shorter fixation durations, and increased positive affect compared to men in the urban condition.

Evolutionary psychologists have proposed women’s historic roles as gatherers and men’s roles as hunters may explain present day sex differences in cognitive ability (Silverman, Choi, & Peters, 2007; Silverman & Eals, 1992). Sex differences in visual processing such that women in general show a bias for processing detailed elements of visual stimuli while men show a bias for processing global elements of a display (Alexander, 2003) may contribute to women’s greater ‘cognitive load’ demonstrated by worsened performance on the DSB and higher fixation count that women show on natural scenes compared to urban. However, in the present study these trends were small and were likely due to chance rather than real difference. Future studies using machine learning to look at gaze paths would provide a stronger test of any sex differences in the visual processing of nature and urban scenes. Alternatively, there may be no sex differences in the attention restoration effect and the processing of nature stimuli, in keeping with the general finding that the effect sizes of gender differences across many cognitive domains are quite small (Hyde, 2005).

4.2. Older Adults

A second goal of the present study was to examine attention restoration in an older adult population. The results of our pilot study of older adults show the same pattern of the younger adults discussed above, namely- no impact of experimental condition on attention measured by DSB or CPT-O. Likewise, the older adults do not differ in mood as a result of their experimental condition, nor were either of the eye-tracking variables significantly different. Finally, older adult men, similar to the younger adults, make more omission errors on the CPT compared to older adult women.

There are still a number of reasons older adults should be included in attention restoration research. The number of adults over the age of 65 years in the United States is expected to double from 43.1 million in 2012 to 83.7 million by 2050 (Ortman, Velkoff, & Hogan, 2014). As older adults become an increasing proportion of the population, there is increased need to provide and evaluate evidence based practices for maximizing quality of life for older adults. Aging is associated with diminished performance of several areas of executive function including mental processing speed, episodic memory, and task switching (Hoyer & Verhaeghen, 2006; Craik & Salthouse, 2008; Dorbath, Hasselhorn, & Titz, 2011; Wasylyshyn & Sliwinski, 2011). Compared with younger adults, older adults have decreased performance on tasks of attentional control (Kray et al., 2005). If the underlying mechanism of older adult's diminished performance on tasks of attentional control is the fatigue of directed attention resources, then the restoration of those resources may be an important intervention to improve older adult's quality of life.

Research in the public health sector aimed at improving quality of life has begun to demonstrate that older adults benefit from exposure to natural environments. For instance, older adults with access to greenspace report stronger social ties to their community (Kweon, Sullivan, & Wiley, 1998) and participate in outdoor physical exercise more (K. B. Watson et al., 2016). Additionally, studies indicate that gardening can reduce stress and decrease symptoms of depression in older adults (Detweiler et al., 2012). However, many of these studies are correlational (Agahi & Parker, 2008) or deal in the perception of restoration (Hassmén, 1996; Pasini, Berto, Brondino, Hall, & Ortner, 2014; Ratcliffe, Gatersleben, & Sowden, 2013) rather than the demonstration of improved cognitive performance.

Despite these potential benefits, older adults are rarely the focus in research on ART. A meta-analysis of the effects of exposure to nature on attention included only one study with an older adult population (Ohly et al., 2016). Residents of a nursing home showed increased concentration after spending an hour outdoors in a garden setting compared to spending an hour indoors, as demonstrated by improved performance on a digit span backwards task (Ottosson & Grahn, 2005).

Furthermore, the aging process impacts men and women in different ways (Cowell et al., 1994; Der & Deary, 2006). For instance, men see a greater decrease in brain matter volume in the frontal and temporal lobes compared to women as they age (Cowell et al., 1994). Women also have a greater life expectancy than men and often make up a greater proportion of participants in studies of healthy older adults. Additionally, men and women interact with nature in different ways. Men choose outdoor leisure activities more often than women across the lifespan (Bennett, 1998). A recent cohort study found that the greater access to neighborhood parks over the life course is associated with the slowing of cognitive decline during later life, and the effect was strongest in women (Cherrie et al., 2018). In sum, the continued exploration of sex difference into later life can build upon known behavioral and cognitive differences to maximize the effectiveness of potential interventions that utilize the restorative impact of nature for each sex.

4.3. Limitations and Future Directions

There are several limitations to this study that may explain the null results found, in contrast to previous research, and that provide ideas for future research. First, the power analysis determining sample size may have been based on an over-estimation of the effect size. Stevenson's 2018 meta-analysis provided several explanations of limitations to previous work that may have contributed to the over-estimation of the effect size of the attention restoration effect. First is the analysis of only posttest measures rather than measures that control for baseline, such as ANCOVAS. Second is the inclusion of both artificial and in vivo exposures to nature in pooled estimates of effect size, which may contribute to the over prediction of artificial exposure's experimental design. Finally, the lack of construct validity for 'directed attention' and the vast number of cognitive tests used to measure change in attention while studying ART may overestimate the effect for more specific constructs.

Another issue is the external validity of the experimental exposure groups. Although a restoration effect has been detected after brief periods of exposure to nature (Berman et al., 2008), it is a possibly that the 12 minute exposure duration was not sufficient to elicit an effect.

In addition, although previous work has successfully detected a restoration effect using artificial, photographic exposures of nature (Gamble et al., 2014; Valtchanov & Ellard, 2015b; Agnes E. Van den Berg, Jorgensen, & Wilson, 2014), there are many differences between spending time outdoors in nature and the experience of participants viewing images of nature in a windowless room, on a computer, after calibrating to an eye tracking device.

Considering the Ulrich stress-reduction model, there are many other sensory cues that one is outdoors including the feeling of the breeze, the sun, the humidity, nature sounds such as birds, bugs, and moving water, and smells an air quality that may provide further cues of wellness and safety (Ratcliffe et al., 2013; Ulrich et al., 1991). Likewise, the attention required to navigate an urban environment are much different than the attention required to sit and look of images of an urban environment must be distinct. Although Stevenson et al (2018) reported that there are no significant differences in effect size between artificial and natural exposure for working memory tasks such as the DSB specifically, they conclude that within many alternative tasks in-vivo exposure to nature produces a larger effect size than artificial exposure to nature. It reminds a possibility that the artificial exposure used in this laboratory experiment was too distinct from real exposure to natural environments, and such should be a consideration for future research.

Previous research has also commented on the many extenuating factors that impact an individual's exposure to greenspace over the course of their lifetime, especially SES, which have impacts on cognition, mood, and psychopathology. Reuben et al. (2019) found that children's access to residential greenspace, measured using satellite imagery of the children's homes, scored higher on IQ tests that assessed executive function, attention and working memory- until they controlled for socioeconomic status. While prior access to greenspace was considered in the current research, the questions included did not relate to outcomes measures and may not have been sensitive enough to distinguish between individuals' differences in prior greenspace exposure.

As the field of attention restoration research surges, there are several important considerations for future research. The first is construct validity- directed attention was first defined by Kaplan as the effortful controlled aspect of attention (Kaplan, 1995; Kaplan & Berman, 2010). Since the introduction of this idea the ART field has extrapolated that to many tasks and generalized it to many facets of life. However the need for specificity is apparent when trying to make comparisons across studies as the recent meta-analyses of Ohly and Stevenson have demonstrated (Ohly et al., 2016; Stevenson et al., 2018).

Expanding this research to older adults remains important- despite the reality that the recruitment of healthy participants over the age of 65 outside of a medical setting is difficult. The potential benefits are this population are numerous, and as this population grows the research will both become easier and more important. In addition, further study on the potential sex differences or the way that sex and gender interact with individual's experience of nature is interesting and should be considered. Men and women interact with nature in different ways and the resulting impact on their affect and cognition will differ too (Bos et al., 2016; Ho et al., 2005; MacBride-Stewart et al., 2016). The adaptive ways in which men and women use their relationship with nature are areas that can be harnessed for increasing health and wellbeing in an increasingly industrialized, artificial world (Agahi & Parker, 2008). As these differences interact with aging, we can become more specific in our approach to implementing this research into increasing wellbeing and health as people age.

REFERENCES

Agahi, N., & Parker, M. G. (2008). Leisure Activities and Mortality. *Journal of Aging and Health*, *20*(7), 855–871. https://doi.org/10.1177/0898264308324631

Alamudun, F., Yoon, H., Hudson, K. B., Morin-ducote, G., & Hammond, T. (2017). Fractal analysis of visual search activity for mass detection during mammographic screening. *Medical Physics*, *44*(3), 832–846. https://doi.org/10.1002/mp.12100

Alexander, G. (2003). An Evolutionary Perspective of Sex-Typed Toy Preferences: Pink, Blue, and the Brain. *Archives of Sexual Behavior, 32*, 7–14. https://doi.org/10.1023/A:1021833110722

Awh, E., Vogel, E. K., & Oh, S. H. (2006). Interactions between attention and working memory. *Neuroscience*, *139*(1), 201–208. https://doi.org/10.1016/j.neuroscience.2005.08.023

Basu, A., Duvall, J., & Kaplan, R. (2019). Attention Restoration Theory: Exploring the Role of Soft Fascination and Mental Bandwidth. *Environment and Behavior*, *51*(9–10), 1055–1081. https://doi.org/10.1177/0013916518774400

Beck AT, Steer RA, C. M. (1988). Psychometric properties of the Beck depression inventory: Twenty-five years of evaluation. *Clin Psychol Rev*, *8*, 77–100.

Bennett, K. M. (1998). Gender and longitudinal changes in physical activities in later life. *Age and Ageing*, *27 Suppl 3*(3), 24–28. https://doi.org/10.1093/ageing/27.suppl_3.24

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science*, *19*(12), 1207–1212. https://doi.org/10.1111/j.1467-9280.2008.02225.x

Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., … Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders*, *140*(3), 300–305. https://doi.org/10.1016/j.jad.2012.03.012

Berto, R., Massaccesi, S., & Pasini, M. (2008). Do eye movements measured across high and low fascination photographs differ ? Addressing Kaplan ' s fascination hypothesis, *28*, 185–191. https://doi.org/10.1016/j.jenvp.2007.11.004

Bertram, C., & Rehdanz, K. (2015). The role of urban green space for human well-being. *Ecological Economics*, *120*, 139–152. https://doi.org/10.1016/j.ecolecon.2015.10.013

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. https://doi.org/10.1016/S1469-0292(01)00038-3

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. *Cognitive Brain Research*, *25*(1), 107–116. https://doi.org/10.1016/j.cogbrainres.2005.04.011

Bolte, G., Nanninga, S., Dandolo, L., & Study, I. (2019). Sex / Gender Di ff erences in the Association between Residential Green Space and Self-Rated Health — A Sex / Gender-Focused Systematic Review.

Bos, E. H., van der Meulen, L., Wichers, M., & Jeronimus, B. F. (2016). A primrose path? Moderating effects of age and gender in the association between green space and mental health. *International Journal of Environmental Research and Public Health*, *13*(5). https://doi.org/10.3390/ijerph13050492

Cherrie, M. P. C., Shortt, N. K., Mitchell, R. J., Taylor, A. M., Redmond, P., Thompson, C. W., … Pearce, J. R. (2018). Green space and cognitive ageing: A retrospective life course analysis in the Lothian Birth Cohort 1936. *Social Science and Medicine*, *196*(January 2017), 56–65. https://doi.org/10.1016/j.socscimed.2017.10.038

Chow, J. T., & Lau, S. (2015). Nature gives us strength: Exposure to nature counteracts ego-depletion. *Journal of Social Psychology*, *155*(1), 70–85. https://doi.org/10.1080/00224545.2014.972310

Cohen, J. (1992). Cohen (1992) - A power primer.pdf. *Psychological Bulletin*.

Conners, C. K., Epstein, J. N., Angold, A., & Klaric, J. (2003). Continuous Performance Test Performance in a Normative Epidemiological Sample. *Journal of Abnormal Child Psychology*, *31*(5), 555–562. https://doi.org/10.1023/A:1025457300409

Cowell, P. E., Turetsky, B. I., Gur, R. C., Grossman, R. I., Shtasel, D. L., & Gur, R. E. (1994). Sex differences in aging of the human frontal and temporal lobes. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *14*(8), 4748–4755. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8046448

Der, G., & Deary, I. J. (2006). Age and sex differences in reaction time in adulthood: Results from the United Kingdom health and lifestyle survey. *Psychology and Aging*, *21*(1), 62–73. https://doi.org/10.1037/0882-7974.21.1.62

Detweiler, M. B., Sharma, T., Detweiler, J. G., Murphy, P. F., Lane, S., Carman, J., … Kim, K. Y. (2012). What is the evidence to support the use of therapeutic gardens for the elderly? *Psychiatry Investigation*, *9*(2), 100–110. https://doi.org/10.4306/pi.2012.9.2.100

DiQuattro, N. E., & Geng, J. J. (2011). Contextual Knowledge Configures Attentional Control

Networks. *Journal of Neuroscience, 31*(49), 18026–18035. https://doi.org/10.1523/JNEUROSCI.4040-11.2011

Dorbath, L., Hasselhorn, M., & Titz, C. (2011). Aging and executive functioning: A training study on focus-switching. *Frontiers in Psychology*, *2*(OCT), 1–12. https://doi.org/10.3389/fpsyg.2011.00257

Gamble, K. R., Howard, J. H., & Howard, D. V. (2014). Not just scenery: Viewing nature pictures improves executive attention in older adults. *Experimental Aging Research*, *40*(5), 513–530. https://doi.org/10.1080/0361073X.2014.956618

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. https://doi.org/10.1016/j.jenvp.2015.11.003

Gonzalez, M. T., Hartig, T., Patil, G. G., Martinsen, E. W., & Kirkevold, M. (2010). Therapeutic horticulture in clinical depression: A prospective study of active components. *Journal of Advanced Nursing*. https://doi.org/10.1111/j.1365-2648.2010.05383.x

Grant, E. R., & Spivey, M. J. (2003). Eye Movements and Problem Solving: Guiding Attention Guides Thought. *Psychological Science*, *14*(5), 462–466. https://doi.org/10.1111/1467-9280.02454

Grégoire, J., & Linden, M. Van Der. (2007). Effect of age on forward and backward digit spans Effect of Age on Forward and Backward Digit Spans. *Aging, Neuropsychology, and Cognition*, *4*(2), 140–149.

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. https://doi.org/10.1016/S0272-4944(02)00109-3

Hartig, T., & Jahncke, H. (2017). Letter to the editor: Attention restoration in natural environments: Mixed mythical metaphors for meta-analysis. *Journal of Toxicology and Environmental Health - Part B: Critical Reviews*, *20*(5), 305–315. https://doi.org/10.1080/10937404.2017.1363101

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and Health. *Annual Review of Public Health*, *35*(1), 207–228. https://doi.org/10.1146/annurev-publhealth-032013-182443

Hassmén, P. (1996). Environmental effects on ratings of perceived exertion in males and females. *Journal of Sport Behavior*, *19*(3), 235–245.

Hedges, L. V. (1981). Distribution Theory for Glass's Estimator of Effect Size and Related Estimators. *Journal of Educational Statistics*, *6*(2), 107–128. https://doi.org/10.2307/1164588

Ho, C. H., Sasidharan, V., Elmendorf, W., Willits, F. K., Graefe, A., & Godbey, G. (2005). Gender and ethnic variations in urban park preferences, visitation, and perceived benefits. *Journal of Leisure Research*. https://doi.org/10.1080/00222216.2005.11950054

Hunt, E., & Lansman, M. (1986). Unified model of attention and problem solving. *Psychological Review*, *93*(4), 446–461. https://doi.org/10.1037/0033-295X.93.4.446

Hyde, J. S. (2005). The Gender Similarities Hypothesis, *60*(6), 581–592. https://doi.org/10.1037/0003-066X.60.6.581

Ikehara, C. S., & Crosby, M. E. (2005). Assessing Cognitive Load with Physiological Sensors. In

Proceedings of the 38th Annual Hawaii International Conference on System Sciences (pp. 295a-295a). https://doi.org/10.1109/HICSS.2005.103

Joye, Y., & Dewitte, S. (2018). Nature's broken path to restoration. A critical look at Attention Restoration Theory. *Journal of Environmental Psychology*, *59*(August), 1–8. https://doi.org/10.1016/j.jenvp.2018.08.006

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Kaplan, S., & Berman, M. G. (2010). Directed attention as a common resource for executive functioning and Self-Regulation. *Perspectives on Psychological Science*, *5*(1), 43–57. https://doi.org/10.1177/1745691609356784

Kaufman, S. B. (2007). Sex differences in mental rotation and spatial visualization ability: Can they be accounted for by differences in working memory capacity? *Intelligence*, *35*(3), 211–223. https://doi.org/10.1016/j.intell.2006.07.009

Kray, J., Eppinger, B., & Mecklinger, A. (2005). Age differences in attentional control: An event-related potential approach. *Psychophysiology*, *42*(4), 407–416. https://doi.org/10.1111/j.1469-8986.2005.00298.x

Kuo, F. E. (2008). Better After Walk in the Park, 1–8. https://doi.org/10.1177/1087054708323000

Kweon, B. S., Sullivan, W. C., & Wiley, A. R. (1998). Green common spaces and the social integration of inner-city older adults. *Environment and Behavior*, *30*(6), 832–858. https://doi.org/10.1177/001391659803000605

MacBride-Stewart, S., Gong, Y., & Antell, J. (2016). Exploring the interconnections between gender, health and nature. *Public Health*, *141*, 279–286. https://doi.org/10.1016/j.puhe.2016.09.020

Mueller, S. T., & Piper, B. J. (2014). The Psychology Experiment Building Language (PEBL) and PEBL Test Battery. *Journal of Neuroscience Methods*, *222*, 250–259. https://doi.org/10.1016/j.jneumeth.2013.10.024

Navarrete-Hernandez, P., & Laffan, K. (2019). A greener urban environment: Designing green infrastructure interventions to promote citizens' subjective wellbeing. *Landscape and Urban Planning*, *191*(August), 103618. https://doi.org/10.1016/j.landurbplan.2019.103618

Nordh, H., Hagerhall, C. M., & Holmqvist, K. (2013). Tracking Restorative Components: Patterns in Eye Movements as a Consequence of a Restorative Rating Task. *Landscape Research*, *38*(1), 101–116. https://doi.org/10.1080/01426397.2012.691468

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: Critical Reviews*, *19*(7), 305–343. https://doi.org/10.1080/10937404.2016.1196155

Olafsdottir, G., Cloke, P., Schulz, A., van Dyck, Z., Eysteinsson, T., Thorleifsdottir, B., & Vögele, C. (2020). Health Benefits of Walking in Nature: A Randomized Controlled Study Under Conditions of Real-Life Stress. *Environment and Behavior*, *52*(3), 248–274. https://doi.org/10.1177/0013916518800798

Ortman, J. M., Velkoff, V. a., & Hogan, H. (2014). An aging nation: The older population in the

United States. *Economics and Statistics Administration, US Department of Commerce, 1964*, 1–28. https://doi.org/10.1016/j.jaging.2004.02.002

Ostrosky-Solís, F., & Lozano, A. (2006). Digit Span: Effect of education and culture. *International Journal of Psychology*, *41*(5), 333–341. https://doi.org/10.1080/00207590500345724

Ottosson, J., & Grahn, P. (2005). A comparison of leisure time spent in a garden with leisure time spent indoors: On measures of restoration in residents in geriatric care. *Landscape Research*, *30*(1), 23–55. https://doi.org/10.1080/0142639042000324758

Pasini, M., Berto, R., Brondino, M., Hall, R., & Ortner, C. (2014). How to Measure the Restorative Quality of Environments: The PRS-11. *Procedia - Social and Behavioral Sciences*, *159*, 293–297. https://doi.org/10.1016/j.sbspro.2014.12.375

Petersen, S. E., & Posner, M. I. (2012). The Attention System of the Human Brain: 20 Years After. *Annual Review of Neuroscience*, *35*(1), 73–89. https://doi.org/10.1146/annurev-neuro-062111-150525

Piper, B., Mueller, S. T., Talebzadeh, S., & Ki, M. J. (2016). Evaluation of the validity of the Psychology Experiment Building Language tests of vigilance, auditory memory, and decision making. *PeerJ*, *4*, e1772–e1772. https://doi.org/10.7717/peerj.1772

Ratcliffe, E., Gatersleben, B., & Sowden, P. T. (2013). Bird sounds and their contributions to perceived attention restoration and stress recovery. *Journal of Environmental Psychology*, *36*, 221–228. https://doi.org/10.1016/j.jenvp.2013.08.004

Rayner, K. (1998). Eye Movements in Reading and Information Processing: 20 Years of Research. *Psychological Bulletin*. https://doi.org/10.1037/0033-2909.124.3.372

Reuben, A., Arseneault, L., Belsky, D. W., Caspi, A., Fisher, H. L., Houts, R. M., … Odgers, C. (2019). Residential neighborhood greenery and children's cognitive development. *Social Science and Medicine*, *230*(April), 271–279. https://doi.org/10.1016/j.socscimed.2019.04.029

Richardson, E. A., & Mitchell, R. (2010). Gender differences in relationships between urban green space and health in the United Kingdom. *Social Science and Medicine*. https://doi.org/10.1016/j.socscimed.2010.04.015

Sahlin, E., Lindegård, A., Hadzibajramovic, E., Grahn, P., Vega Matuszczyk, J., & Ahlborg, G. (2016). The Influence of the Environment on Directed Attention, Blood Pressure and Heart Rate—An Experimental Study Using a Relaxation Intervention. *Landscape Research*, *41*(1), 7–25. https://doi.org/10.1080/01426397.2014.982079

Schmeichel, B. J. (2007). Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *Journal of Experimental Psychology: General*, *136*(2), 241–255. https://doi.org/10.1037/0096-3445.136.2.241

Segal, D. L., Coolidge, F. L., Cahill, B. S., & O'Riley, A. (2008). Psychometric properties of the Beck Depression Inventory--II (BDI-II) among community-dwelling older adults. *Behavior Modification*, *32*(1), 3–20. https://doi.org/10.1177/0145445507303833

Silverman, I., Choi, J., & Peters, M. (2007). The Hunter-gatherer theory of sex differences in spatial abilities: Data from 40 countries. *Archives of Sexual Behavior*. https://doi.org/10.1007/s10508-006-9168-6

Silverman, I., & Eals, M. (1992). Sex differences in spatial abilities: Evolutionary theory and data. In *The adapted mind: Evolutionary psychology and the generation of culture*.

Smilek, D., Carriere, J. S. A., & Cheyne, J. A. (2010). Failures of sustained attention in life, lab, and brain: Ecological validity of the SART. *Neuropsychologia*, *48*(9), 2564–2570. https://doi.org/10.1016/j.neuropsychologia.2010.05.002

Stevenson, M. P., Dewhurst, R., Schilhab, T., & Bentsen, P. (2019). Cognitive restoration in children following exposure to nature: Evidence from the attention network task and mobile eye tracking. *Frontiers in Psychology*, *10*(FEB), 1–10. https://doi.org/10.3389/fpsyg.2019.00042

Stevenson, M. P., Schilhab, T., & Bentsen, P. (2018). Attention Restoration Theory II: a systematic review to clarify attention processes affected by exposure to natural environments. *Journal of Toxicology and Environmental Health - Part B: Critical Reviews*, *21*(4), 227–268. https://doi.org/10.1080/10937404.2018.1505571

Swanwick, C., Dunnett, N., & Wololley, H. (2003). Nature, Role and Value of Green Space in Towns and Cities: An Overview. *Built Environment*, *29*(3), 94–106.

Taylor, Andrea Faber; Kuo, F. E. (2009). Better After Walk in the Park. *Journal of Attention Disorders*, *12*(5), 402–409. https://doi.org/10.1177/1087054708323000

Ulrich, R. S., Simons, Robert 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*, 201–230. https://doi.org/0272-4944/91/030201 + 30503.00/0

Valtchanov, D., & Ellard, C. G. (2015a). Cognitive and affective responses to natural scenes: Effects of low level visual properties on preference, cognitive load and eye-movements. *Journal of Environmental Psychology*, *43*, 184–195.

https://doi.org/10.1016/j.jenvp.2015.07.001

Valtchanov, D., & Ellard, C. G. (2015b). Cognitive and affective responses to natural scenes: Effects of low level visual properties on preference, cognitive load and eye-movements. *Journal of Environmental Psychology*, *43*. https://doi.org/10.1016/j.jenvp.2015.07.001

Van den Berg, A. E., & van den Berg, C. G. (2011). A comparison of children with ADHD in a natural and built setting. *Child: Care, Health and Development*, *37*(3), 430–439. https://doi.org/10.1111/j.1365-2214.2010.01172.x

Van den Berg, Agnes E., Jorgensen, A., & Wilson, E. R. (2014). Evaluating restoration in urban green spaces: Does setting type make a difference? *Landscape and Urban Planning*. https://doi.org/10.1016/j.landurbplan.2014.04.012

Vonasch, A. J., Vohs, K. D., Pocheptsova Ghosh, A., & Baumeister, R. F. (2017). Ego Depletion Induces Mental Passivity: Behavioral Effects Beyond Impulse Control. *Motivation Science*, *3*(4), 321–336. https://doi.org/10.1037/mot0000058

Vossel, S., Geng, J. J., & Fink, G. R. (2014). Dorsal and ventral attention systems: Distinct neural circuits but collaborative roles. *Neuroscientist*, *20*(2), 150–159. https://doi.org/10.1177/1073858413494269

Wass, S. V., Forssman, L., & Leppänen, J. (2014). Robustness and precision: How data quality may influence key dependent variables in infant eye-tracker analyses. *Infancy*, *19*(5), 427–460. https://doi.org/10.1111/infa.12055

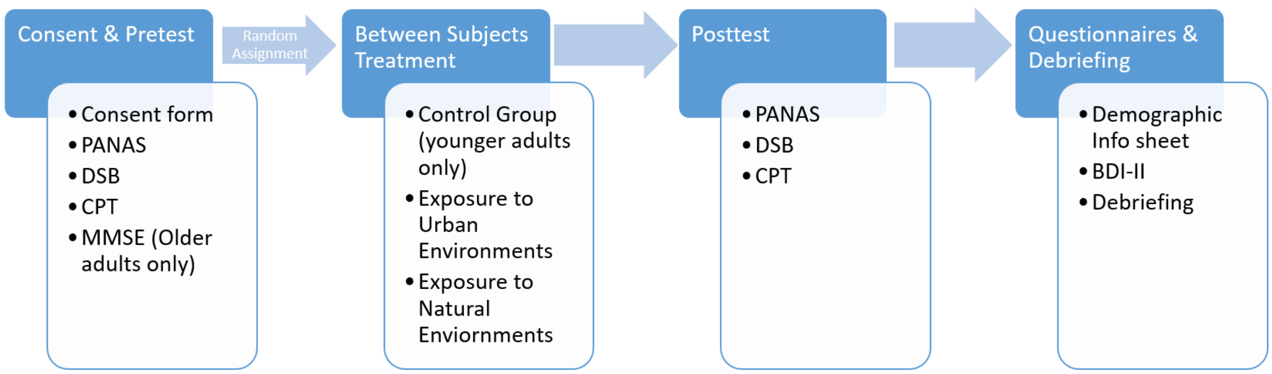
Wasylyshyn, C., & Sliwinski, M. J. (2011). Aging and Task Switching: A Meta-Analysis. *Psychology and Aging*, *26*(1), 15–20. https://doi.org/10.1037/a0020912.Aging

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. *Journal of Personality and Social Psychology*. https://doi.org/10.1037/0022-3514.54.6.1063

Watson, K. B., Carlson, S. A., Gunn, J. P., Galuska, D. A., Connor, A. O., Greenlund, K. J., & Fulton, J. E. (2016). Physical Inactivity Among Adults Aged 50 Years and Older — United States 2014. *Morbidity and Mortality Weekly Report (MMWR)*, *65*(36), 954–958. https://doi.org/10.15585/mmwr.mm6536a3

APPENDIX A

Figure 1. Experimental Design



Note. Measures are represented by the following abbreviations: Positive and Negative Affect Schedule (PANAS), Digit Span Backwards (DSB), Continuous Performance Task (CPT), Beck Depression Inventory (BDI-II), Mini Mental State Examination (MMSE).

Table 1

Younger Adult Pretest Differences between Sex and Experimental Condition

	Natural Condition		Urban Condition		Control Condition	
	Male n=31 M (SD)	Female n=36 M (SD)	Male n=32 M (SD)	Female n=31 M (SD)	Male n=29 M (SD)	Female n=34 M (SD)
Age in years	19.31_a (.98)	19.11_a (1.45)	19.28_a (1.224)	19.00_a (.931)	19.10_a (1.12)	18.76_a (1.02)
Attention						
Pretest DSB Total	9.10_a (2.57)	7.97_b (1.66)	8.66_a (2.01)	8.17_a (1.65)	9.43_a (1.69)	8.62_a(1.99)
Pretest DSB Longest	5.55_a (1.55)	4.56_b(1.58)	5.16_a(1.38)	5.21_a(.83)	5.30_a(.87)	5.15_a(1.40)
Total Pre commission Errors (CPT)	12.81_a(5.41)	14.44_a(7.25)	15.63_a(7.14)	14.27_a(5.74)	14.57_a(6.07)	13.68_a(6.29)
Total Pre Omission Errors (CPT)	5.03_a(3.72)	5.28_a(4.41)	15.16_a(56.49)	5.97_a(7.89)	16.89_a(60.45)	4.12_a(3.01)
Mood						
Pretest Negative Affect (PANAS)	13.60_a(4.72)	13.54_a(3.56)	13.13_a(5.02)	13.10_a(3.07)	13.46_a(3.80)	13.38_a(3.20)
Pretest Positive Affect (PANAS)	28.53_a(7.87)	25.34_a(6.69)	27.31_a(7.27)	27.93_a(9.25)	28.79_a(6.60)	24.12_b(7.31)
Depression (BDI-II)	29.67_a(5.82)	30.52_a(6.23)	29.73_a(6.41)	34.61_a(13.60)	29.76_a(5.97)	34.69_b(8.96)
Nature Exposure						
Time Spent Outside Today (minutes)	55.94_a(58.31)	42.44_a(28.29)	58.97_a(37.59)	72.77_a(142.39)	66.00_a(110.89)	57.53_a(96.31)
Time Typically spent outside per week (hours)	11.78_a(9.20)	13.12_a(16.99)	15.59_a(10.07)	7.90_b(7.24)	14.07_a(13.41)	9.82_a(7.49)
Lifetime access to greenspace (%)	86.94_a(21.67)	74.37_a(33.80)	93.84_a(11.10)	83.94_a(27.16)	78.83_a(34.32)	80.39_a(29.79)
Preferred Environment: Urban	5	10	4	8	8	6
Preferred Environment: Natural	21	19	22	18	17	21
Preferred Environment: Undecided	5	7	6	5	4	7

Note: Values in the same row and subtable not sharing the same subscript are significantly different at $p< .05$ in the two-sided test of equality for column means. Cells with no subscript are not included in the test. Tests assume equal variances and are adjusted for all pairwise comparisons within a row of each innermost subtable using the Bonferroni correction.

Table 2
Older Adult Pretest Differences between Sex and Experimental Condition

	Natural Condition		Urban Condition	
	Male n=3 M (SD)	Female n=5 M (SD)	Male n=6 M (SD)	Female n=6 M (SD)
Age in years	74.00$_a$(7.21)	68.4$_a$(3.05)	68.97$_a$(2.90)	77.83$_b$(8.06)
Attention				
Pretest DSB Total	9.67$_a$(1.53)	10.40$_a$(1.52)	8.00$_a$(2.35)	8.67$_a$(2.25)
Total Pre Omission Errors (CPT)	4.33$_a$(4.16)	1.00$_a$(1.73)	5.50$_a$(3.78)	1.50$_b$(1.76)
Mood				
Pretest Negative Affect (PANAS)	13.00$_a$(3.00)	10.20$_a$(.45)	10.50$_a$(.84)	13.17a(2.99)
Pretest Positive Affect (PANAS)	39.00$_a$(8.49)	33.20$_a$(4.66)	38.00$_a$(5.73)	36.00$_a$(8.44)
Depression (BDI-II)	26.33$_a$(20.21)	26.40$_a$(1.52)	28.83$_a$(7.99)	26.00$_a$(3.90)
Nature Exposure				
Time Spent Outside Today (minutes)	36.67$_a$(25.47)	63.00$_a$(56.52)	37.67$_a$(23.72)	30.17$_a$(15.75)
Time Typically spent outside per week (hours)	14.00$_a$(10.15)	14.80$_a$(9.63(	19.83$_a$(12.21)	8.50$_a$(4.37)
Lifetime access to greenspace (%)	50.00$_a$(34.64)	96.00$_b$(5.48)	72.00$_a$(15.56)	74.00$_a$(31.90)
Preferred Environment: Urban	1	0	0	1
Preferred Environment: Natural	2	4	6	3
Preferred Environment: Undecided	0	1	0	2

Note: Values in the same row and subtable not sharing the same subscript are significantly different at $p< .05$ in the two-sided test of equality for column means. Cells with no subscript are not included in the test. Tests assume equal variances and are adjusted for all pairwise comparisons within a row of each innermost subtable using the Bonferroni correction.

Table 3. Younger Adult Correlations for Predictors and Dependent Variables.

Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Digit Span Backwards											
2.Continous Performance Task-Omissions	-0.04										
3.Negatve Affect	-0.08	.17*									
4. Positive Affect	-0.10	0.05	0.08								
5. Depression	-0.02	-0.00	.23**	-0.10							
6.Average Fixation Duration	-0.00	-0.10	0.06	-.17*	0.03						
7.Average Fixation Count	0.00	-0.08	-.15*	.19**	-0.06	-.55**					
8.Time spent Outdoors Today	-0.06	0.09	0.03	0.01	0.08	-0.00	-0.12				
9. Time spent outdoors per week	-0.09	0.06	0.05	.18*	-0.13	0.01	-0.11	.25**			
10. Lifetime access to greenspace	0.11	.16*	-0.03	-0.05	-0.09	0.02	0.04	0.10	-0.05		
11. Enjoyment of Urban Environments	-0.07	-0.03	0.08	-0.0	0.10	0.05	-0.04	-0.00	-0.01	0.03	

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 4. Older Adult Correlations for Predictors and Dependent Variables.

Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Digit Span Backwards											
2.Continous Performance Task-Omissions	-0.17										
3.Negatve Affect	0.26	-0.00									
4. Positive Affect	-.50*	0.08	-0.20								
5. Depression	-0.01	-0.01	-0.22	0.20							
6.Average Fixation Duration	-0.18	0.08	-0.06	0.16	0.13						
7.Average Fixation Count	0.02	0.10	-0.10	0.25	0.29	.79**					
8.Time spent Outdoors Today	-0.43	0.03	-0.09	-0.08	-0.01	-0.04	-0.14				
9. Time spent outdoors per week	-.53*	-0.02	-0.14	0.31	-0.04	0.07	0.00	0.22			
10. Lifetime access to greenspace	0.03	-0.25	0.17	-0.40	-0.04	0.17	0.13	0.36	0.30		
11. Enjoyment of Urban Environments	0.30	0.00	0.15	-0.12	-0.00	.61**	.70**	-0.07	-0.38	-0.12	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).