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The Effects of Nature Stimuli on Mood, Self-Control, Physiology, and Health Decision Making

Author
Wally, Christopher Michael

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The Effects of Nature Stimuli on Mood, Self-Control, Physiology, and Health Decision Making

by

Christopher Michael Wally

A dissertation submitted in partial satisfaction of the requirements for the degree
Doctor of Philosophy

in

Psychological Sciences

Dissertation Committee Members

Professor Linda D. Cameron (Chair)

Professor Anna V. Song

Professor Sarah Depaoli

2016

The Dissertation of Christopher M. Wally is approved, and it is acceptable

in quality and form for publication on microfilm and electronically:

Sarah Depaoli

Anna V. Song

Linda D. Cameron, Chair

University of California, Merced
2016

I dedicate this dissertation to my two dogs, Louie and Penny. Thank you for helping me through what was otherwise the most stressful and trying time of my life (so far). Through identity crises, depression, a divorce, and being a graduate student, you greeted me with wagging tails and wet kisses. You reminded me of what matters most in life (belly rubs), and your unconditional love made everything a little more tolerable. For that I am forever grateful.

Table of Contents

List of Tables

List of Figures

Curriculum Vita

3 Grand Cypress Ct.
St. Charles, MO 63304
636-288-8245
cwally@ucmerced.edu

Christopher Michael Wally

EDUCATION

University of California, Merced – Merced, CA — Graduation: December 2016

- Ph.D. Health Psychology

Truman State University - Kirksville, MO — May 2011

- B.S. Psychology
- Minors: Statistical Methods and Health Studies
- GPA: 3.78/4.0 (Magna Cum Laude)
- > 95th Percentile on Senior Psychology Major Field Test

TEACHING

Courses Taught

- Social Psychology — Summer 2015
- Social Psychology — Summer 2016

Courses Serving as Teaching Fellow/Assistant

- Social Psychology — Fall 2011
- Introduction to Psychological Statistics — Spring 2012
- Social Psychology — Fall 2012
- Cognition, Affect, & Health — Spring 2013
- Social Psychology — Fall 2013
- Introduction to Psychology — Spring 2014
- Social Psychology — Fall 2014
- Social Psychology — Fall 2015
- Introduction to Psychology — Spring 2016

Guest Lectures

- "Love and Close Relationships" - Social Psychology, 10/20/11
- "Probability and Sampling Distributions" - Intro Statistics, 2/23/12

- “Research Methods in Social Psychology” – Social Psychology, 8/28/12
- “Research Methods (cont.) and Ethics in Research” – Social Psychology, 8/30/12
- “Love and Close Relationships” – Social Psychology, 11/8/12
- “Resilience, Positive Emotions, and Self-Compassion” – Cognition, Affect, & Health, 2/5/13
- “Resilience, Positive Emotions, and Self-Compassion (cont.)” – Cognition, Affect, & Health, 2/7/13
- “Optimism and Goal Disengagement” – Cognition, Affect, & Health, 3/19/13
- “Mindfulness Meditation and Health” – Cognition, Affect, & Health, 4/18/13
- “Belonging, Attraction, and Rejection” – Social Psychology, 11/19/13
- “Love and Close Relationships” – Social Psychology, 11/21/13
- ”Love and Close Relationships” – Social Psychology, 11/13/14
- “Attitudes and Attitude Change” – Social Psychology, 10/6/15
- “Persuasion and Advertising” – Social Psychology, 10/8/15
- “Interpersonal Attraction” – Social Psychology, 11/3/15

Teaching Workshops Presented

- Setting Expectations, 1/14/15
- Learning Outcomes and Curriculum Design, 3/10/15

Teaching Workshops Attended

- Start with the Outcome: Designing Learner-Centered Lessons, 9/11/13
- Grading Effectively and Efficiently, 11/6/13
- Setting Expectations, 2/4/14
- Engaging Students through Active Learning, 2/20/14
- A Brief History of Education, 4/4/14
- Composing a Teaching Philosophy, 4/15/14
- Critical Thinking in the Classroom, 1/29/15
- Best Practices for Large Classroom, 1/29/15
- Leading a Discussion, 1/29/15
- Designing Rubrics, 3/10/15
- Instructional Assessment and Student Evaluations, 3/10/15

Teaching Certifications

- Level 1 Instructional Intern, Center for Research on Teaching Excellence
  Spring 2014
- Level 2 Instructional Intern, Center for Research on Teaching Excellence
  Spring 2015

PROFESSIONAL

Service

- Graduate Student Representative - Health Psychology Job Search Committee
  2012 - 2013
- Graduate Student Representative – Health Care Advisory Board
  2014-2015
- Graduate Student Rep. – Chancellor's Advisory Committee on Sustainability
  2015-2016
- Graduate Student Rep. UC Merced – The Society for Health Psychology (APA Div. 38) 2015-2016

Memberships

- Society of Behavioral Medicine Fall 2011 - present
- Society for Personality and Social Psychology Spring 2013 – present
- APA Division 38 – Health Psychology Spring 2013 – present
- Society for the Teaching of Psychology Fall 2015 - present
- UC Merced Graduate Pedagogy Association Fall 2015 – present

Activities

- Coder for National Cancer Institute's Incidental Affect Meta-Analysis
  Summer 2012
- Merit Writing Workshop for Psychology Graduate Students
  Spring 2014
- Co-founding Member – UC Merced Graduate Pedagogy Association
  Fall 2015
- Completion of UC Merced's Missing Data Analysis Seminar
  Fall 2015

AWARDS

- $3,885 - Graduate Division General Scholarship – UC Merced Spring 2012

- $7,070 - Psychological Sciences Summer Fellowship – UC Merced Summer 2013
- Meritorious Student Abstract – *A randomized-controlled trial of social norms to increase physical activity*. – Society of Behavioral Medicine, Philadelphia, Pennsylvania. April 2014
- $250 – Instructional Internship Level 1 Completion – CRTE Spring 2014
- $4,105 – Psychological Sciences Summer Fellowship – UC Merced Summer 2014
- $75 – Most Innovative Presentation – *Biophilic design: A health innovation* – UC Merced March 2015
- $4,570 – Psychological Sciences Summer Fellowship – UC Merced Summer 2015

PEER-REVIEWED PUBLICATIONS

Wally, C. M., & Cameron, L. D. (Accepted). A randomized-controlled trial of social norms to increase physical activity. *Annals of Behavioral Medicine.*

Wally, C. M., & Cameron, L. D. (Under Revision). The restorative effects of nature on self-control: A systematic review.

Cameron, L. D., **Wally, C. M.,** & Harre, N. (Preparing for Submission). Social norms and disposable drink use.

Cameron, L. D., **Wally, C. M.,** & Harre N. (Under Revision). A randomized-controlled trial of social norms to decrease disposable drink use.

Landau, M. J., Arndt, J., Cameron, L. D., Spina, M., & **Wally, C. M.** (Preparing for Submission). The use of metaphor in conveying risk of sun exposure.

Wally, C. M., & Cameron, L. D. (Preparing for Submission). A randomized-controlled trial of brief nature exposure through photographs: Effects on mood, self-control, and health decision making.

Wally, C. M., & Cameron, L. D. (Preparing for Submission). Nature in the workspace: A randomized-controlled trial of the effects of natural elements on mood, physiology, self-control, and health decision making.

OTHER PUBLICATIONS

Cameron, L. D. & **Wally, C. M.** (2015). Coping with chronic illness. *International Encyclopedia of the Social & Behavioral Sciences* (2nd edition).

PRESENTATION OF RESEARCH

Oral Presentations

Wally, C. M. (2012, April). *Blockage of life goals following prostate cancer.* Talk given at the Psychological Sciences Colloquium, University of California, Merced, Merced, California.

Wally, C. M., & Depaoli, S. (2014, March). *Intrinsic motivation partially mediates self-control and exercise*. Paper presented at the University of California, Merced Psychological Sciences Symposium, Merced, California.

Wally, C. M., & Cameron, L. D. (2014, April). *A randomized-controlled trial of social norms to increase physical activity.* Paper presented at the Soceity of Behavioral Medicine, Philadelphia, Pennsylvania.

Wally, C. M. (2014, November). *Restorative benefits of nature*. Invited talk given at the Excellence in Health Yosemite Retreat, Wawona, Yosemite National Park, California.

Wally, C. M. (2015, March). *The restorative effects of nature on self-control.* Paper presented at the University of California, Merced Psychological Sciences Symposium, Merced, California.

Wally, C. M., & Carroll, P. (2015, March). *Biophilic design: A health innovation.* Talk given at the Health Science Research Institute's Translational Research Symposium, University of California, Merced, Merced, California.

Wally, C. M. (2015, March). *Social norms and physical activity.* Talk given at the University of California, Merced's GradSLAM! Competition, Merced, California.

Wally, C. M. (2015, March). *Social norms as health communication: Physical activity and disposable drink container use.* Talk given at the Health Psychology Colloquium, University of California, Merced, Merced, California.

Wally, C. M. (2015, May). *Get out! The benefits of interacting with nature.* Invited talk given at the Building a Culture of Health in the Central Valley Symposium, University of California, Merced, Merced, California.

Poster Presentations

Grant, J., Korenfeld, I., **Wally, C. M.**, & Truitt, A. (2009, April). *Inhalation-to-exhalation ratio affects HRV training success*. Poster presented at the meeting of the Association for Applied Psychophysiology and Biofeedback, Albuquerque, New Mexico.

Wally, C. M., Korenfeld, I., Brooks, K., Carrell, D., Lau, D., Peterson, J., Schafer, M., Truitt, A., Fuller, J., Westermann-Long, A., & Korenfeld, D. (2009, September). *Chanting "Om" increases heart rate variability by slowing respiration*. Poster presented at the A.T. Still University Biomedical Symposium, Kirksville, Missouri.

Grant, J., **Wally, C. M.**, & Truitt, A. (2010, April). *The effects of Kargyraa throat-singing and singing a fundamental note on heart rate variability*. Poster presented at the meeting of the Biofeedback Foundation of Europe, Rome, Italy.

Wally, C. M., Korenfeld, I., Brooks, K., Peterson, J., & Schafer, M. (2010, October). *The effects of three respiration rates on blood pressure and heart rate variability*. Poster presented at Truman State University Conference, Kirksville, Missouri.

Wally, C. M., & Hoyt, M. (2012, April). *Blockage of life goals following prostate cancer: Relationships to sexual functioning and psychological distress*. Poster presented at the meeting of the Society of Behavioral Medicine, New Orleans, Louisiana.

Wally, C. M., & Depaoli, S. (2015, February). *Intrinsic motivation partially mediates self-control and exercise.* Poster accepted for presentation at the meeting of the Society for Personality and Social Psychology, Long Beach, California.

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Abstract of the Dissertation

Background: Previous research suggests an evolutionary predisposition for humans to seek out and maintain a connection with nature. Natural elements including sunlight, plants, water, and natural scenery have been shown to be beneficial to human health and functioning.

Objective: This dissertation aimed to replicate previous research on the benefits of exposure to nature stimuli and extend this knowledge by testing for an effect of nature on self-control.

Methods: Two randomized-controlled trials tested the effects of exposure to varying degrees of nature stimuli. In Study One, college students (N = 203) were randomly assigned to either undergo an ego-depleting task or a control task and to view either photographs of natural scenes or urban architecture. Outcomes were changes in mood, task persistence, and health decision making. In Study Two, college students (N = 126) were randomly assigned to either complete tasks in a room with natural elements (sunlight, plants, water fountain, window views of scenery) or a room devoid of any natural stimuli (a windowless storage room). Outcomes were changes in mood, physiology, task performance and persistence, and health decision making.

Results: In Study One, participants completing the ego-depletion task reported feeling more frustrated, confused, and fatigued compared to participants completing the control task, but this effect quickly dissipated. A trend emerged for ego-depleted participants viewing nature photographs, such that they reported greater overall feelings of vigor compared to nature photo viewers completing the control task. There were no differences between groups in task persistence or health decision making. In Study Two, participants in the nature room showed a greater decrease in heart rate throughout the session compared to participants in the control room. Additionally, participants in the control room successfully solved more anagrams than participants in the nature room. No other effects for mood, task persistence, physiology, or health decision making were significant.

Conclusions: With the exception of greater relaxation of heart rate, no evidence was found that nature exposure through viewing scenic photographs or working in a space with natural stimuli has any meaningful effects on mood, self-control, or health decision making over a short time period. Additional research is needed to elucidate the type and duration of nature exposure necessary to produce beneficial effects, and for whom exposure may be most beneficial.

The Effects of Nature Stimuli on Mood, Physiology, Self-Control, and Health Decision Making

Introduction

Every modern person owes his or her existence to eons of natural selection; an unbroken chain of evolution beginning with single celled organisms and progressing 3.8 billion years to the intelligent primates we are today (Mojzsis et al., 1996). Contemporary humans (Homo sapiens) came about roughly 200,000 years ago (McDougall, Brown, & Fleagle, 2005). Throughout this evolutionary process, our ancestors depended on interaction with the natural world and other organisms for survival and reproduction. Sunlight, water, and other life forms such as plants, animals, and bacteria; all were necessary and partially responsible for shaping Homo sapiens over the years into present form.

Very recently, a fraction of a second on the evolutionary time scale, humans have become disconnected from these natural components of life. Even as our ancestors moved from hunting and gathering to agricultural practices around 10,000 years ago (Balter, 2007), cultivation of food and knowledge of natural systems preoccupied most people. In just the last few hundred years, with the industrial revolution and the rapid advancement of technology, people have abandoned what was once an intimate connection with the natural world. Instead of being outdoors in the sunlight, physically active, and interacting with the local flora and fauna, the modern human spends the majority of time indoors under artificial light, is largely sedentary, and remains in artificially contrived environments along with few, if any, natural elements. Evolutionary perspectives suggest an incongruity between the way we currently live and the environments our bodies and minds evolved to cope with (Kaplan, 1995; Ulrich, 1983; Wilson, 1984).

It is estimated that by the year 2050, around 66% of the world's population will live in urban areas (United Nations, 2014). With this continual shift away from nature and into human-designed, densely populated spaces, it is unclear what consequences to mental and physical health are occurring. While insights into the effects of nature deprivation remain largely speculative, there is an emerging body of research suggesting exposure to nature has beneficial effects. Recent research suggests interacting with nature can improve symptoms of mental disorders such as depression and anxiety (Berman et al., 2012; Marselle, Irvine, & Warber, 2014; Shanahan et al., 2016), as well as attention disorders such as attention deficit hyperactivity disorder (ADHD) (Kuo & Taylor, 2004).

Recent reviews outline potential benefits of nature exposure for cognitive, psychological, and physiological well-being and functioning (Hartig et al., 2014; Keniger et al., 2013). High-quality experimental and quasi-experimental studies on the topic remain sparse, but existing research findings are encouraging. Two prominent theories within environmental psychology have guided much of this work, and are reviewed below.

Theoretical Perspectives on Benefits of Nature

The two major theories directing work on the benefits of interacting with nature are Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989; Kaplan, 1995) and Psycho-Evolutionary Theory (PET) (Ulrich, 1983; Ulrich et al., 1991). ART proposes that attentional resources become depleted with use and can be restored after contact with nature. PET proffers that stressors lead to fatigue and nature holds stress-reducing properties allowing for recovery. There is some overlap between theories, and the two are not necessarily mutually exclusive.

Attention Restoration Theory

The first major theory within environmental psychology guiding work on the benefits of interacting with nature is Attention Restoration Theory (ART) (Berman, Kaplan, & Jonides, 2008; Kaplan & Kaplan, 1989; Kaplan, 1995). This theory builds on William James' (1892) theories of attention and will, and posits that attention can be separated into two components: (1) directed attention, a finite resource where effortful cognitive processes are required to focus attention on a stimulus and inhibit distractions, and use of the attentional resource leads to fatigue; and (2) involuntary attention, where stimuli automatically capture attention by being intriguing or important. Directed attention bears similarities to the social psychological concept of self-control (Kaplan & Berman, 2010), as both concepts are based on a limited resource account of mental resources (Baumeister et al., 1998; Kaplan, 1995). Conversely, involuntary attention largely reflects a stimulus driven attentional function that more or less automatically operates when interesting or unexpected stimuli are present. ART predicts that stimuli engaging involuntary attention allow for directed attention to replenish, because attention is captured in a bottom-up fashion, and does not require cognitive effort.

According to ART, natural environments have the greatest potential to restore directed attention, due to their inherently fascinating features. Natural environments are said to elicit 'soft fascination,' a low arousal state that allows for reflection. Other stimuli, such as sporting events, sexual content, or violence classify as 'hard fascination,' and capture attention involuntarily but are accompanied by high arousal. The theory supports an evolutionary perspective, such that stimuli capturing involuntary attention are thought to be most related to survival and safety. As Kaplan puts it, "it is only in the modern world that the split between the important and the interesting has become extreme. All too often the modern human must exert effort to do the important while resisting distraction from the interesting" (Kaplan, 1995, p. 170).

Psycho-Evolutionary Theory

The second main theory concerning exposure to nature within environmental psychology is Psycho-Evolutionary Theory (Ulrich, 1983; Ulrich et al., 1991). Psycho-Evolutionary Theory (PET) posits that experiencing stressors leads to psychological, physiological, cognitive, and behavioral changes resulting in a depletion of energy and fatigue. For example, appraising a situation as stressful activates the body's stress response, which increases the workload of the cardiovascular and neuroendocrine systems in the body. This change in physiology heightens arousal and depletes energy resources. These effects can be exacerbated depending on actions taken to cope with the stressor. PET proposes that contact with nature attenuates the stress response through a reduction of arousal and negative affect, as well as an experience of positive affect. A positive emotional state and lower level of physiological arousal then allow for recovery from stressors.

Borrowing from other theoretical perspectives, PET proffers that when stressed, people prefer less complex and stimulating environments such as nature over cognitively overloading urban settings. PET also borrows from evolutionary theory to suggest natural landscapes are innately preferred by people for their survival value. For example, having access to vegetation and water, and being able to spot predators would have been beneficial to our ancestors, and this evolved preference has stayed in human genes. Encountering such environments is considered to be pleasing and rewarding on an unconscious level, representing a biological preparedness for recovery from stress in natural settings.

Benefits of Interacting with Nature

ART and PET have led to a variety of studies examining nature's benefits. Researchers have differed in how they define nature and what qualifies as sufficient exposure. Methods have ranged from laboratory studies involving exposure to pictures or videos of natural scenes (e.g., Berto, 2005; Hartig et al., 1996); field experiments including walks in parks or visiting wooded areas (e.g., Berman et al., 2012; Plante et al., 2006); to quasi-experiments featuring naturally occurring groups interacting with nature in some capacity such as greenspace near the home (e.g., Kuo & Sullivan, 2001), indoor plants in the work setting (e.g., Han, 2009), or backpackers on long trips (e.g., Hartig, Mang, & Evans, 1991). Regardless of how nature has been defined, three general categories of benefits have emerged: Cognitive, psychological, and physiological.

Cognitive Benefits of Nature

Overall, the most evidence exists for improvements in attention and working memory performance. Many of the studies testing for cognitive benefits or attention restoring effects utilized an experimental laboratory design, with a pre-test attention task to mentally fatigue participants, followed by exposure to nature in some capacity, and finally a post-test featuring some variety of an attention or working memory task tapping cognitive ability. Studies using pictures or videos of nature were most common, and generally found better performance after viewing nature media versus urban based stimuli (Berman, Jonides, & Kaplan, 2008, Study 2; Berto, 2005, Study 1; Berto, 2005, Study 3; Berto et al., 2010; Beute & de Kort, 2014, Study 1; Cackowski & Nasar, 2003; Hartmann, Apaolaza, & Alija, 2013; Laumann, Garling, & Stormark, 2003; Parsons et al., 1998).

Another common method was to include at least one condition that involved walking or immersing oneself in nature for brief periods of time. Parks, forest trails, and scenic campus areas were frequently used. These natural areas were often compared to walks in an urban or indoor setting with little vegetation. Many studies found support for cognitive benefits of natural walks (Berman et al., 2012; Berman, Jonides, & Kaplan, 2008, Study 1; Duvall, 2011; Hartig et al., 2003; Hartig, Mang, & Evans, 1991, Study 2; Mayer et al., 2009, Study 1).

Other studies persisted for longer periods of time, such as weeks or months, and found so-called instorative or vitalizing effects of nature. That is to say, exposure to nature without a prior depletion task led participants to perform better on cognitive tasks such as attention and short-term memory at follow-up compared to controls, suggesting benefits above and beyond replenishment (Cimprich & Ronis, 2003; Hartig, Mang, & Evans 1991, Study 1; Kuo & Sullivan, 2001; Taylor, Kuo, & Sullivan, 2002).

Not all studies obtained significant results for restoration or cognitive benefits. One study failed to find an effect using the laboratory procedure (Hartig et al., 1996).

Two studies found no effects or a decrease in cognitive performance from baseline when participants walked in parks vs. urban environments (Bodin & Hartig, 2003; Johansson, Hartig, & Staats, 2011). Another study used a working memory task as a measure of cognitive ability and did not find differences between groups in performance (Beute and de Kort, 2014, Study 2). A quasi-experiment of public housing residents assigned to apartments with nearby greenspace or with mainly urban elements showed improved cognitive performance for adolescent girls living near greenspace, but not adolescent boys (Taylor, Kuo, & Sullivan, 2002).

Psychological Benefits of Nature

Many of the studies testing for psychological benefits of interacting with nature examined variations of mood measures, mainly positive affect. Generally, evidence was found for greater positive affect or happiness when exposed to nature. This occurred through the use of picture slides or videos (Beute & de Kort, 2014; Hartig et al., 1996; Hartmann, Apaolaza, & Alija, 2013, Studies 1 & 3; Mayer et al., 2009; Ulrich et al., 1991; van den Berg, Koole, & van der Wulp, 2003), walks or immersion in nature (Berman et al., 2012; Berman, Jonides, & Kaplan, 2008, Study 1; Hartig et al., 2003; Hartig, Mang, & Evans, 1991, Study 2; Nisbet & Zelenski, 2011, Studies 1 & 2; Tyrvainen et al., 2014; van den Berg & Custers, 2011), and field or quasi experiments such as backpacking trips (Hartig, Mang, & Evans, 1991, Study 1).

Two additional psychological benefits receiving support were feelings of restoration (Beil & Hanes, 2014; Bodin & Hartig, 2003; Lee et al., 2009; Tyrvainen et al., 2014) and vitality/energy (Johansson, Hartig, & Staats, 2011; Kjellgren & Buhrkall, 2010; Park et al., 2010; Plante et al., 2006; Ryan et al., 2010, Studies 2 & 3; Tyrvainen et al., 2014) following contact with nature. Other benefits included reductions in negative affect (Kinnafick & Ntoumani, 2014, Study 1, Nisbet & Zelenski, 2011; Tyrvainen et al., 2014), reductions in aggression and frustration (Hartig et al., 2003; Kuo & Sullivan, 2001; Kweon et al., 2000; Park et al., 2010; Ulrich et al., 1991; van den Berg, Koole, & van der Wulp, 2003), and reductions in feelings of depression (Park et al., 2010; van den Berg, Koole, & van der Wulp, 2003).

There were some studies however, that did not find any significant mood differences between groups or testing occasions. Two studies found no differences between positive or negative affect after viewing pictures of nature or pictures of urban settings (Berman, Jonides, & Kaplan, 2008, Study 2; Brown, Barton, & Gladwell, 2013), and another found decreases for urban slide viewings (Ulrich, 1981). Two studies had participants walk/run along an urban route or a park route and found mood following the exposure to be the same for both environments (Bodin & Hartig, 2003; Johansson, Hartig, & Staats, 2011). In another study, sitting while viewing slideshows of either natural or urban pictures led to a decrease in positive affect for both groups, whereas walking on a treadmill while viewing either picture set increased positive affect (Kinnafick & Ntoumani, 2014, Study 1). When this procedure was repeated outdoors, there were no mood differences or changes (Kinnafick & Ntoumani, 2014, Study 2).

Physiological Benefits of Nature

In terms of physical health and physiological benefits of interacting with nature, mixed evidence exists. Studies reporting effects showed exposure to nature resulted in decreased heart rate (Laumann, Garling, & Stormark, 2003; Lee et al., 2009; Park et al., 2010; Parsons et al., 1998; Ulrich et al., 1991), decreased blood pressure (Hartig et al., 2003; Lee et al., 2009; Park et al., 2010; Pretty et al., 2005), greater low-frequency to high frequency ratio (Beute & de Kort, 2014), increased heart-rate variability (Brown, Barton, & Gladwell, 2013; Gladwell et al., 2012; Park et al., 2010), quicker return to baseline physiology following a stressor (Parsons et al., 1998; Ulrich et al., 1991), and greater relaxation (Ulrich, 1981).

Additionally, some studies found subjective stress to be lower after exposure to nature (Beil & Hanes, 2013; Dijkstra, Pieterse, & Pruyn, 2008; Kjellgren & Buhrkall, 2010; van den Berg, Koole, & van der Wulp, 2003), although in one study the effect was only significant for males (Kweon et al., 2008). Subjective well-being (Raanaas, Patil, & Hartig, 2010) was also found by one study to be perceived as better after interacting with nature. In a few studies, objective measures of stress including cortisol and salivary alpha amylase were utilized. There were positive results, as with one study (van den Berg & Custers, 2011) finding support that gardening led to a quicker recovery from a stressor compared to reading, and two others finding cortisol levels were lower shortly before and after visiting a forest and viewing it for 15 minutes, compared to visiting an urban area (Lee et al., 2009; Park et al., 2010).

Other findings included that indoor plants present in a school classroom reduced sick leave and resulted in fewer punishments than a control classroom without plants (Han, 2009). Similarly, indoor plants placed in offices for three months led to fewer neuro-psychological symptoms such as fatigue, headache, nausea, and concentration problems as well as fewer sickness and allergy symptoms compared to when plants were not present (Fjeld et al., 1998). Patients recovering from gall bladder surgery recovered more quickly and used fewer strong and moderate pain killers when window views were of vegetation instead of a brick wall (Ulrich, 1984). Finally, one study provided evidence for increased immune function following three two-hour walks in a forest compared to a city. Results showed increased natural killer (NK) cell activity and numbers during a forest visit compared to the city visit. Further, this effect persisted for 30 days after the trip had ended, suggesting a long-lasting immune enhancing effect of spending extended periods of time in nature. In addition to NK cell improvements, epinephrine concentrations in urine were found to be lower during the forest trip compared to the city trip (Li et al., 2008).

Conversely, several other studies did not find significant results for physiological benefits. A multi-day study measuring alpha-amylase throughout the day found only marginally significant differences after walking in a forest or a city (Yamaguchi, Deguchi, & Miyazaki, 2006). Another study measuring cortisol found no significant differences between groups viewing and walking in a city center, park, or urban woodland (Tyrvainen et al., 2014). A study involving 20 minute exposure to a nature reserve, park, urban plaza, and shopping mall found higher alpha amylase when visiting the shopping mall, but no other effects for alpha amylase or cortisol (Beil & Hanes, 2013).

Further, in one study, patients recovering at a coronary/pulmonary rehabilitation center had window views of vegetation or of buildings. For women, having building views led to decreased self-reported physical health, whereas for men having building views led to decreased self-reported mental health. No benefits of having the natural window view emerged (Raanaas, Patil, & Hartig, 2011). A study measuring heart rate, blood pressure, and respiration found no differences for these variables between urban and nature slideshow viewing groups (Gladwell et al., 2012). A study comparing walking in natural and urban environments with a relaxation group found no physiological differences between groups at follow-up (Hartig, Mang, & Evans, 1991). More research is needed to better clarify the benefits of nature to physiological health, as at this point the evidence is mixed.

Reconnecting with Nature

Even as research on the benefits of nature continues to emerge, it is unlikely that most people will have the time or the opportunities to live in ways completely harmonious with nature. Modern living and occupational demands require time be spent primarily indoors, surrounded by man-made objects and designs. Fortunately, there has been a recent push to bring nature back into the spaces in which people live and work. This movement is calling for building planners and architects to reconsider the way buildings are designed by incorporating features mimicking our evolutionary upbringings.

This is the idea of biophilic design: translate the human affinity to connect with nature into the design and décor of the built environment (Kellert, 2005; Kellert, Heerwagen, & Mador, 2008). This is based on the premise of biophilia, which argues that humans have an innate inclination to affiliate with other forms of life and natural processes (Kellert & Wilson, 1993; Wilson, 1984). By bringing life back into indoor spaces, people may reap some of the benefits of nature while remaining indoors. Furthermore, if improvements in attention, memory, mood, energy, and physiology can be shown to occur indoors in the presence of natural elements, businesses interested in improving worker productivity, morale, and well-being would have a reason to invest in the design and maintenance of such buildings.

Improving Productivity: The Case for Self-Control Theory

Self-control, or 'willpower', can be thought of as the ability to delay gratification, direct attention, resist temptations, and regulate emotions, thoughts, and impulses (Baumeister, et al., 1998; Shoda, Mischel, & Peake, 1990). This is the theory on the depletion and recovery of mental resources driving research within social psychology, similar to attention restoration theory's (ART) approach within environmental psychology. At the trait level, this research developed out of investigations into the ability of children to delay gratification of immediate impulses for larger rewards at a later time (Mischel & Ebbesen, 1970). Follow-up research to the original studies suggests those children who successfully delayed gratification were rated as more popular by teachers and peers, scored higher on their SAT's, had higher incomes, and had lower BMI's than the other children who originally went for the immediate reward (Shoda, Mischel, & Peake, 1990). This early research showed that individuals with good self-control tend to fare better in life than those with poor self-control.

At the situational level, a popular approach to self-control research is the strength model of self-control. This model suggests the energy available for tasks is a finite resource that can be depleted with repeated use. This phenomenon is known as 'ego-depletion', and can occur when engaging in tasks requiring self-control, which then reduces energy available for subsequent tasks (Baumeister, Vohs, & Tice, 2007).

Experiments have demonstrated that exerting self-control in a variety of domains (directing attention, resisting temptation, controlling impulses, regulating emotions, suppressing thoughts, etc.) depletes a common, global self-control resource. Further, this leads to worse performance on subsequent tasks requiring self-control (Hagger, Wood, Stiff, & Chatzisarantis, 2010).

Until recently, the prevailing view in self-control research was that physical energy is utilized in order to meet the demands of exerting prolonged cognitive effort. Glucose has been proposed as the primary source of this energy (Galliot et al., 2007). Some studies have supported this notion (Denson et al., 2010), but newer studies have challenged this view (e.g., Clarkson et al., 2010; Job, Dweck, & Walton, 2010; Molden et al., 2012). A more recent model of self-control, the process model of self-control (Inzlicht & Schmeichel, 2012), proposes that shifts in both attention and motivation are the driving forces behind self-control success or failure. Specifically, it is posited that acts of deliberative attentional control (such as ART's concept of directed attention) gradually lead to attention being shifted toward cues signaling reward and personal gratification. Similarly, shifts in motivation from impulse inhibition to approach and gratification of interesting and rewarding stimuli are said to occur as depletion sets in.

Deliberately controlling and directing attention to tedious tasks can be thought of as an analog to productivity. Many of the tasks used to deplete participants in self-control research involve completion of difficult and frustrating tasks, similar to those performed in a work environment (Hagger et al., 2010). Furthermore, evaluation of self-control frequently involves assessment of persistence or performance on challenging tasks (Hagger et al., 2010).

The presence of natural elements may serve as a way to replenish or mitigate the loss of attention and motivational resources central to self-control. If it can be demonstrated that exposure to natural elements such as sunlight, window views of nature, indoor plants, pictures of nature, and other biophilic stimuli can improve self-control, the case can be made that nature improves or restores self-control. By extension, improving self-control in the work environment may lead workers to be more productive and make better choices for well-being. With the internet at many people's fingertips, focusing on the task at hand and resisting distraction has become ever more important.

Evidence that Nature Improves Self-Control

As previous reviews have found (Hartig et al., 2014; Keniger et al., 2013), there is at least some evidence that interacting with nature has benefits for cognitive variables such as attention and working memory, psychological variables such as mood and subjective energy, and physiological variables such as heart rate, blood pressure, and other indices of greater parasympathetic nervous system activity. These benefits can be taken to suggest that interacting with nature leads to greater self-control. The primary evidence for this claim comes from research conducted under attention restoration theory (ART), as this work has tested the effects of nature on restoring a limited cognitive resource, which is the main focus of state models of self-control such as the strength model (Baumeister, Vohs, & Tice, 2007). These concepts are so similar that it has been argued directed attention may be the mechanism underlying self-control and executive functioning (Kaplan & Berman, 2010).

Additional evidence comes from research conducted under psycho-evolutionary theory (PET), which has found evidence for the psychological and physiological benefits of nature. Inducing positive affect has been found to moderate the effect of ego-depletion (Tice et al., 2007), as has being vitalized from feeling autonomous in decision making (Moller, Deci, & Ryan, 2006). Conversely, negative affect has been reported after participants face a depleting task (Ciarocoo, Sommer, & Baumeister, 2001; Stewart et al., 2009). According to the process model of self-control, when attention and motivation shift to rewarding stimuli, positive affect is thought to result. It is possible that positive affect and the feeling of renewed energy observed after interacting with nature may also aid in improving self-control. Studies using the self-control framework rarely test for physiological changes, but the findings from environmental psychology lend support that physiological changes may contribute to the recovery of attention and motivation necessary for self-control.

To the author's knowledge, only two papers have tested the relationship between nature and self-control directly. Beute and de Kort (2014, Study 1) assigned participants to one of four conditions including ego-depletion for three picture exposure conditions with natural, urban, or no content, along with a non-depletion and no picture content condition. Results suggested depleted participants had slower reaction times than non-depleted participants on a stroop task, replicating previous self-control findings. Following ego-depletion, participants viewing nature pictures had faster reaction times compared to both the urban picture and no content groups. The nature group's reaction time was comparable to the non-depletion, no content condition. Participants in the depletion conditions reported a decline in hedonic tone compared to the non-depletion group. No significant physiological effects were found.

In their second study, Beute and de Kort (2014, Study 2) assigned participants to be ego-depleted or non-depleted, and to view either urban or nature pictures as recovery. This time the 2-back working memory task was used as a measure of performance. No significant differences emerged between nature and urban picture conditions on task performance. Hedonic tone improved for both nature slide conditions relative to the urban slide conditions. Some minor physiological effects emerged. Ego-depleted participants showed recovery of heart rate when viewing either set of pictures. Heart-rate variability responses for all participants improved after viewing nature slides.

Chow and Lau (2015) conducted three studies testing the effect of exposure to nature through picture slides on recovery from ego-depletion. In study one, participants were shown pictures of nature or rested following ego-depletion. The group shown nature photos persisted longer on unsolvable anagrams, a common measure used to assess ego-depletion. In study two, participants were randomly assigned to view nature or urban photos following ego-depletion, and to imagine themselves in the photographed places. Participants completed graduate-record exam (GRE) analytic questions at pre and post-test. It was found that participants in the nature condition showed a significant improvement from pre to post test, whereas the urban condition did not. There was no main effect for condition. In study three, participants were randomly assigned to be ego-depleted or not depleted, as well as view nature photos or urban photos. All participants completed a series of difficult anagrams as the outcome measure. For depleted participants, results showed that participants viewing nature photos performed better on the anagram task than those viewing urban photos. Non-depleted participants performed equally well, regardless of picture stimuli viewed.

Aims of the Present Research

Building on recent work, the overall research aims of this dissertation are:

1) Replicate findings suggesting that interacting with nature can improve mood and self-control.
2) Include an objective health decision task as an additional evaluation of self-control performance.
3) Move toward greater external and ecological validity by demonstrating that natural elements present in the immediate environment can improve self-control and physiology.

Study One

The first study was designed to replicate and extend previous research using the picture viewing paradigm of nature exposure. In addition to assessing changes in mood throughout the study, this randomized controlled trial utilized a self-control task (unsolvable anagrams) and a health decision task (food choice) as outcome measures. Unsolvable anagrams are frequently used in ego-depletion research as a valid assessment of self-control (Hagger et al., 2010). The health decision task was added as a way to assess self-control in a more realistic manner with real world consequences. Obesity and unhealthy dietary choices reflect a growing problem in the United States (Owen, Bauman, & Brown, 2009), and research on dietary choices and self-control remains sparse.

A comparison between mentally depleted (ego-depleted) participants and non-depleted participants was conducted, as well as between participants viewing scenic nature photographs and photographs of urban environments. Participants were therefore randomly assigned to one of four conditions in a 2 X 2 factorial design: [1] no depletion, urban photos; [2] no depletion, nature photos; [3] ego-depletion, urban photos; and [4] ego-depletion, nature photos. Several hypotheses were tested with each of the outcome variables.

With mood, it was hypothesized that:

H1: A three-way interaction between Depletion Condition, Photo Condition, and Time would occur for negative affect. Specifically, it was hypothesized that ego-depleted participants viewing nature photos would show a decrease in negative affect after viewing the photos relative to ego-depleted participants viewing urban photos, who would continue to display a heightened level of negative affect following the depletion task. This hypothesis is displayed graphically in Figure 1.

H2: A three-way interaction between Depletion Condition, Photo Condition, and Time would occur for positive affect. Specifically, it was hypothesized that ego-depleted participants viewing nature photos would show an increase in positive affect after viewing the photos compared to ego-depleted participants viewing urban photos, who would continue to display a lower level of positive affect following the depletion task. This hypothesis is displayed graphically in Figure 2.

For the unsolvable anagram task, it was hypothesized that:

H3: An interaction between Depletion Condition and Photo Condition would occur for time spent on the anagram task. Specifically, it was hypothesized that ego-depleted participants viewing urban photos would persist at the task for less time than ego-depleted participants viewing nature photos or non-depleted participants viewing either type of photos. This hypothesis is displayed graphically in Figure 3.

For the health decision task, it was hypothesized that:

H4: An interaction between Depletion Condition and Photo Condition would occur for number of unhealthy and healthy snacks chosen. Specifically, it was hypothesized that ego-depleted participants viewing urban photos would choose more unhealthy snacks and fewer healthy snacks than ego-depleted participants viewing nature photos or non-depleted participants viewing either type of photos. This hypothesis is displayed graphically in Figure 4 for unhealthy snacks, and Figure 5 for healthy snacks.

Method

Participants

Students attending a university in the western U.S. participated in the study in exchange for course credit. The study utilized a 2 X 2 factorial design, with Depletion Condition (no depletion, ego-depletion) as one factor and Photograph Condition (Urban, Nature) as the second factor. Anyone over the age of 18 was eligible to participate. Participants were randomly assigned to conditions using a computer-generated randomization list by the first author. Participants were blind to condition allocations throughout the study, but researchers were not as session preparation required setting up the picture slideshows.

A power analysis was conducted in G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) for an interaction effect within a two-way ANOVA for the anagram task and health decision task outcome measures. To detect a small to medium effect size of $f = 0.20$, with $\alpha = .05$, and $1 - \beta = 0.80$, a total sample size of 199 participants would be required. Given the target N of 199 participants, a sensitivity analysis was then conducted to determine what effects could be detected for the analysis of changes in mood. With $\alpha = .05$, $1 - \beta = 0.80$, $N = 199$, and four repeated measurements, a small effect size of $f = 0.10$ could be detected.

Figure 6 depicts the flow of participants through the study. Of the obtained sample of 203 participants, 82.3% were female; ages ranged from 18 to 27 years old ($M = 19.71$, $SD = 1.49$); and ethnicities were 51.7 % Hispanic, 25.1% Asian, 12.3% White, 6.9% Black, 2.5% Pacific Islander, and 1.5% other. Notably, 48.8% of participants indicated that English was not their first language.

Procedure

The university's institutional review board approved the study prior to data collection. Participants were recruited through the university's research participant pool and were run alone in individual sessions. Data collection began and was completed in the spring of 2016. Study advertisements described the study aim as investigating the relationship between executive function and personality, and indicated that participants should come to the session with at least a small appetite for snacks. All research sessions were scheduled for one hour.

Research sessions were conducted in a small interior room without windows. Participants were directed to sit at a desk facing the back wall that included a computer monitor. The monitor remained off until the picture viewing portion of the study and the mouse and keyboard to the computer were unplugged. The desk had sufficient space for participants to complete the paper questionnaires used throughout the majority of the study. Informed consent was obtained from all participants in the study.

An initial packet of questionnaires was then administered that included the State-Trait Anxiety Inventory (STAI) (Spielberger, Gorusch, Lushene, Vagg, & Jacobs, 1983), the Connectedness to Nature Scale (Mayer & Frantz, 2004), and the Dutch Eating Behavior Questionnaire – Restrained Eating subscale (van Strien, Frijters, Bergers, & Defares, 1986). These were included in the study because of suspected moderating effects with one or more of the outcome variables. Anxiety has been shown in previous research to be related to self-control (Tangney, Baumeister, & Boone, 2004), and it was suspected that individuals high in anxiety may have lower self-control, and thus may become more easily frustrated and perform poorly on the anagram assessment and health decision task. Connection to nature was included because it was suspected that individuals strongly identifying with nature may receive greater benefits from the nature manipulations than individuals without a strong connection to nature (Mayer & Frantz, 2004). Restrained eating was included because for individuals actively monitoring their diet or attempting to lose weight, the number of snacks selected would likely not reflect choices under normal conditions (van Strien, Frijters, Bergers, & Defares, 1986). Additionally, the Profile of Mood States (POMS) (Shacham, 1983) was included at the end of this packet to measure positive and negative affective states at baseline.

Next, participants completed one of two versions of a letter crossing task, depending on assignment to either no-depletion condition or ego-depletion condition. In the no-depletion condition, an easy version of the task was administered. In the ego-depletion condition, a complex version of the task designed to be mentally fatiguing was administered. Participants were asked to stop the task after 20 minutes. Everyone completing the easy version finished in less than 20 minutes, whereas no one doing the complex version finished in 20 minutes. Following completion or stoppage of the letter crossing task, the POMS was administered for a second time.

A questionnaire numbered 1 – 30 was then given to participants. Participants were told they would view a slideshow of 30 photographs on the computer monitor and were to indicate on the form whether they had already visited the location depicted, would like to visit the location, or would not like to visit the location. Depending on assigned condition, the slideshow was either 30 photographs of famous urban landscapes or 30 photographs of scenic natural landscapes such as national parks and wilderness areas. The photographs changed automatically every 15 seconds and were displayed in a Microsoft Power Point presentation. The slideshow took seven and a half minutes to view. Immediately following the picture viewing task, the POMS was administered for a third time.

The unsolvable anagram task was then administered. There were six anagrams included on the form, and participants were instructed to work on the task for as long as they pleased and could ask to stop working at any time. Unbeknownst to participants, only two of the six anagrams had solutions; the other four were insoluble. The experimenter surreptitiously timed participants using a stopwatch from the moment instructions were given until the participant asked to stop. A time cap was set at 15 minutes at which point the experimenter stopped participants if they were still working.

Time spent on the task was recorded on the form as it was collected. The POMS was administered for the fourth and final time following completion of the anagram task.

Lastly, participants completed a questionnaire with demographic information. As participants completed this form, the experimenter retrieved a box of snacks from a drawer and placed the box next to the participant. The box included exactly five of each of the following items: Healthy – clementines, snack sized almond packs, and bagged dried apple crisps; Unhealthy – snack sized candy bars, snack sized sweet candy, and chips. Participants were instructed to help themselves to whatever they liked and to take as much as they wanted. The experimenter then left the room for three minutes under the guise of forgetting something in a different room. After the experimenter returned, participants were debriefed as to the true purpose of the study. Participants were encouraged not to disclose the details of the study to anyone else. No participants reported hearing about the study or its aims from others. Once questions were answered and the participant left, the experimenter recorded the number of each snack chosen and refilled the box for the next session accordingly.

Measures

State-Trait Anxiety Inventory (STAI). The STAI (Spielberger et al., 1983) is a questionnaire that assesses anxiety. For the present study, only questions pertaining to trait anxiety were included. The trait version features 20 items such as, "I feel like crying," "I am happy," and "I try to avoid facing a crisis or difficulty." Participants were instructed to circle a number next to each statement ranging from 1 (*almost never*) to 4 (*almost always*) describing how they generally feel. Some of the items were reverse coded, and scores were generated by summing all items. Internal consistency was high (Cronbach's $\alpha = .89$). The full questionnaire is included in Appendix A.

Connectedness to Nature Scale. This questionnaire (Mayer & Frantz, 2004) assesses the degree of connectedness one feels with Earth and the natural world. There are 14 items, for example, "I often feel a sense of oneness with the natural world around me," I often feel a kinship with animals and plants," and "I feel that all inhabitants of Earth, human and nonhuman, share a common 'life force'." Participants wrote a number ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) next to each item indicating the way they generally feel. Some items were reverse coded, and scores were generated by summing all items. Internal consistency was acceptable (Cronbach's $\alpha = .76$). The full questionnaire is included in Appendix B.

Dutch Eating Behavior Questionnaire – Restrained Eating Subscale. This questionnaire (van Strien et al., 1986) assesses any restrained eating tendencies participants may have. There are 10 items, such as "Do you try to eat less at mealtimes than you would like to eat?" "Do you deliberately eat foods that are slimming?" and "Do you take into account your weight with what you eat?" Participants wrote a number ranging from 1 (*never*) to 5 (*very often*) next to each item. Items were summed to generate scores. Internal consistency was high (Cronbach's $\alpha = .92$). The full questionnaire is included in Appendix C.

Profile of Mood States (POMS) Short Form. The POMS (Shacham, 1983) assesses various dimensions of positive and negative affective states. There are six subscales that comprise the measure, each including between five and eight descriptor items. The subscales are: depression, vigor, anger/frustration, tension, confusion, and fatigue. For example, some of the items comprising the depression subscale are “unhappy,” “hopeless,” and “worthless.” Participants wrote a number between 1 (*not at all*) and 5 (*extremely*) next to each descriptor item. Items were then averaged to compute a score for each subscale. The vigor subscale is considered a measure of positive affective state, whereas the other five subscales are considered measures of different negative affective states. The full questionnaire is included in Appendix D.

Letter Crossing Task. This task was adapted from the ‘letter e’ task used in previous ego-depletion studies (Baumeister et al., 1998; Fennis, Janssen, & Vohs, 2009, Experiment 4). The instructions begin by stating that passages from a scientific journal article will be presented and participants are asked to follow rules related to the crossing out of letters. Text from a highly technical Nature Review journal article on the biologic pathways of cancer treatment was chosen (Yu, Lee, Herrmann, Buettner, & Jove, 2014). Depending on assigned condition, participants either had an easy task in the no-depletion condition (cross out all occurrences of the letter ‘x’) or an increasingly difficult task in the ego-depletion condition (cross out all occurrences of the letter ‘e’ with additional rules).

An initial paragraph showed all instances of the respective letter (x or e) crossed out as an example, and was followed by 3-4 paragraphs of text where participants were instructed to cross out the respective letter of their assigned condition as practice. For the no-depletion condition, this same instruction was continued for two additional pages of text. The text was set to 12 point font in Times New Roman style, and all lines were double spaced with a space between paragraphs in the no-depletion condition. In the ego-depletion condition, once participants finished the first practice page of crossing out e’s, the task continued for an additional three pages of text. Two new rules were introduced at this point to make the task more difficult: 1) Anytime an ‘e’ is directly followed by another vowel, as in ‘beauty,’ do not cross out the ‘e.’ 2) Anytime a vowel appears two letter before an ‘e,’ as in ‘vowel,’ do not cross out the ‘e.’ Additionally, the text was set to 10 point font in Calibri style with single spacing and no spaces between paragraphs to make it more difficult to spot letters. Both versions of the task are included in Appendix E.

Urban and Nature Photographs and Questionnaire. As a cover story for viewing photographs, all participants were given a 30-item questionnaire corresponding to pictures shown on a Microsoft Power Point slideshow. The instructions asked: “Would you like to visit the place in (photo number)?” Response options were “Yes,” “No,” and “Already have.” This was repeated for each of the 30 photos. The photographs varied depending on assigned condition. In the Urban Photo condition, 30 pictures of famous urban architecture and settings were shown. Efforts were made to select photos without natural elements (e.g., no grass, trees, or water). In the Nature Photo condition, 30 pictures of scenic natural landscapes such as national parks and wilderness areas were displayed. Each photograph remained on the screen for 15 seconds, after which the slideshow automatically transitioned to the next picture. The slideshow completed after seven and a half minutes. The photo questionnaire, urban photos, and nature photos can be found in Appendices F-H, respectively.

Unsolvable Anagram Task. Anagrams are words that can be made from other words or groups of letters by rearranging the order of the letters. In this task, participants attempted to solve six anagrams by figuring out a word that could be spelled by rearranging a meaningless group of letters. Two of the anagrams had real solutions (e.g., EERIVCE = RECEIVE) whereas the other four did not have solutions (e.g., AESIDUD). Each group of letters had a blank line next to it where participants could write in their answer. Participants were instructed to work on the anagrams for as long as they would like, and to let the experimenter know when they wanted to stop. Participants were surreptitiously timed as they worked on the task. A time cap was set at 15 minutes at which point the experimenter stopped participants if they were still working. Time spent on the task was recorded on the form as it was collected and served as the outcome measure. The measure can be found in Appendix I.

Demographic and Personal Characteristics. The final questionnaire included items assessing gender, age, ethnicity, and whether English was the participant's first language. Additionally, two questions asked whether participants knew what the study was about or if they felt deception was used. Appendix J includes the form.

Snacks. A variety of healthy and unhealthy snacks were used for the health decision task. Snacks were selected to be roughly equivalent in caloric value and to offer a broad range of choices. The healthy snacks included clementines, snack sized almond packs, and bagged dried apple crisps. The unhealthy snacks included snack sized candy bars (Twix, Snickers, M&M's), snack sized sweet candy (Skittles, Starburst), and small chip bags (Lay's, Cheetos, Doritos, Fritos). Five of each type of healthy and unhealthy snack were included in a box placed near participants. For each type of unhealthy snack, all varieties were represented at least once among the choices (i.e., Twix, Snickers, and M&M's were all represented among the five snack sized candy choices). The number of healthy snacks and unhealthy snacks chosen were counted for each participant, creating a sum score for each category.

Analyses

All analyses were conducted using SPSS® version 24. Significance tests were set at $p < .05$. To test for a priori differences between conditions, a one-way ANOVA was used for age, whereas gender, ethnicity, and English as first language were tested using chi-square analysis. All data were tested for violations of normality and sphericity prior to analysis. In cases where violations were detected, appropriate corrections or transformations were applied and are reported with the results.

A 2(Ego-Depletion/No-Depletion) X 2(Nature Photos/Urban Photos) X 4 (Time) repeated measures ANOVA was conducted to test Hypotheses H1 and H2 related to changes in mood. H1 is displayed in Figure 1, and predicted that ego-depleted participants viewing nature photos would show a decrease in negative affect after viewing the photos compared to ego-depleted participants viewing urban photos, who would continue to display a heightened level of negative affect following the depletion task. H2 is displayed in Figure 2, and predicted that ego-depleted participants viewing nature photos would show an increase in positive affect after viewing the photos compared to ego-depleted participants viewing urban photos, who would continue to display a lower level of positive affect following the depletion task.

A two-way ANOVA was used to test Hypothesis H3 related to the unsolvable anagram task. H3 is displayed in Figure 3, and predicted that ego-depleted participants viewing urban photos would persist at the task for less time than ego-depleted participants viewing nature photos or non-depleted participants viewing either type of photos. Moderation analyses were tested using a stepwise linear regression. Continuous moderator variables were mean centered and entered in block one, followed by the dummy coded condition variables in block two, and the interaction variable in block three. This was repeated separately for Depletion Condition, Photo Condition, and the three-way interaction of each condition variable and the relevant moderator.

A two-way ANOVA was also used to test Hypothesis H4 related to the health decision task. H4 is represented graphically in Figure 4 and Figure 5, and predicted that ego-depleted participants viewing urban photos would choose more unhealthy snacks and fewer healthy snacks than ego-depleted participants viewing nature photos or non-depleted participants viewing either type of photos. To account for non-normality, sum scores of unhealthy and healthy snacks were square-root transformed prior to analysis. Moderation analyses were again tested using a stepwise linear regression. Continuous moderator variables were mean centered and entered in block one, followed by the dummy coded condition variables in block two, and the interaction variable in block three. This was repeated separately for Depletion Condition, Photo Condition, and the three-way interaction of each condition variable and the relevant moderator.

Results

Baseline Equivalence Across Conditions

The four conditions did not differ on any of the demographic or personal characteristics; age, $F(3, 202) = 0.21$, $p = .89$; gender, $\chi^2(3, N = 203) = 3.05$, $p = .38$; ethnicity, $\chi^2(18, N = 203) = 14.22$, $p = .72$; or English as first language, $\chi^2(3, N = 203) = 1.52$, $p = .68$. Means, standard deviations, and correlations of study variables are displayed in Table 1.

Effects of Conditions on Mood

Table 2 presents the results of the Repeated Measures ANOVA of Depletion Condition, Photo Condition, and Time on differences in Profile of Mood States (POMS) subscale mean scores for Vigor, Anger/Frustration, Confusion, and Fatigue. Each of these mood states revealed significant interactions, along with a main effect for Time. The subscale factors of Depression and Tension did not reveal any significant interaction effects, and are excluded from the table. Controlling for Trait Anxiety and Connectedness to Nature did not change these results.

For Vigor, which represents positive affect, there was not a significant three-way interaction between Depletion Condition, Photo Condition, and Time; which failed to support H2. However, a significant interaction between Depletion Condition and Photo Condition was found. This interaction is displayed in Figure 7. Simple effects analyses revealed a trend towards significance that Ego-Depleted participants viewing Nature Photos scored higher on average on the Vigor subscale compared to Non-Depleted participants viewing Nature Photos; $t(95.20) = 1.94$, $p = .055$, $d = .40$.

For Anger/Frustration, there was not a significant three-way interaction, failing to support H1. However, there was a significant interaction between Depletion Condition and Time. This interaction is displayed in Figure 8. Simple effects analyses revealed that

Anger/Frustration was higher for participants in the Depletion Condition compared to Non-Depleted participants immediately following the letter crossing task, with *t*(180.24) = 3.01, p =.003, d = .44.

For Confusion, there was not a significant three-way interaction between Depletion Condition, Photo Condition, and Time; failing to support H1. However, there was a significant interaction between Depletion Condition and Time. This interaction is displayed in Figure 9. Simple effects analyses revealed that Confusion was higher for participants in the Depletion Condition compared to Non-Depleted participants immediately following the letter crossing task, with *t*(192.57) = 2.65, p =.009, d = .38.

For Fatigue, there was also not a significant three-way interaction; failing to support H1. However, there was a significant interaction between Depletion Condition and Time. This interaction is displayed in Figure 10. Simple effects analyses revealed a trend towards significance that Fatigue was higher for participants in the Depletion Condition compared to Non-Depleted participants immediately following the letter crossing task, with *t*(194.94) = 1.92, p =.056, d = .28.

Effects of Conditions on Unsolvable Anagram Task

The results of the two-way ANOVA of Depletion Condition and Photo Condition on Anagram Task Persistence are presented in Table 3. Neither the main effects of Condition or the interaction of Depletion Condition and Photo Condition were significant; failing to support H3. Whether or not participants had undergone ego-depletion did not impact persistence on the task. Similarly, the types of photos viewed did not lead to changes in task persistence. The results are displayed graphically in Figure 11. Whether or not participants reported English as their first language did not differentially affect time spent on the anagram task, F(1, 194) = 2.17, p = .14, η^2_p = .01. Trait Anxiety did not moderate the effect of Depletion Condition, R^2 = 0.022, ΔR^2 = 0.004, F(3, 198) = 1.51, p = .21; Photo Condition, R^2 = 0.044, ΔR^2 = 0.000, F(3, 198) = 0.13, p = .94; or the interaction of Depletion and Photo Condition, R^2 = 0.152, ΔR^2 = 0.004, F(5, 196) = 0.93, p = .46 on persistence at the anagram task. Similarly, Connectedness to Nature did not interact with Depletion Condition, R^2 = 0.045, ΔR^2 = 0.02, F(3, 196) = 3.04, p = .08; Photo Condition, R^2 = 0.113, ΔR^2 = 0.003, F(3, 196) = 0.85, p = .47; or the interaction of Depletion and Photo Condition, R^2 = 0.050, ΔR^2 = 0.026, F(5, 194) = 0.13, p = .07 on persistence at the anagram task.

Effects of Conditions on Health Decision Task

The results of the two-way ANOVAs of Depletion Condition and Photo Condition on number of unhealthy and healthy snacks chosen are displayed in Table 4. Neither the main effects of Condition or the interaction of Depletion Condition and Photo Condition were significant; failing to support H4. Ego-depleted participants did not differ from non-depleted participants in number of unhealthy or healthy snacks chosen. Similarly, participants viewing nature photos did not differ from participants viewing urban photos in number of unhealthy or healthy snacks chosen. The results for unhealthy snacks are presented in Figure 12. The results for healthy snacks are displayed in Figure 13.

Restrained Eating did not moderate Depletion Condition, R^2 = 0.006, ΔR^2 = 0.000, F(3, 199) = 0.39, p = .76; or Photo Condition, R^2 = 0.018, ΔR^2 = 0.012, F(3, 199) = 1.19, p = .32 for number of unhealthy snacks chosen, and also did not interact with

Depletion Condition, $R^2 = 0.032$, $\Delta R^2 = 0.026$, $F(3, 199) = 2.17$, $p = .09$; or Photo Condition, $R^2 = 0.012$, $\Delta R^2 = 0.011$, $F(3, 199) = 0.83$, $p = .48$ for number of healthy snacks chosen. Connectedness to Nature did not interact with Depletion Condition, $R^2 = 0.008$, $\Delta R^2 = 0.002$, $F(3, 197) = 0.50$, $p = .68$; Photo Condition, $R^2 = 0.006$, $\Delta R^2 = 0.000$, $F(3, 197) = 0.41$, $p = .75$; or the interaction of Depletion and Photo Condition, $R^2 = 0.009$, $\Delta R^2 = 0.003$, $F(5, 195) = 0.34$, $p = .89$ for number of unhealthy snacks chosen. Connedtedness to Nature did not interact with Photo Condition, $R^2 = 0.008$, $\Delta R^2 = 0.000$, $F(3, 197) = 0.52$, $p = .67$; however, there was an interaction with Depletion Condition, $R^2 = 0.059$, $\Delta R^2 = 0.046$, $F(3, 197) = 4.10$, $p = .008$ for number of healthy snacks chosen; but not for the interaction of Depletion and Photo Condition, $R^2 = 0.009$, $\Delta R^2 = 0.003$, $F(5, 195) = 0.34$, $p = .89$ for number of healthy snacks chosen.

Discussion

Findings are discussed in turn, followed by general comments. For negative affect, H1 hypothesized that among ego-depleted participants, a decrease in negative affect would occur for nature photo viewers following the photo viewing portion of the experiment compared to urban photo viewers. The types of photographs viewed (nature or urban) was found to have no impact on any negative affective mood state. There was, however, an impact of depletion condition on negative affect, as participants in the ego-depletion condition showed a greater increase in Anger/Frustration, Confusion, and Fatigue following completion of the letter-crossing task compared to non-depleted participants.

For positive affect, H2 hypothesized that for ego-depleted participants viewing nature photos, an increase in positive affect would occur following the photo viewing compared to urban photo viewers. This hypothesis also failed to receive support, as there was no significant change in positive affect over time between conditions. However, there was an interaction between Depletion Condition and Photo Condition, such that a trend emerged for Vigor being higher on average for ego-depleted nature photo viewers than non-depleted nature photo viewers.

For persistence on the unsolvable anagram task, H3 hypothesized that ego-depleted participants viewing urban photos would persist at the task for less time than ego-depleted participants viewing nature photos or non-depleted participants viewing either type of photos. This hypothesis failed to receive support, as there were no significant differences in time spent on the task for depletion status, type of photos viewed, or their interaction.

For the health decision task, H4 hypothesized that ego-depleted participants viewing urban photos would choose more unhealthy snacks and fewer healthy snacks than ego-depleted participants viewing nature photos or non-depleted participants viewing either type of photos. This hypothesis failed to receive support as both the number of unhealthy and healthy snacks chosen did not vary based on depletion condition, photo condition, or their interaction.

Study One attempted to replicate and extend previous research using a photo viewing paradigm of nature exposure. Overall, the findings from Study One failed to support each of the hypotheses. Based on these results, viewing photographs of natural scenes was not enough to have any meaningful influence on mood, self-control, or decision making. Some previous work has also failed to find significant effects in these domains (Beute & de Kort, 2014, Study 2; Hartig et al., 1996). However, the results of the present experiment stand in contrast to the majority of previous published work that has used a similar, and at times less intensive exposure to nature stimuli and found significant effects (e.g., Berman, Jonides, & Kaplan, 2008; Berto, 2005; Ulrich et al., 1991).

There are several possible reasons for the discrepancies in current findings and those of previous work. For mood, the Profile of Mood States (POMS) was used in this study. Other studies have used measures of mood ranging from the POMS (e.g., van den Berg et al., 2003), the Positive and Negative Affective Schedule (e.g., Berman et al., 2008), to other less common measures (e.g., Beute & de Kort, 2014). In addition to the measure used, the frequency of measurement has varied between studies. Mood was assessed at four time points in the present experiment; possibly leading to a sense of boredom or repetitiveness among participants influencing the speed and accuracy of their responses. It is also possible that the photographs were not sufficient in and of themselves to influence mood, and participants perceived the task as just another part of the study to complete.

For the self-control task, failure to find an effect may have been due to the unsolvable nature of the anagram task, with participants recognizing the impossibility of the task and giving up accordingly. Variations of the anagram task have been used extensively in the ego-depletion literature (Hagger et al., 2010); and in this study only two of the anagrams on the measure had real solutions. This may have led to participants becoming equally discouraged in all conditions upon realizing the difficulty of the task. Alternatively, some researchers have argued that the type of task used may be tapping into different dimensions of cognitive processing (Beute & de Kort, 2014). These authors argue that higher-order processes, such as tasks involving working memory, may be subject to becoming fatigued in different ways than simpler processes such as impulse control (i.e., resisting the urge to stop the anagram task), which may be performed without much cognitive effort. This could explain why time spent on the task was roughly equivalent between conditions.

For the health decision task, a proxy measure of self-control via impulse control, a number of factors may have influenced snack selection. First, what were chosen as snack options may not have been equally appealing to participants. Efforts were made to select snack choices roughly equivalent in caloric value, but in doing so some options may have been more enticing than others. Second, although participants were instructed to come to the study session with at least a small appetite; it is possible that because study sessions were held throughout the day that some participants were either not hungry at all and took no snacks or were participating before meal time and took a large number of snacks. Third, while some minor changes in the mood states of Anger/Frustration, Confusion, and Fatigue occurred for a brief period for ego-depleted participants, this effect quickly dissipated by the next assessment. Furthermore, depletion did not show any effect on the anagram task, suggesting that self-control failed to be affected by the depletion manipulation in both assessments.

Some additional limitations are worth acknowledging. The study session was scheduled for one hour, limiting the length of time taken for each task. The letter crossing task used for the depletion task may not have been performed for long enough to lead to ego-depletion. Similarly, the recovery period, which included completing the POMS and the picture viewing task, took around 10 minutes prior to the participant beginning the anagram task. Ten minutes may be sufficient time for a complete recovery of mental resources regardless of what type of task was used for depletion.

If nature does in fact have beneficial effects on things like mood, attention, and self-control, as previous research suggests that it might (e.g., Hartig et al., 2014; Keniger et al., 2013), it is likely that the degree or "intensity" of nature exposure matters. Simply viewing photographs, however scenic they may be, may be failing to capture what is necessary and important about nature in restoring attention, improving mood, and ultimately improving self-control. The second study of this dissertation therefore moved to a more externally and ecologically valid research design by focusing on manipulating natural elements in the immediate environment.

Study Two

Based on the shortcomings of the first experiment, several changes were incorporated into the design of the second study. As before, a randomized controlled trial was used to assess mood, self-control, and health decision making as outcome measures; although each was altered slightly. Additionally, physiological measurements including heart rate and blood pressure were included to test predictions made by Psycho-Evolutionary Theory (Ulrich, 1983; Ulrich et al., 1991) and to add to the limited research literature on physiological effects of nature exposure.

In Study Two, nature exposure was changed to be more "intense" by changing both the type and the duration of nature exposure. In this study, the immediate work environment (i.e., the room the study was completed in) was the independent variable. The rationale for this change is supported by the practice of biophilic design, which aims to incorporate nature into the design and décor of buildings and workspaces (Kellert, 2005; Kellert, Heerwagen, & Mador, 2008). Few studies have systematically examined the impact of nature in workspaces, and existing studies have produced mixed results (Fjeld et al., 1998; Han, 2009). Many claims are made about the benefits of having plants in workspaces in the popular press, but little research exists to support these claims. Indeed, much of the biophilic design movement is based on anecdotes and informal observations.

The concept of biophilia underlies the biophilic design movement, which argues that humans have an innate inclination to affiliate with other forms of life and natural processes (Kellert & Wilson, 1993; Wilson, 1984). Including plants and other natural elements in indoor spaces provides a greater level of nature exposure than simply viewing photographs, and the potential for indirect benefits (e.g., improved indoor air quality from plants, less eye strain from natural light) is also higher. The present study sought to add to the literature on nature in workspaces and biophilic design, and to test whether or not productivity, as measured by persistence and performance on a self-control task, could be improved by the presence of natural stimuli.

Participants were randomly assigned to one of two conditions: [1] Control Room, or [2] Nature Room. The study sessions were increased to be 90 minutes long, and participants spent the entire session in their respective assigned rooms. The Control Room contained no natural elements and had only a desk cubicle facing a blank wall. The Nature Room had two large windows with natural light looking out at a scenic view, live potted plants, and a trickling water fountain nearby. The exposure to nature continued throughout the study session, and now involved visual and auditory sensory input.

All participants completed the difficult version of the letter crossing task, leading to an equivalent level of ego-depletion in each condition. The only difference between conditions was the room the participants completed the study in. Because the room was the independent variable, the recovery period following the letter crossing task was cut down to three minutes to minimize restoration of willpower from rest. Mood assessments were changed to be administered at three time points instead of four, to minimize boredom and repetitiveness for participants. The anagram task was changed to be solvable, as some previous research has found improvements in performance on cognitive tasks following nature exposure (Berman et al., 2008; Berto, 2005; Chow & Lau, 2015), rather than focusing solely on persistence alone. The health decision task was changed to be the quantity of unhealthy snacks (candy) chosen, to reduce the number of choices and provide a less ambiguous test of impulse control. Several hypotheses were tested for each outcome variable.

For mood, it was hypothesized that:

H1: An interaction between Condition and Time would occur for negative affect. Specifically, it was hypothesized that participants in the Nature Room would show a small increase in negative affect following the baseline measurement; compared to Control Room participants who would show a larger increase in negative affect following the baseline measurement. This hypothesis is displayed graphically in Figure 14.

H2: An interaction between Condition and Time would occur for positive affect. Specifically, it was hypothesized that participants in the Nature Room would remain constant in positive affect throughout the study; compared to Control Room participants who would show a decrease in positive affect following the baseline measurement. This hypothesis is displayed graphically in Figure 15.

For physiology, it was hypothesized that:

H3: An interaction between Condition and Time would occur for heart rate. Specifically, it was hypothesized that Nature Room participants would show a larger decrease in heart rate following the baseline measurement compared to Control Room participants, who would show only a slight decrease in heart rate following the baseline measurement. This hypothesis is displayed graphically in Figure 16.

H4: An interaction between Condition and Time would occur for systolic and diastolic blood pressure. Specifically, it was hypothesized that Nature Room participants would show a larger decrease in systolic and diastolic blood pressure following the baseline measurement compared to Control Room participants, who would show only a slight decrease in systolic and diastolic blood pressure following the baseline measurement. This hypothesis is displayed graphically in Figures 17 and 18.

For the anagram task, it was hypothesized that:

H5: A main effect of Condition would occur for both time spent on the anagram task and number of anagrams correctly solved. Specifically, it was hypothesized that Nature Room participants would persist for longer at the task and solve more anagrams than Control Room participants. This hypothesis is displayed graphically in Figure 19.

For the health decision task, it was hypothesized that:

H6: A main effect of Condition would occur for number of snacks eaten. Specifically, it was hypothesized that Nature Room participants would eat fewer snacks than Control Room participants. This hypothesis is displayed graphically in Figure 20.

Method

Participants

Students attending a university in the western U.S. participated in the study in exchange for course credit. The study utilized a basic randomized experimental design, with assignment to the Nature Room as the experimental condition, and assignment to the Control Room as the control condition. Anyone over the age of 18 who had not participated in the first study was eligible to participate. The first author randomly assigned participants to conditions by flipping a coin. Participants were blind to condition allocations and purpose of the experiment throughout the study, but researchers were not as the room environment was the manipulation.

A power analysis was conducted in G*Power (Faul et al., 2007) for a two-tailed t-test for the anagram task and health decision task outcome measures. To detect a medium effect size of Cohen's $d = 0.50$, with $\alpha = .05$, and $1 - \beta = 0.80$, a total sample size of 128 participants would be required. Given the target N of 128 participants, a sensitivity analysis was then conducted to determine what effects could be detected for the analyses of changes in mood, heart rate, and blood pressure. With $\alpha = .05$, $1 - \beta = 0.80$, $N = 128$, and three repeated measurements, a small effect size of $f = 0.11$ could be detected.

Figure 21 depicts the flow of participants through the study. Of the obtained sample of 126 participants, 70.6% were female; ages ranged from 18 to 41 years old ($M = 20.39$, $SD = 2.64$); and ethnicities were 52.4 % Hispanic, 27% Asian, 11.1% White, 6.3% Black, and 3.2% other. Notably, 51.6% of participants indicated that English was not their first language.

Procedure

The university's institutional review board approved the study prior to data collection. Participants were recruited through the university's research participant pool and were run alone in individual sessions. Data collection began in the spring of 2016 and was completed in the summer of 2016. Study advertisements described the study aim as investigating the relationship between creative problem solving and personality, and indicated that participants should come to the session with at least a small appetite for snacks. Participants were excluded from signing up for the study if they had participated in study one. All research sessions were scheduled for one and a half hours.

Depending on assigned condition, research sessions were either conducted in the small, interior room without windows used in study one or a small conference room with added natural features. The interior room had no windows and contained only a cubicle facing a blank wall. The conference room had natural light from two large windows with views of a lake and mountains, a running water fountain, a table fern, and a potted palm tree. Participants were directed to sit where they could see out both windows and have the plants in direct sight. The water fountain was positioned close by and provided the constant sound of trickling water down rocks. There was sufficient workspace to complete the paper questionnaires in both conditions. Informed consent was obtained from all participants in the study prior to data collection.

An initial packet of questionnaires was then administered that included the Connectedness to Nature Scale (Mayer & Frantz, 2004) and the Dutch Eating Behavior Questionnaire – Restrained Eating subscale (van Strien et al., 1986). These were included in the study because of potential moderating effects with one or more of the outcome variables.

Following completion of the initial packet of questionnaires, physiological measurements were taken from participants using a small automated blood pressure cuff machine. Prior to this point in the study, the machine was kept out of sight by the experimenter. Participants sat upright with their left arm lying flat on the table while having measurements taken. The blood pressure cuff was placed on the participant's left arm by the experimenter, who then activated the machine. Participants were instructed not to fidget while the machine took readings, which took about 30 seconds to complete. The experimenter wrote down the readings from the machine and did not allow the participant to see their readings. Following the physiological measurement, the machine was once again placed out of sight of the participant and the Profile of Mood States (POMS) (Shacham, 1983) was administered to measure positive and negative affective states at baseline.

Next, all participants completed the difficult version of the letter crossing task used in study one. This task was designed to lead to ego-depletion. Participants were asked to stop the task after 20 minutes. No one finished before the 20 minute time limit. Following completion of the letter crossing task, physiological measurements were again taken using the procedure described above and the POMS was administered for a second time.

At this point the experimenter stepped out of the room under the guise of forgetting something in another room. A timer was set so that the experimenter would return after three minutes. This was built into the study to allow the participant time to sit in the assigned room environment and recover briefly from the ego-depleting task. After the experimenter returned, the anagram task was administered. In this version of the anagram task, all anagrams were solvable and progressed from easy to difficult. There were 12 anagrams included on the form, and participants were instructed to work on the task for as long as they pleased and could ask to stop working at any time. The experimenter surreptitiously timed participants using a stopwatch from the moment instructions were given until the participant asked to stop. A time cap was set at 20 minutes at which point the experimenter stopped participants if they were still working. Time spent on the task was recorded on the form as it was collected. After the session, the number of correctly solved anagrams was checked and tallied.

Physiological readings were then taken for the third and final time. The POMS was administered for the third and final time following the physiological measurements. The last portion of the experiment was the health decision task. For this study, a bowl of chocolate candies was retrieved from another room that included exactly ten of each of the following snack sized candies: Snickers, Twix, Reese's Peanut Butter Cups, and KitKats. Participants were told a cover story that the experiment was pilot testing a new method of assessing personality traits. A form was administered to participants with instructions to eat as much candy as they liked and to free write about the sensations or thoughts they had while eating the candy. The experimenter answered any questions then left the room so the participant could eat and complete the form in privacy. A questionnaire with demographic information was included on the back side of the form.

After six minutes, the experimenter returned to check on the participant. If additional time was needed, the experimenter left for additional two minute blocks of time. When the participant was finished with the health decision task and demographic questionnaire, participants were debriefed as to the true purpose of the study. Participants were encouraged not to disclose the details of the study to anyone else. No participants reported hearing about the study or its aims from others. Once questions were answered and the participant left, the experimenter recorded the number of snacks chosen and refilled the bowl for the next session accordingly.

Materials

Nature Room Stimuli. A Boston Fern (*Nephrolepis exaltata*) was placed at the center of the conference room table, roughly one meter away from where participants were seated. A potted Areca Palm tree (*Dypsis lutescens*) that was around one meter tall was placed against the wall to the participants' right side in the room. A medium sized water fountain was placed in the corner of the room behind and to the left of where participants were seated. The fountain was made of artificial material and resembled a rock cascade, which water cascaded down to produce a soothing water current sound. Two large glass pane windows ran the width of the wall immediately in front of and to the left of where participants were seated. All sessions were conducted during the daytime hours allowing for the room to be entirely lit by natural light. The view from the window in front of participants included rolling hills and mountains, and the view from the window to the left of participants included a lake, field, and trees.

Control Room Stimuli. The Control Room contained desk cubicles, storage cabinets, and a research freezer. Participants were seated at the cubicle facing the back, blank wall. There were no windows in the room and all light was from two overhanging fluorescent lights. An intermittent buzzing noise occurred from the research freezer stored in the corner. This sound occurred every five to ten minutes and lasted for a few minutes each time. This was consistent for all participants run in this condition throughout the study.

Measures

Connectedness to Nature Scale. This questionnaire (Mayer & Frantz, 2004) assesses the degree of connectedness one feels with Earth and the natural world. There are 14 items, for example, "I often feel a sense of oneness with the natural world around me," I often feel a kinship with animals and plants," and "I feel that all inhabitants of Earth, human and nonhuman, share a common 'life force'." Participants wrote a number ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) next to each item indicating the way they generally feel. Some items were reverse coded, and scores were generated by summing all items. Internal consistency was acceptable (Cronbach's $\alpha = .77$). This is the same questionnaire that was used in study one, and is included in Appendix B.

Dutch Eating Behavior Questionnaire – Restrained Eating Subscale. This questionnaire (van Strien et al., 1986) assesses any restrained eating tendencies participants may have. There are 10 items, such as "Do you try to eat less at mealtimes than you would like to eat?" "Do you deliberately eat foods that are slimming?" and "Do you take into account your weight with what you eat?" Participants wrote a number ranging from 1 (*never*) to 5 (*very often*) next to each item. Items were summed to generate scores. Internal consistency was high (Cronbach's $\alpha = .90$). This questionnaire was also used in study one and is included in Appendix C.

Profile of Mood States (POMS) Short Form. The POMS (Shacham, 1983) assesses various dimensions of positive and negative affective states. There are six subscales that comprise the measure, each including between five and eight descriptor items. The subscales are: depression, vigor, anger, tension, confusion, and fatigue. For example, some of the items comprising the depression subscale are "unhappy," "hopeless," and "worthless." Participants wrote a number between 1 (*not at all*) and 5 (*extremely*) next to each descriptor item. Items were then averaged to compute a score for each subscale. The vigor subscale is considered a measure of positive affective state, whereas the other five subscales are considered measures of different negative affective states. This questionnaire is the same as in study one, and is referenced in Appendix D.

Letter Crossing Task. This task was adapted from the 'letter e' task used in previous ego-depletion studies (Baumeister et al., 1998; Fennis et al., 2009, Experiment 4). The instructions begin by stating that passages from a scientific journal article will be presented and participants are asked to follow rules related to the crossing out of letters. Text from a highly technical Nature Review journal article on the biologic pathways of cancer treatment was chosen (Yu et al., 2014). All participants in this study completed the difficult version of the task involving crossing out all occurrences of the letter 'e' with additional complex rules.

An initial paragraph showed all instances of the letter 'e' crossed out as an example, and was followed by 3-4 paragraphs of text where participants were instructed to cross out the letter 'e' as practice. Once participants finished the first practice page of crossing out e's, the task continued for an additional three pages of text. Two new rules were introduced at this point to make the task more difficult: 1) Anytime an 'e' is directly followed by another vowel, as in 'beauty,' do not cross out the 'e.' 2) Anytime a vowel appears two letter before an 'e,' as in 'vowel,' do not cross out the 'e.' Additionally, the text was set to 10 point font in Calibri style with single spacing and no spaces between paragraphs to make it more difficult to spot letters. This is the same measure used in study one as the difficult version of the task included in Appendix E.

Automatic Blood Pressure Monitor. An automated Omron Intellisense™ IA2 blood pressure monitor and heart rate device utilizing an oscillometric measurement method was used for all physiological measurements. A cuff was placed on the participant's left upper arm and after the press of a button, the machine automatically cycled for between 20 - 40 seconds and displayed physiological readings. The heart rate and blood pressure readings displayed were manually recorded by the experimenter on each measurement occasion. Variations in measurement time occurred because the machine is designed to inflate and deflate the cuff at a rate based on the participant's blood pressure and arm size.

Anagram Task. Anagrams are words that can be made from other words or groups of letters by rearranging the order of the letters. In this task, participants attempted to solve twelve anagrams of increasing difficulty by figuring out a word that could be spelled by rearranging a meaningless group of letters. All of the anagrams in this study had real solutions (e.g., BAREZ = ZEBRA). Each group of letters had a blank line next to it where participants could write in their answer. Participants were instructed to work on the anagrams for as long as they would like, and to let the experimenter know when they wanted to stop. Participants were surreptitiously timed as they worked on the task. A time cap was set at 20 minutes at which point the experimenter stopped participants if they were still working. Time spent on the task was recorded on the form as it was collected and served as the outcome measure. The measure used in study two can be found in Appendix K.

Chocolate Candy and Free Writing Task. A bowl with snack sized chocolate candies was used for the health decision task. The bowl contained ten Snickers, ten Twix, ten Reese's Peanut Butter Cups, and ten KitKats. The candies were selected to be roughly equivalent in caloric value and to offer several choices. As a cover story for choosing candy, participants were told they were engaging in a "taste test task" involving sampling candy and free writing about thoughts and sensations related to eating the candy. Participants were instructed to help themselves to as much candy as they would like, and to write about any sensations related to the taste of the candy or other bodily sensations and perceptions experienced while eating the candy. The number of candies eaten was recorded by the experimenter following the task as a sum score. The measure used for the writing task is displayed in Appendix L.

Demographic and Personal Characteristics. The final questionnaire was the same as used in study one and included items assessing gender, age, ethnicity, and whether English was the participant's first language. Additionally, two questions asked whether participants knew what the study was about or if they felt deception was used. Appendix J includes the form.

Analyses

All analyses were conducted using SPSS® version 24. Significance tests were set at $p < .05$. To test for a priori differences between conditions, an independent samples t-test was used for age, whereas gender, ethnicity, and English as first language were tested using chi-square analysis. All data were tested for violations of normality and sphericity prior to analysis. In cases where violations were detected, appropriate corrections or transformations were applied and are reported with the results.

Two separate repeated measures ANOVAs were conducted to test Hypotheses H1 and H2 related to changes in mood. H1 is displayed in Figure 14, and predicted that Nature Room participants would show a small increase in negative affect following baseline, whereas Control Room participants would show a larger increase in negative affect following baseline. H2 is displayed in Figure 15, and predicted that Nature Room participants would remain constant in positive affect throughout the study, whereas Control Room participants would show a decrease in positive affect following baseline.

Three separate repeated measures ANOVAs were also conducted to test Hypotheses H3 and H4 in reference to changes in physiology. H3 is displayed in Figure 16, and predicted that Nature Room participants would show a larger decrease in heart rate following the baseline measurement compared to Control Room participants, who would show only a slight decrease in heart rate following the baseline measurement. H4 is displayed in Figures 17 and 18, and predicted Nature Room participants would show a larger decrease in systolic and diastolic blood pressure following the baseline measurement compared to Control Room participants, who would show only a slight decrease in systolic and diastolic blood pressure following the baseline measurement.

An independent samples t-test was used to test Hypothesis H5 related to time spent on the anagram task and number of anagrams correctly solved. H5 is displayed in Figure 19, and predicted that Nature Room participants would persist for longer at the task than Control Room participants, and that Nature Room participants would solve more anagrams than Control Room participants. Moderation analyses were tested using a stepwise linear regression. Continuous moderator variables were mean centered and entered in block one, followed by the dummy coded condition variable in block two, and the interaction variable in block three.

An independent samples t-test was also used to test Hypothesis H6 in reference to number of snacks eaten. H6 is displayed in Figure 20, and predicted that Nature Room participants would choose fewer snacks than Control Room participants. To account for non-normality, sum scores of snacks were square-root transformed prior to analysis. Moderation analyses were again tested using a stepwise linear regression. Continuous moderator variables were mean centered and entered in block one, followed by the dummy coded condition variable in block two, and the interaction variable in block three.

Results

Baseline Equivalence Across Conditions

The two conditions did not differ on: gender $\chi^2(1, N = 124) = 0.81, p = .67$; ethnicity $\chi^2(5, N = 124) = 2.22, p = .82$; or English as first language $\chi^2(1, N = 123) = 0.67, p = .41$. However, there was a statistically significant difference in age between conditions, with $t(79.41) = 2.36, p = .021, d = .53$. The control condition had an average age of 20.91 years with $SD = 3.42$ years. The nature condition had an average age of 19.83 years with $SD = 1.21$ years. This difference was not considered practically significant, and was due to older aged particpant outliers in the control condition. Correlations, means, and standard deviations of study variables are displayed in Table 5.

Effects of Conditions on Mood

Table 6 presents the results of the Repeated Measures ANOVA of Condition (Nature Room vs. Control Room) and Time on differences in Profile of Mood States (POMS) subscale mean scores for Depression, Vigor, Anger/Frustration, Tension, Confusion, and Fatigue. Neither the main effect of Condition or interaction of Time and Condition were significant for any subscale items. The subscale items of Vigor, Anger/Frustration, and Fatigue had main effects for Time. Vigor is plotted in Figure 22, Anger/Frustration is plotted in Figure 23, and Fatigue is plotted in Figure 24. Both H1 and H2 failed to receive support, as there were no differences in either positive or negative affect between Nature or Control Room participants over Time. Controlling for Connectedness to Nature did not change these results.

Effects of Condition on Physiology

Table 7 presents the results of the Repeated Measures ANOVAs of Condition and Time on differences in physiological indicators of heart rate, systolic blood pressure, and diastolic blood pressure. Time effects were significant for each variable, and a significant interaction effect of Time and Condition was found for heart rate. No other interaction effects were significant. Heart rate is plotted in Figure 25, systolic blood pressure is plotted in Figure 26, and diastolic blood pressure is plotted in Figure 27. Within-subjects simple effects analyses showed that the interaction effect for heart rate was due to a greater decrease in heart rate for participants in the Nature Room; *F*(2, 110) = 24.24, $p < .001$, $\eta^2_p = .31$ compared to the decrease in heart rate for participants in the Control Room; *F*(2, 122) = 10.19, $p < .001$, $\eta^2_p = .14$. This supported H3, as although participants in the Nature Room started with a higher heart rate on average, the decrease in heart rate over the course of the session was nearly twice that of the Control Room participants. H4 failed to receive support, as participants in both the Nature and Control Rooms showed identical changes in sysotlic and diastolic blood pressure over Time. Controlling for Connectedness to Nature did not change any physiological results.

Effects of Condition on Anagram Task

The independent samples t-test of Condition on Anagram Task Persistence was not significant, *t*(122.45) = 0.34, *p* =.734, *d* = .06, which failed to support H5 that Nature Room participants would persist for longer. A comparison of the amount of time spent on the task by participants in the Nature and Control Rooms is plotted in Figure 28. The analysis of the number of anagrams correctly solved for each condition revealed the opposite pattern of that predicted by H5, such that participants in the Control Room solved significantly more anagrams than participants in the Nature Room, *t*(123.92) = 2.34, *p* =.021, *d* = .42. Figure 29 compares the anagrams solved in each condition.

Whether or not participants reported English as their first language did not differentially affect time spent on the anagram task, F(1, 121) = 0.00, *p* = .99, $\eta^2_p = <.01$; or number of anagrams correctly solved, F(1, 121) = 0.85, *p* = .36, $\eta^2_p = <.01$. Connedtedness to Nature did not moderate Room Condition for either anagram persistence, $R^2 = 0.005$, $\Delta R^2 = 0.003$, F(3, 122) = 0.21, *p* = .89; or number of anagrams solved, $R^2 = 0.044$, $\Delta R^2 = 0.000$, F(3, 122) = 1.89, *p* = .14.

Effects of Condition on Health Decision Task

The independent samples t-test of Condition on number of candies chosen was not significant, *t*(121.39) = 0.77, *p* =.443, *d* = .14, which failed to support H6 that Nature Room participants would eat fewer candies than Control Room participants. A comparison of the number of candies selected by participants in each condition is displayed in Figure 30. Restrained Eating did not interact with Room Condition for number of candies selected, $R^2 = 0.010$, $\Delta R^2 = 0.001$, F(3, 122) = 0.43, *p* = .74. Connectedness to Nature also did not interact with Room Condition for number of candies selected, $R^2 = 0.179$, $\Delta R^2 = 0.018$, F(3, 122) = 1.35, *p* = .26.

Discussion

Findings are discussed in order, followed by general comments. For negative affect, H1 hypothesized that participants assigned to the Nature Room would show a small increase in negative affect throughout the course of the study, whereas participants in the Control Room would show a larger increase in negative affect over Time. The room participants completed the study in was found to have no effect on the changes in negative affective mood states, as all participants showed identical changes in negative mood at each measurement occasion. For positive affect, H2 hypothesized that Nature Room participants would show no change in positive affect throughout the study, compared to Control Room participants who would show a decrease in positive affect over Time. This hypothesis also failed to receive support, as positive affect did not vary between rooms.

For heart rate, H3 hypothesized that participants assigned to the Nature Room would show a larger decrease in heart rate compared to Control Room participants over Time. This hypothesis was supported, as Nature Room participants showed a decrease in heart rate nearly twice that of Control Room participants. It is worth noting, however, that participants in the Nature Room Condition started with a higher average heart rate at baseline.

For systolic and diastolic blood pressure, H4 hypothesized that Nature Room participants would show a larger decrease in systolic and diastolic blood pressure throughout the study compared to Control Room participants, who were predicted to show only a slight decrease over Time. This hypothesis failed to receive support as Room had no effect on changes in blood pressure.

For the anagram task, H5 hypothesized that Nature Room participants would persist for longer at the task, and that they would correctly solve more anagrams than Control Room participants. In reference to time spent on the task, the hypothesis was not supported as neither Room differed in time spent on the task. As for number of anagrams correctly solved, the hypothesis also failed to be supported, as the opposite of what was predicted occurred when Control Room participants were found to have solved more anagrams than Nature Room participants.

Finally, for the health decision task, H6 hypothesized that Nature Room participants would eat fewer snacks than Control Room participants. This hypothesis was not supported, as number of snacks eaten did not differ based on Condition.

Study Two attempted to address issues raised by Study One, and to extend previous research on the effects of nature stimuli in a work/office environment. Only the hypothesis related to changes in heart rate was supported; all other hypotheses failed to be supported by the findings. Based on the results of Study Two, being surronded by natural stimuli, including live plants, sunlight, the sound of trickling water, and window views of natural scenery may have a small effect on lowering heart rate. This adds to the literature on physiological effects of nature, and is line with some previous research finding similar effects of nature on reducing heart rate (Laumann et al., 2003; Lee et al., 2009; Park et al., 2010; Parsons et al., 1998; Ulrich et al., 1991). Blood pressure, however, was not influenced by these natural stimuli. This result is consistent with two other studies finding no influence of picture slides (Gladwell et al., 2012) or walking in a nature area (Hartig et al., 1991) on blood pressure.

As the physiological effects of nature exposure are still unclear, this study contributes to the developing literature on the topic. There does not currently appear to be enough studies using similar methodology to estimate meta-analytic effects of exposure; whether for physiological effects, attention/cognitive effects, or psychological/mood effects. Considerable variation in the definition of “nature” remains. This study attempted to move from the minimal intensity exposure of photographs used in Study One to a more practical and generalizable approach based on malleable factors in a common office work setting; and building design features such as larger windows allowing for more natural light, as advocated by biophilic design.

This study also found, opposite of what was predicted, that participants in the Control Room (which was devoid of any natural stimuli) correctly solved more anagrams on average than participants in the Nature Room. It is possible that the nature stimuli, through the attention-grabbing, "soft-fascination" mechanism proposed by Attention Restoration Theory (Kaplan & Kaplan, 1989), served as a distraction from the task instead of enhancing focus. Alternatively, it is possible that a type I error was made and that Room plays no role in influencing performance. After all, while statistically significant, the practical significance of solving less than one more anagram is low.

Other lack of findings mirror those of Study One, and point to the possibility that issues with the design of the studies exist. It is possible that the college student sample is not representative of how the population at large reacts to nature stimuli. Measures selected for the study may not have accurately captured changes in the intended outcomes, such as mood. The duration of Study Two, although longer than Study One, only took between 60 – 90 minutes for participants to complete. Working in an office setting for an entire business day, repeatedly, likely leads to greater fluctuations in mood and physiology than that observed during the brief study sessions. What influence natural stimuli have on productivity and the decisions people make throughout the day is still largely unknown, and remains an important question for future research.

General Discussion

With the exception of a greater reduction in heart rate in Study Two, natural stimuli, whether defined as viewing scenic photographs on a computer screen or completing tasks in a room with natural stimuli, did not otherwise have any significant effects on mood, self-control, or health decision making over a short time period. In fact, contrary to what was predicted, participants in the Nature Room of Study Two performed slightly worse than participants in the Control Room on the anagram task. Evidence for the letter crossing task as a successful ego-depletion task was found in Study One, as the subjective negative affective mood states of Frustration, Confusion, and Fatigue were observed to increase following the task relative to the no-depletion group.

Similarly, in both studies it was found that significant effects of time occurred for many of the negative affective mood subscales. Generally, significant increases in negative mood occurred following the difficult version of the letter-crossing task and the anagram task. This lends support to the strength model of self-control (Baumeister et al., 1998), as these changes in negative mood occurred following tasks commonly used to elicit ego-depletion among participants. However, no differences in persistence at the anagram task were observed in either study, suggesting that focusing solely on task performance or persistence may be failing to capture other meaningful effects of ego-depletion.

Recently, a large scale effort was made by psychological researchers to address concerns with the replication of findings in self-control research using the ego-depletion paradigm. This investigation (Hagger & Chatzisarantis, 2016), which recruited 2,141 participants in 23 independent research laboratories across 11 countries, attempted to replicate a single tightly controlled experiment. The sequential-task paradigm was used (as was done in the current dissertation experiments), in which an initial task is completed in attempt to deplete self-control, followed by a second task on which performance or persistence is assessed. The results of the investigation revealed that when meta-analyzing the results of the trials, a small effect size of only $d = 0.04$ for ego-depletion was achieved, with a 95% confidence interval that included zero [-0.07, 0.15]. (Hagger & Chatzisarantis, 2016). Again, these studies all selected variables based on performance or persistence as main outcome measures. The results of the current dissertation studies suggest that including measures of subjective mood states and physiology may add another dimension to research on the effects of ego-depletion.

The failure to find significant impacts of nature manipulations on self-control contrasts with the findings of Beute and de Kort (2014, Study 1), who found that ego-depleted participants performed better on a stroop task after viewing nature photos compared to ego-depleted participants viewing either urban photos or no content at all. However, in their second study, Beute and de Kort (2014, Study 2) found no effect of photo viewing on a working memory task, consistent with the results from Study One of this dissertation. Beute and de Kort argue that because the task involved a greater amount of cognitive processing (working memory task instead of a reaction time task), that nature photos were not able to restore or buffer this mental resource. The unsolvable anagram task used in Study One and the solvable anagram task used in Study Two of this dissertation can also be considered to involve a high degree of cognitive processing, and may be beyond the ability of a simple nature exposure to recharge.

Chow and Lau (2015, Study 1) used a similar procedure to that in Study One of this dissertation with nature photographs, utilizing the letter crossing task as the ego-depletion mechanism and unsolvable anagrams as the outcome measure. Contrary to the null findings of dissertation Study One, Chow and Lau (2015, Study 1) found that nature photo viewers persisted at an unsolvable anagram task longer than the control group. However, the control group in their study simply rested and did not view photographs, whereas in Study One of this dissertation participants viewed photographs of urban settings in the control condition. The effects of viewing photographs of either type may have impacted recovery differently than quiet rest. In Chow and Lau’s third study (2015), participants were either ego-depleted or not depleted, and viewed nature photos or urban photos, similar to the procedure of dissertation Study One. Results showed that depleted participants viewing nature photos performed better on the anagram task than those viewing urban photos and that non-depleted participants performed equally well, regardless of picture stimuli viewed. This again contrasts to the null findings of Study One of this dissertation, although Chow and Lau (2015, Study 3) assessed number of anagrams solved whereas Study One examined anagram persistence.

Implications

Theoretically, the studies conducted contribute to the literature by adding to the evidence base of the effects of nature on human health and functioning. To my knowledge, these studies are the first to incorporate self-control outcome variables with an environmental manipulation at the setting (room) level. Furthermore, these studies are the first to include a health decision task as a proxy measure of ego-depletion through impulse control. Although null results were found for nearly all of the outcome variables, this research utilized well-controlled randomized designs and contributes to the understanding of what components of nature exposure may be important in influencing mood, physiology, and self-control.

The environmental psychology theory of Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989; Kaplan, 1995) was not supported by the results of these studies. ART predicts that attentional resources should have been restored following the viewing of nature photos in Study One, and the ability to focus should have been higher overall in the nature room in Study Two. This also calls into question the relationship between limited resource models of self-control (e.g., Baumeister et al., 1998) and ART, which have been proposed as being conceptually similar in the underlying dimension of directed attention (Kaplan & Berman, 2010).

Psycho-Evolutionary Theory (PET) (Ulrich, 1983; Ulrich et al., 1991) received partial support from the findings of the present experiments. PET includes tenets of nature serving physiologically soothing properties, which is supported by the decrease in heart rate found for participants in the nature room in Study Two. However, the lack of changes in mood due to nature stimuli fails to fit with what is predicted from this theory.

Overall, the null results of nature stimuli on cognitive tasks and mood outcome variables fails to replicate much of the current research within environmental psychology. In a similar sense to the replication attempt within social psychology (Hagger & Chatzisarantis, 2016), more tightly controlled research is needed to better understand what type and how much nature exposure is sufficient to produce meaningful effects. Currently, there is not enough research to conduct a meta-analysis on different types of nature exposure to determine effect size estimates. The results of the present experiments suggest that perhaps greater "intensity" and duration of nature exposure are necessary to achieve even small effects on mood, physiology, and self-control.

Practically speaking, a major strength of the manipulations are their potential for simple replication by other experimenters and widespread adoption by the public. Placing plants in workspaces is relatively inexpensive and can add additional benefits beyond those examined, such as indoor air filtration. Working with building designers to incorporate more natural light into workspaces could save on heating costs during the winter and cut back on electric bills during daylight hours. Photographs of scenic landscapes placed around workspaces or as backgrounds of computer screens may inspire creativity and awe among observers. Having a more immersive natural environment could help workers relax better and remain more calm during workday tasks.

Limitations and Future Directions

The findings from both experiments should be interpreted within the context of several limitations. Both studies were performed using a convenience sample of college student participants. While ethnically diverse with over 50% of participants identifying as Hispanic in both studies, the study was comprised mostly of healthy young women studying at the university level. Further research is needed to determine if results would be different in people of different ages, ethnicities, education levels, and health states.

As previously mentioned, the short duration of both studies is problematic in drawing firm conclusions. Viewing photos for seven and a half minutes in an otherwise artificial environment does not compare with the millenia of adaptations to natural surrondings of our ancestors. What effects may emerge after observing participants for longer periods of time is unclear. Anecdotal evidence from outdoorsmen and backpackers suggests spending multiple days in nature has positive effects on what could be considered "morale," or "lifting your spirits." Indeed, one study interviewing backpackers found long lasting effects on well-being following a backpacking trip (Hartig et al., 1991), and other research has found even short walks in parks or wooded areas can improve well-being (Berman et al., 2012; Berman, Jonides, & Kaplan, 2008, Study 1; Duvall, 2011; Hartig et al., 2003).

Issues of “dosage,” or “intensity” also emerge from the current research. Should we expect that photographs or desk plants will have the same effect as a week-long backpacking trip in the mountains? The present studies are limited in what can be said about the type of nature exposure. Similarly, many of the situations faced by our ancestors involved interacting with nature while physically active, something not addressed by the current research. Studies involving physical activity in nature raise other issues, as controlling for the benefits of exercise can be difficult. Future research should continue to study exposure to nature in physically active contexts, and determine if synergistic effects between nature and physical activity exist.

Finally, the current research was limited in scope of variables examined. Several other important factors should be examined in future research, in both laboratory studies and field experiments. For example, is there a relationship between the number of natural elements present and aggression? Are people more likely to act prosocially when near natural stimuli? Can nature inspire creativity and problem solving in real world contexts? These and other questions remain to be addressed by future research.

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References

Balter, M. (2007). Seeking agriculture’s ancient roots. *Science, 316*, 1830-1835.

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology, 74*, 1252-1265.

Baumeister, R. F., Vohs, K. D., & Tice, D. M. (2007). The strength model of self-control. *Current Directions in Psychological Science, 16,* 351-355.

Beil, K., & Hanes, D. (2013). The influence of urban natural and built environments on physiological and psychological measures of stress – A pilot study. *International Journal of Environmental Research and Public Health, 10,* 1250-1267.

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science, 19,* 1207-1212.

Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., Kaplan, S., . . .Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders, 140,* 300-305.

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology, 25,* 249-259.

Berto, R., Baroni, M. R., Zainaghi, A., & Bettell, S. (2010). An exploratory study of the effect of high and low fascination environments on attentional fatigue. *Journal of Environmental Psychology, 30*, 494-500.

Beute, F., & de Kort, Y. A. W. (2014). Natural resistance: Exposure to nature and self-regulation, mood, and physiology after ego-depletion. *Journal of Environmental Psychology*, *40*, 167-178.

Bodin, M., & Hartig, T. (2003). Does the outdoor environment matter for psychological restoration gained through running? *Psychology of Sport and Exercise, 4*, 141-153.

Brown, D. K., Barton, J. L., & Gladwell, V. F. (2013). Viewing nature scenes positively affects recovery of autonomic function following acute-mental stress. *Environmental Science and Technology, 47*, 5562-5569.

Cackowski, J. M., & Nasar, J. L. (2003). The restorative effects of roadside vegetation: Implications for automobile driver anger and frustration. *Environment and Behavior, 35*, 736-751.

Chow, J. T., & Lau, S. (2015). Nature gives us strength: Exposure to nature counteracts ego-depletion. *The Journal of Social Psychology, 155,* 70-85.

Ciarocco, N. J., Sommer, K. L., & Baumeister, R. F. (2001). Ostracism and ego depletion: The strains of silence. *Personality and Social Psychology Bulletin, 27,* 1156-1163.

Cimprich, B., & Ronis, D. L. (2003). An environmental intervention to restore attention in women with newly diagnosed breast cancer. *Cancer Nursing, 26*, 284-292.

Clarkson, J., Hirt, E., Jia, L., & Alexander, M. (2010). When perception is more than reality: The effects of perceived versus actual resource depletion on self-regulatory behavior. *Journal of Personality and Social Psychology, 98,* 29-46.

Denson, T., von Hippel, W., Kemp, R., & Teo, L. (2010). Glucose consumption decreases impulsive aggression in response to provocation in aggressive individuals. *Journal of Experimental Social Psychology, 46*, 1023-1028.

Dijkstra, K., Pieterse, M. E., & Pruyn, A. (2008). Stress-reducing effects of indoor plants in the built healthcare environment: The mediating role of perceived attractiveness. *Preventive Medicine, 47*, 279-283.

Duvall, J. (2011). Enhancing the benefits of outdoor walking with cognitive engagement strategies. *Journal of Environmental Psychology, 31*, 27-35.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomechanical sciences. *Behavioral Research Methods, 39*, 175-191.

Fennis, B. M., Janssen, L., & Vohs, K. D. (2009). Acts of benevolence: A limited-resource account of compliance with charitable requests. *Journal of Consumer Research, 35*, 906-924.

Fjeld, T., Veiersted, B., Sandvik, L., Riise, G., & Levy, F. (1998). The effect of indoor foliage plants on health and discomfort symptoms among office workers. *Indoor Built Environment, 7*, 204-209.

Galliot, M. T., Baumeister, R., DeWall, C., Maner, J., Plant, E., Tice, D. M., . . .Schmeichel, B. J. (2007). Self-conrol relies on glucose as a limited energy source: Willpower is more than a metaphor. *Journal of Personality and Social Psychology, 92*, 325-336.

Gladwell, V. F., Brown, D. K., Barton, J. L., Tarvainen, M. P., Kuoppa, P., Pretty, J., . . . Sandercock, G. R. H. (2012). The effects of views of nature on autonomic control. *European Journal of Applied Physiology, 112*, 3379-3386.

Hagger, M. S., & Chatzisarantis, N. L. D. (2016). A multilab preregistered replication of the ego-depletion effect. *Perspectives on Psychological Science, 11*, 546-573.

Hagger, M. S., Wood, C., Stiff, C., & Chatzisarantis, N. L. D. (2010). Ego-depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin, 135*, 495-525.

Han, K. (2009). Influence of limitedly visible leafy indoor plants on the psychology, behavior, and health of students at a junior high school in Taiwan. *Environment and Behavior, 41*, 658-692.

Hartig, T., Book, A., Garvill, J. Olsson, T. Garling, T. (1996) Environmental influences on psychological restoration. *Scandinavian Journal of Psychology, 37*, 378-393.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Garling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology, 23*, 109-123.

Hartig, T., Mang, M., & Evans, G. W. (1991). Restorative effects of natural environment preferences. *Environment and Behavior, 23*, 3-26.

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health, 35*, 207-228.

Hartmann, P., Apaolaza, V., & Alija, P. (2013). Nature imagery in advertising: Attention restoration and memory effects. *International Journal of Advertising, 32*, 183-210.

Inzlicht, M., & Schmeichel, B. J. (2012). What is ego depletion? Toward a mechanistic revision of the resource model of self-control. *Perspectives on Psychological Science, 7*, 450-463.

James, W. (1892). *Psychology: The briefer course*. New York: Holt.

Job, V., Dweck, C. S., & Walton, G. M. (2010). Ego depletion – is it all in your head? Implicit theories about willpower affect self-regulation. *Psychological Science, 21*, 1686-1693.

Johansson, M., Hartig, T., & Staats, H. (2011). Psychological benefits of walking: Moderation by company and outdoor environment. *Applied Psychology: Health and Well-Being, 3*, 261-280.

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

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*, 169-182.

Kaplan, S., & Berman, M. G. (2010). Directed attention as a common resource for executive functioning and self-regulation. *Perspectives on Psychological Science, 5*, 43-57.

Kellert, S. (2005). *Building for Life: Understanding and designing the human-nature connection.* Washington, D.C.: Island Press.

Kellert, S., Heerwagen, J. H., & Mador, M. L. (2008). *Biophilic design: The theory, science, and practice of bringing buildings to life.* New Jersey: John Wiley & Sons, Inc.

Kellert, S., & Wilson, E. O. (1993). *The biophilia hypothesis.* Washington, D.C.: Island Press.

Keniger, L. E., Gaston, K. J., Irvine, K. N., & Fuller, R. A. (2013). What are the benefits of interacting with nature? *International Journal of Environmental Research and Public Health, 10*, 913-935.

Kinnafick, F. E., Ntoumani, C. T. (2014). The effect of the physical environment and levels of activity on affective states. *Journal of Environmental Psychology, 38*, 241-251.

Kjellgren, A., & Buhrkall, H. (2010). A comparison of the restorative effect of a natural environment with that of a simulated natural environment. *Journal of Environmental Psychology, 30*, 464-472.

Kuo, F. E., & Sullivan, W. C. (2001). Aggression and violence in the inner city: Effects of environment via mental fatigue. *Environment and Behavior*, *33*, 543-571.

Kuo, F. E., & Taylor, A. F. (2004). A potential treatment for attention-deficit/hyperactivity disorder: Evidence from a national study. *American Journal of Public Health, 94*, 1580-1586.

Kweon, B. S., Ulrich, R. S., Walker, V. D., & Tassinary, L. G. (2008). Anger and stress: The role of landscape posters in an office setting. *Environment and Behavior, 40*, 355-381.

Laumann, K., Garling, T., & Stormark, K. M. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology, 23*, 125-134.

Lee, J., Park, B. J., Tsunetsugu, Y., Kagawa, T., & Miyazaki, Y. (2009). Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. *Scandinavian Journal of Forest Research, 24*, 227-234.

Li, Q., Morimoto, K., Kobayashi, M., Inagaki, H., Katsumata, M., Hirata, Y., Hirata, K., . . . Krensky, A. M. (2008). Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. *International Journal of Immunopathology and Pharmacology, 21*, 117-127.

Marselle, M. R., Irvine, K. N., & Warber, S. L. (2014). Examining group walks in nature and multiple aspects of well-being: A large-scale study. *Ecopsychology, 6*(3), 134-147.

Mayer, F. S., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology, 24*, 503-515.

Mayer, F. S., Frantz, C. M., Bruelman-Senecal, E., & Dolliver, K. (2009). Why is nature beneficial? The role of connectedness to nature. *Environment and Behavior, 41*, 607-643.

McDougall, I., Brown, F. H., & Fleagle, J. G. (2005). Stratigraphic placement and age of modern humans from Kibish, Ethiopia. *Nature, 433*, 733-736.

Mischel, W., & Ebbesen, E. B. (1970). Attention in delay of gratification. *Journal of Personality and Social Psychology, 16,* 329-337.

Mojzsis, S. J., Arrhenius, G., McKeegan, K. D., Harrison, T. M., Nutman, A. P., & Friend, C. R. L. (1996). Evidence for life on Earth before 3,800 million years ago. *Nature, 384*, 55-59.

Molden, D. C., Hui, C. M., Scholer, A. A., Meier, B. P., Noreen, E. E., D'Agostino, P. R., & Martin, V. (2012). Motivational versus metabolic effects of carbohydrates on self-control. *Psychological Science, 23*, 1137-1144.

Moller, A. C., Deci, E. L., & Ryan, R. M. (2006). Choice and ego-depletion: The moderating role of autonomy. *Personality and Social Psychology Bulletin, 32*, 1024-1036.

Nisbet, E. K., & Zelenski, J. M. (2011). Underestimating nearby nature: Affective forecasting errors obscure the happy path to sustainability. *Psychological Science, 22*, 1101-1106.

Owen, N., Bauman, A., & Brown, W. (2009). Too much sitting: A novel and important predictor of chronic disease risk? *British Journal of Sports Medicine, 43*, 81-82.

Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T, & Miyazaki, T. (2010). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine, 15*, 18-26.

Parsons, R., Tassinary, L. G., Ulrich, R. S., Hebl, M. R., & Grossman-Alexander, M. (1998). The view from the road: Implications for stress recovery and immunization. *Journal of Environmental Psychology, 18*, 113-139.

Plante, T. G., Cage, C., Clements, S., & Allison, S. (2006). Psychological benefits of exercise paired with virtual reality: Outdoor exercise energizes whereas indoor virtual exercise relaxes. *International Journal of Stress Management, 13*, 108-117.

Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005). The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research*, *15*, 319-337.

Raanaas, R. K, Patil, G. G., Hartig, T. (2010). Effects of an indoor foliage plant intervention on patient well-being during a residential rehabilitation program. *HortScience, 45*, 387-393.

Raanaas, R. K, Patil, G. G., Hartig, T. (2011). Health benefits of a view of nature through the window: A quasi-experimental study of patients in a residential rehabilitation center. *Clinical Rehabilitation, 26*, 21-32.

Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., & Gagne, M. (2010). Vitalizing effects of being outdoors and in nature. *Journal of Environmental Psychology, 30*, 159-168.

Schmeichel, B. J., & Vohs, K. D. (2009). Self-affirmation and self-control: Affirming core values counteracts ego-depletion. *Journal of Personality and Social Psychology, 96*, 770-782.

Shacham, S. (1983). A shortened version of the profile of mood states. *Journal of Personality Assessment*, *47*, 305-306.

Shanahan, D. F., Bush, R., Gaston, K. J., Lin, B. B., Dean, J., Barber, E., & Fuller, R. A. (2016). Health benefits from nature experiences depend on dose. *Scientific Reports, 6*, 28551.

Shoda, Y., Mischel, W., & Peake, P. K. (1990). Predicting adolescent cognitive and self-regulatory competencies from preschool delay of gratification: Identifying diagnostic conditions. *Developmental Psychology, 26*, 978-986.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Stewart, C. C., Wright, R. A., Hui, S. K. A., & Simmons, A. (2009). Outcome expectancy as a moderator of mental fatigue influence on cardiovascular response. *Psychophysiology, 46*, 1141-1149.

Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality, 72*, 271-324.

Taylor, A. F., Kuo, F. E., & Sullivan, W. C. (2002). Views of nature and self-discipline: Evidence from inner city children. *Journal of Environmental Psychology, 22*, 49-63.

Tice, D. M., Baumeister, R. F., Shmueli, D., & Muraven, M. (2007). Restoring the self: Positive affect helps improve self-regulation following ego-depletion. *Journal of Experimental Social Psychology, 43*, 379-384.

Tyrvainen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. *Journal of Environmental Psychology*, *38*, 1-9.

Ulrich, R. S. (1981). Natural versus urban scenes: Some psychophysiological effects. *Environment and Behavior, 13*, 523-556.

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill, Eds., *Human Behavior and Environment*. New York: Plenum Press, Vol. 6, *Behavior and the Natural Environment*, 85-125.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science, 224*, 420-421.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*, 201-230.

United Nations, Department of Economic and Social Affairs, Population Division (2014). *World urbanization prospects: The 2014 revision, highlights* (ST/ESA/SER.A/352).

Van den Berg, A. E., & Custers, M. H. G. (2011). Gardening promotes neuroendocrine and affective restoration from stress. *Journal of Health Psychology, 16*, 3-11.

Van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental preference and restoration: (How) are they related? *Journal of Environmental Psychology, 23*, 135-146.

Van Strien, T., Frijters, J. E. R., Bergers, G. P. A., & Defares, P. B. (1986). The Dutch eating behavior questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders, 5*, 295-315.

Yamaguchi, M., Deguchi, M., & Miyazaki, Y. (2006). The effects of exercise in forest and urban environments on sympathetic nervous activity of normal young adults. *The Journal of International Medical Research, 34*, 152-159.

Yu, H., Lee, H., Herrmann, A., Buettner, R., & Jove, R. (2014). Revisiting STAT3 signalling in cancer: New and unexpected biological functions. *Nature Reviews, 14*, 736-746.

Wally, C. W., & Cameron, L. D. (in prep). A systematic review of the restorative effects of nature on self-control.

Wilson, E. O. (1984). *Biophilia: The human bond with other species.* Cambridge, MA: Harvard University Press.

Table 1

Correlations, Means, and Standard Deviations For Study One Measures and Outcomes (N = 203)

Variable	1	2	3	4	5	6
1. State-Trait Anxiety Inventory	–					
2. Connectedness to Nature Scale	**−0.28***	–				
3. Restrained Eating - DEBQ	**0.16***	0.06	–			
4. Anagram Persistence	0.04	-0.1	0.03	–		
5. Unhealthy Snack Sum	0.11	-0.09	-0.08	-0.01	–	
6. Healthy Snack Sum	-0.01	-0.12	0.02	0.02	**−0.24***	–
M	40.95	46.96	25.19	540.39	0.99	0.77
SD	8.92	7.18	9.23	253.49	0.93	0.83

Note. * indicates $p < .05$. *M* = mean, *SD* = standard deviation. DEBQ = Dutch Eating Behavior Questionnaire.

Table 2

Repeated-Measures ANOVA for Depletion Condition, Photo Condition, and Time

POMS Subscale	Variable	*df*	*F*	η^2_p
Vigor				
	Time	3	**87.56***	0.31
	Depletion Condition	1	0.45	<0.01
	Photo Condition	1	0.04	<0.01
	Depletion X Photo Interaction	1	**4.31***	0.02
	Time X Depletion Interaction	3	1.29	<0.01
	Time X Photo Interaction	3	1.31	<0.01
	Time X Depletion X Photo Interaction	3	0.16	<0.01
Anger/Frustration				
	Time	3	**45.33***	0.19
	Depletion Condition	1	1.44	<0.01
	Photo Condition	1	2.52	0.01
	Depletion X Photo Interaction	1	0.25	<0.01
	Time X Depletion Interaction	3	**4.63***	0.02
	Time X Photo Interaction	3	1.68	<0.01
	Time X Depletion X Photo Interaction	3	1.05	<0.01
Confusion				
	Time	3	**54.19***	0.22
	Depletion Condition	1	2.11	0.01
	Photo Condition	1	0.91	<0.01
	Depletion X Photo Interaction	1	0.81	<0.01
	Time X Depletion Interaction	3	**3.55***	0.02
	Time X Photo Interaction	3	1.48	<0.01
	Time X Depletion X Photo Interaction	3	2.55	0.01
Fatigue				
	Time	3	**18.60***	0.09
	Depletion Condition	1	0.2	<0.01
	Photo Condition	1	0.01	<0.01
	Depletion X Photo Interaction	1	0.01	<0.01
	Time X Depletion Interaction	3	**3.57***	0.02
	Time X Photo Interaction	3	1.7	0.01
	Time X Depletion X Photo Interaction	3	0.31	<0.01

Note. *df* = degrees of freedom. ***** $p < .05$. η^2_p = partial eta squared effect size.

Table 3

Results of Two-Way ANOVA of Depletion Condition and Photo Condition on Anagram Persistence

Variable	*df*	*F*	η^2_p
Depletion Condition	1	3.29	0.02
Photo Condition	1	0.01	<0.01
Depletion X Photo Interaction	1	0.6	<0.01

Note. *df* = degrees of freedom. * $p < .05$. η^2_p = partial eta squared effect size.

Table 4

Results of Two-Way ANOVAs of Depletion Condition and Photo Condition on Snack Choices

Snack Type	Variable	*df*	*F*	η^2_p
Unhealthy				
	Depletion Condition	1	0.08	<0.01
	Photo Condition	1	0.12	<0.01
	Depletion X Photo Interaction	1	0.01	<0.01
Healthy				
	Depletion Condition	1	1.05	<0.01
	Photo Condition	1	0.13	<0.01
	Depletion X Photo Interaction	1	0.13	<0.01

Note. *df* = degrees of freedom. ***** $p < .05$. η^2_p = partial eta squared effect size. Data were square-root transformed to account for skew.

Table 5

Correlations, Means, and Standard Deviations For Study Two Measures and Outcomes (N = 126)

Variable	1	2	3	4	5
1. Connectedness to Nature Scale	–				
2. Restrained Eating - DEBQ	0	–			
3. Anagram Persistence	-0.03	0.09	–		
4. Anagram Performance	-0.05	**0.21***	**0.34***	–	
5. Candy Sum	0.07	-0.09	0.07	-0.07	–
M	48.74	25.63	639.27	7.2	2.99
SD	6.86	9.03	314.31	1.64	1.66

Note. * indicates p < .05. *M* = mean, *SD* = standard deviation. DEBQ = Dutch Eating Behavior Questionnaire.

Table 6

Results of Mood Repeated-Measures ANOVA for Condition and Time

POMS Subscale	Variable	*df*	*F*	η^2_p
Depression				
	Time	2	2.93	0.02
	Condition	1	0.01	<0.01
	Time X Condition Interaction	2	0.71	0.01
Vigor				
	Time	2	**64.18***	0.34
	Condition	1	2.56	0.02
	Time X Condition Interaction	2	0.24	<0.01
Anger				
	Time	2	**11.50***	0.09
	Condition	1	0.67	0.01
	Time X Condition Interaction	2	0.13	<0.01
Tension				
	Time	2	2.69	0.02
	Condition	1	0.01	<0.01
	Time X Condition Interaction	2	0.71	0.01
Confusion				
	Time	2	2.5	0.02
	Condition	1	0.32	<0.01
	Time X Condition Interaction	2	0.61	0.01
Fatigue				
	Time	2	**15.94***	0.11
	Condition	1	0.01	<0.01
	Time X Condition Interaction	2	0.18	<0.01

Note. *df* = degrees of freedom. ***** $p < .05$. η^2_p = partial eta squared effect size.

Table 7

Results of Physiological Repeated-Measures ANOVAs for Condition and Time

Physiological Indicator	Variable	*df*	*F*	η^2_p
Heart Rate				
	Time	2	**34.78***	0.23
	Condition	1	2.08	0.02
	Time X Condition Interaction	2	**3.94***	0.03
Systolic Blood Pressure				
	Time	2	**33.00***	0.22
	Condition	1	0.02	0.001
	Time X Condition Interaction	2	0.27	0.002
Diastolic Blood Pressure				
	Time	2	**18.93***	0.14
	Condition	1	1.76	0.01
	Time X Condition Interaction	2	0.21	0.002

Note. *df* = degrees of freedom. ***** $p < .05$. η^2_p = partial eta squared effect size.

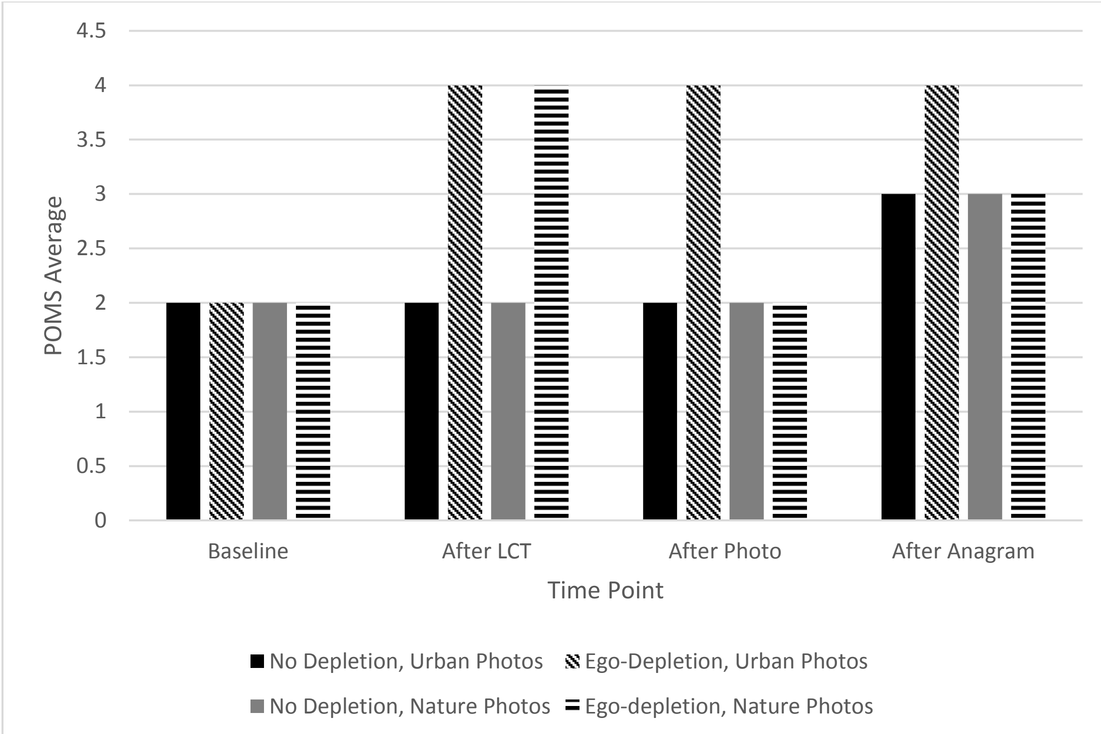

Figure 1. Hypothesized interaction of Depletion Condition, Photo Condition, and Time for negative affective states. POMS = profile of mood states; LCT = letter crossing task.

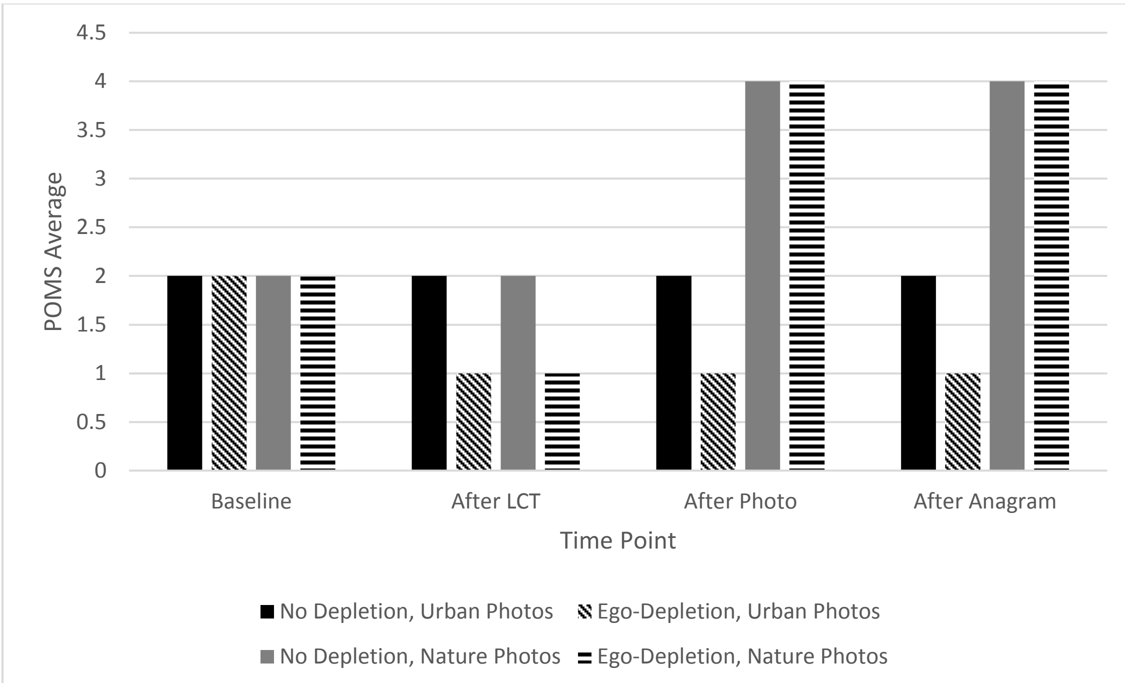

Figure 2. Hypothesized interaction of Depletion Condition, Photo Condition, and Time for positive affect. POMS = profile of mood states; LCT = letter crossing task.

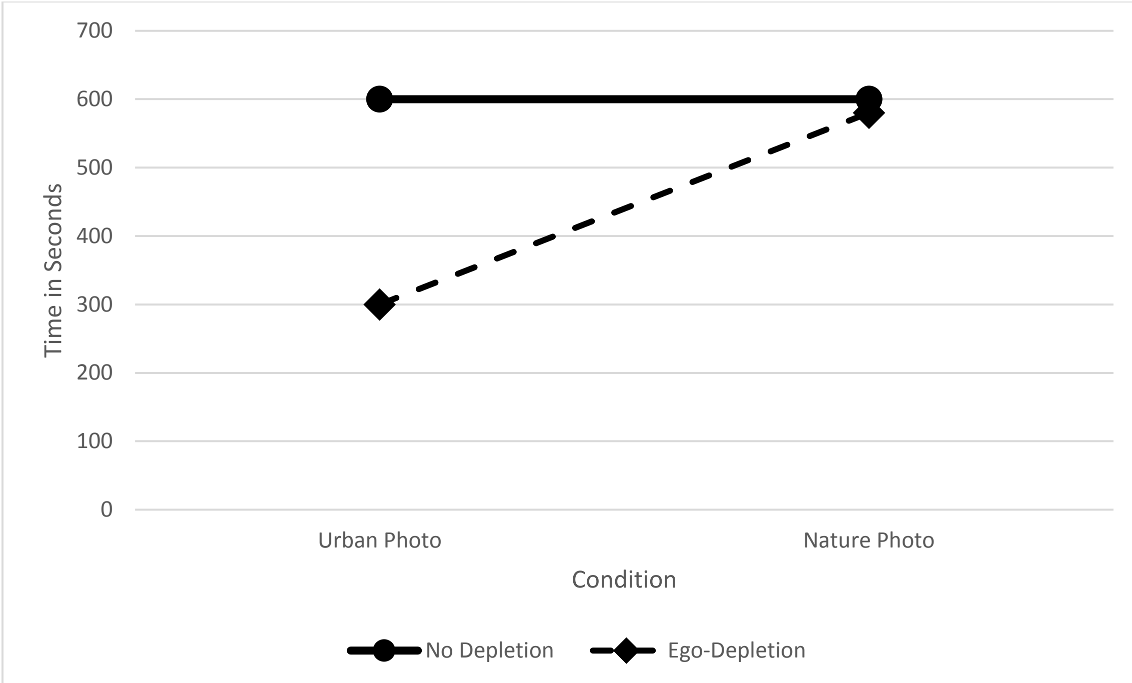

Figure 3. Hypothesized interaction of Depletion Condition and Photo Condition for time spent on unsolvable anagram task.

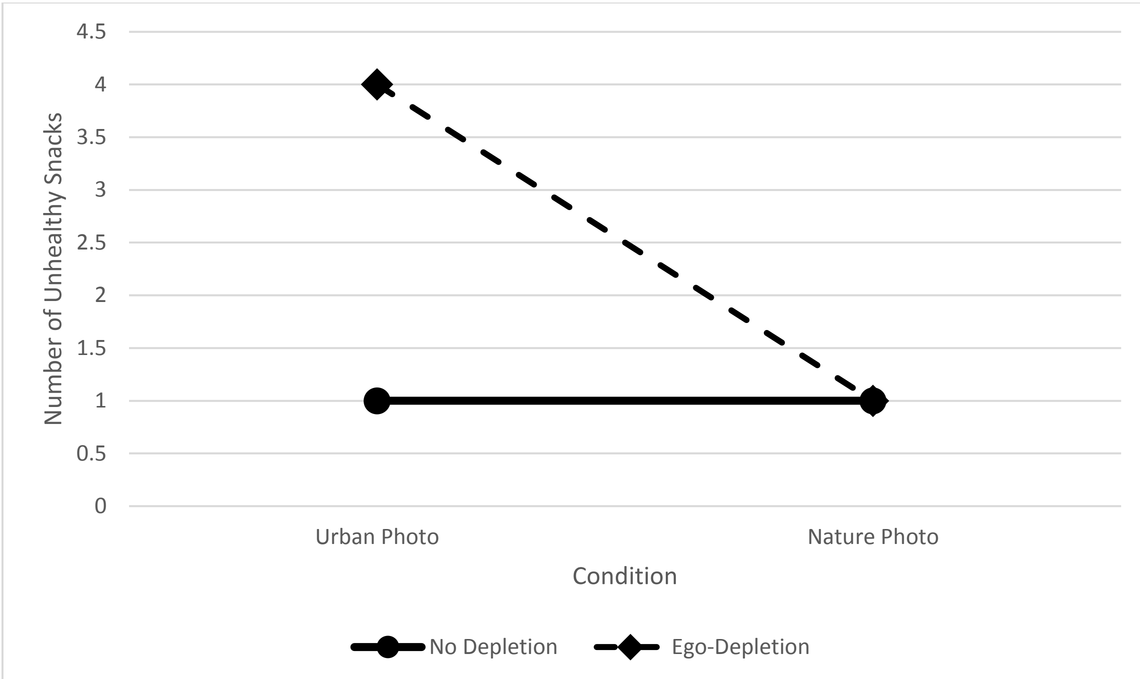

Figure 4. Hypothesized interaction of Depletion Condition and Photo Condition for number of unhealthy snacks chosen in the health decision task.

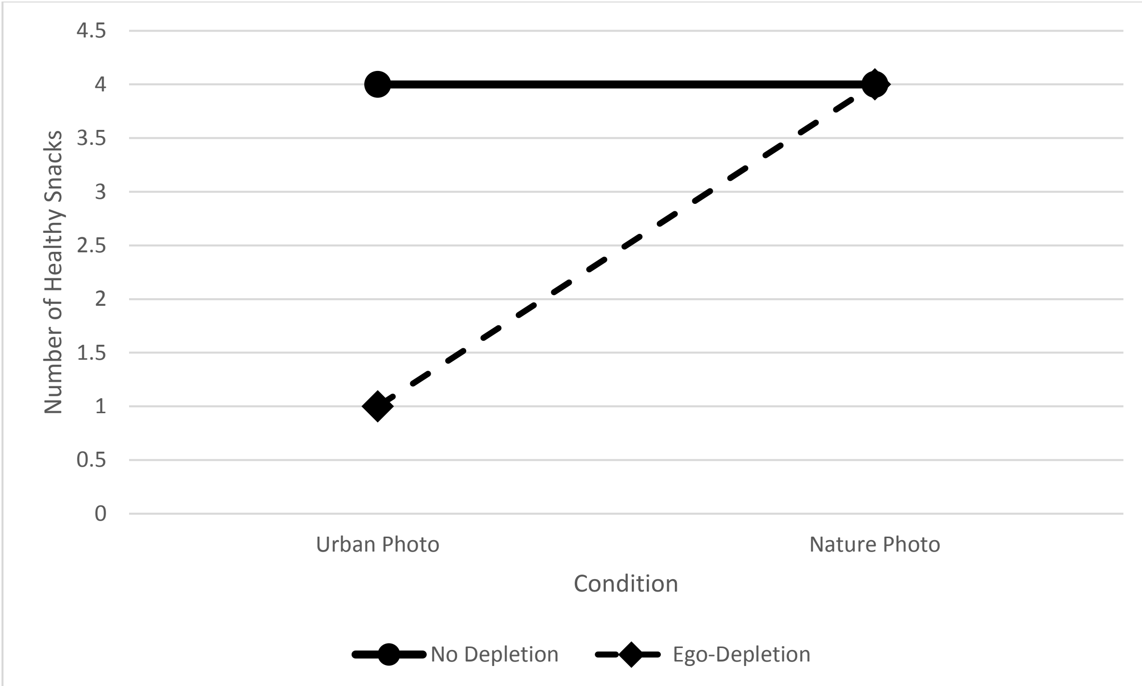

Figure 5. Hypothesized interaction of Depletion Condition and Photo Condition for number of healthy snacks chosen in the health decision task.

Participant Flow Through Study One

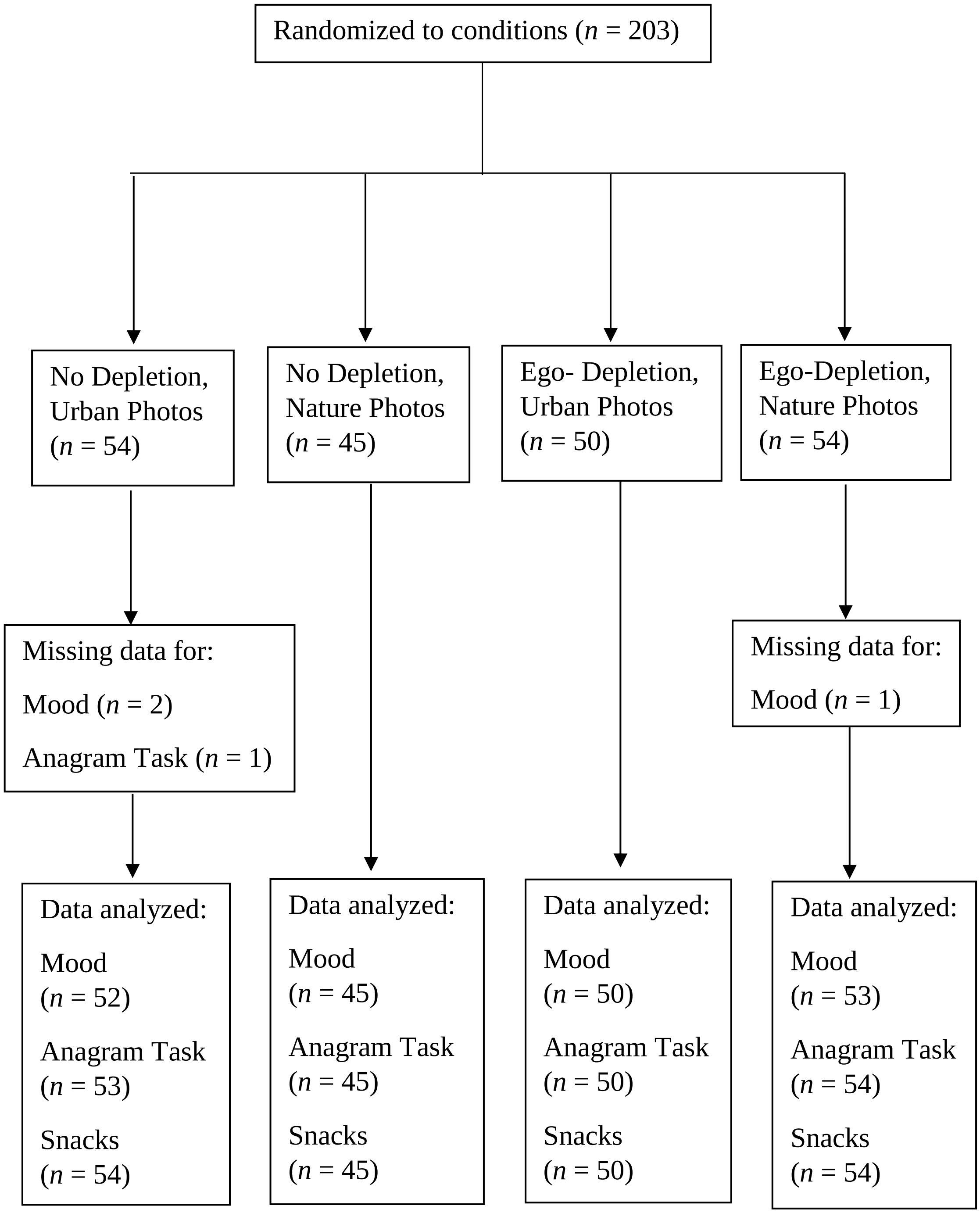

Figure 6. Flow diagram of participants through study one.

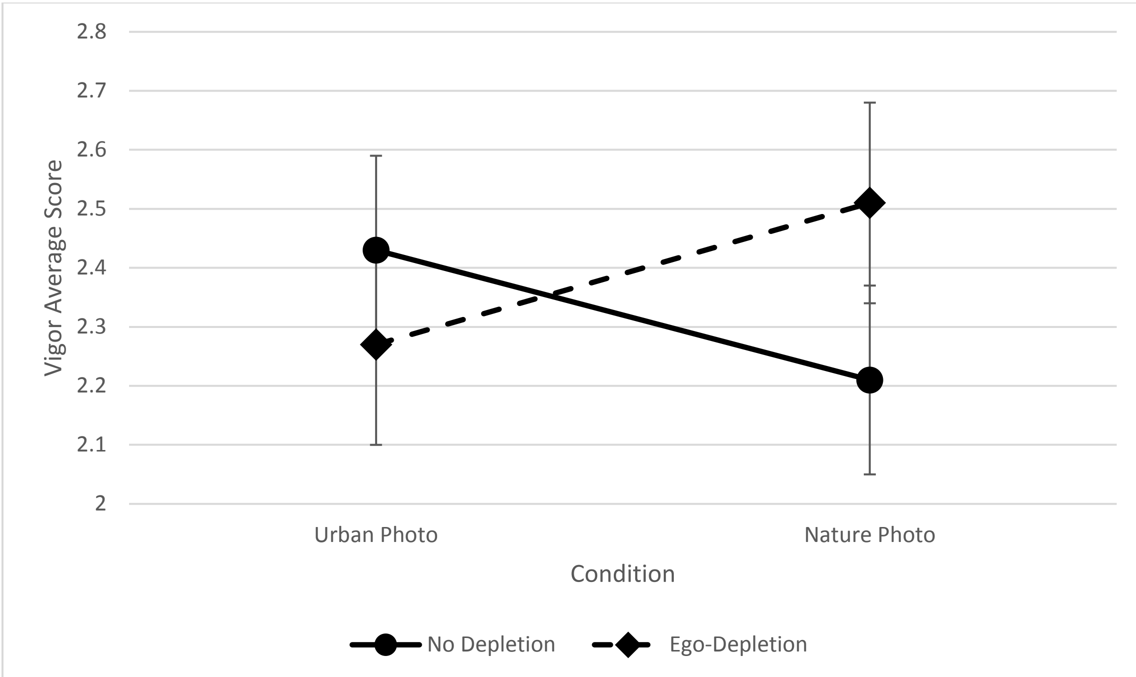

Figure 7. Average POMS Vigor Subscale score by condition. Ego-depleted participants viewing nature photos showed a trend toward significance for higher Vigor scores than non-depleted participants viewing nature photos (p =.055, d = .40). Error bars denote one standard error around the mean.

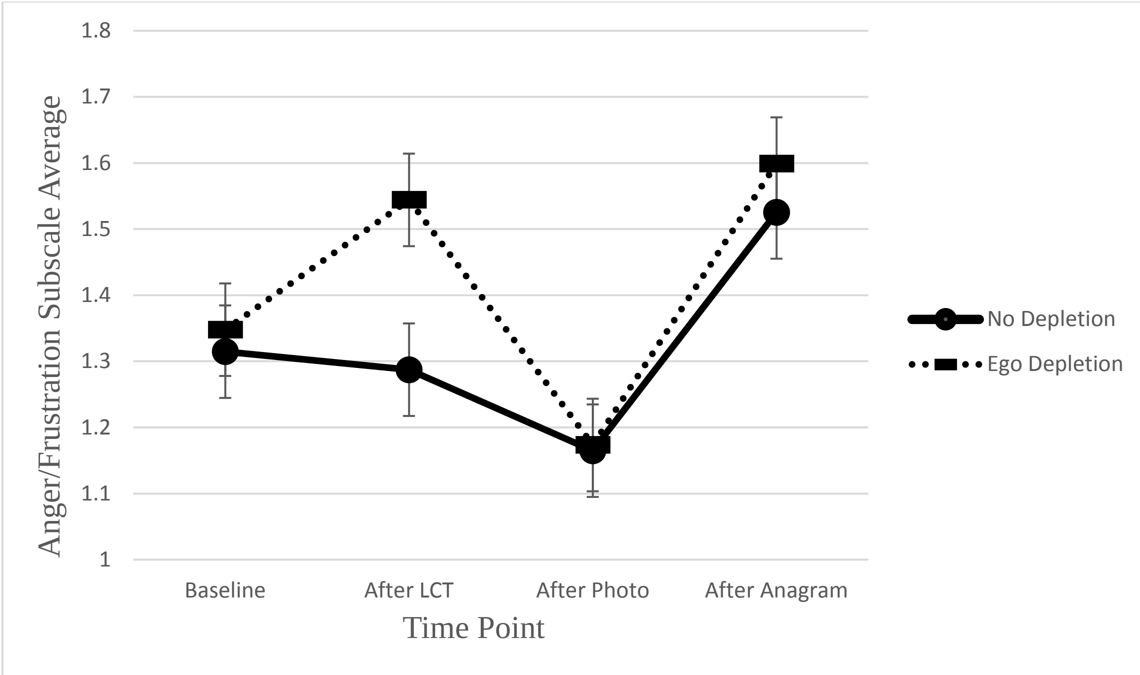

Figure 8. Average POMS Anger/Frustration Subscale score by Depletion Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

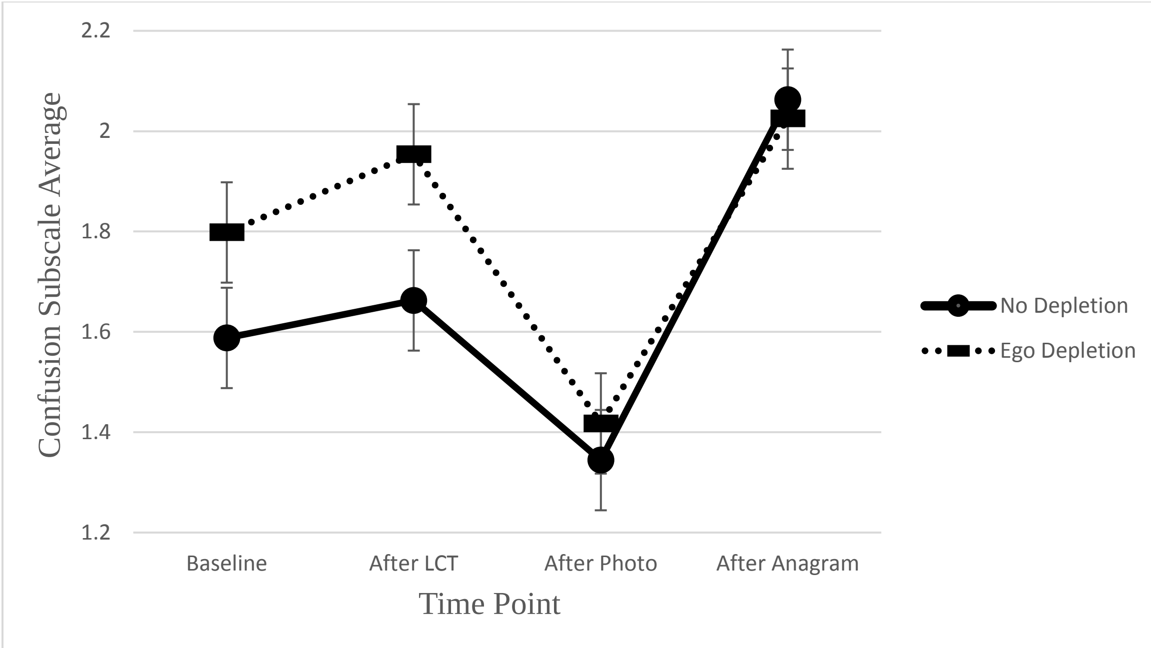

Figure 9. Average POMS Confusion Subscale score by Depletion Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

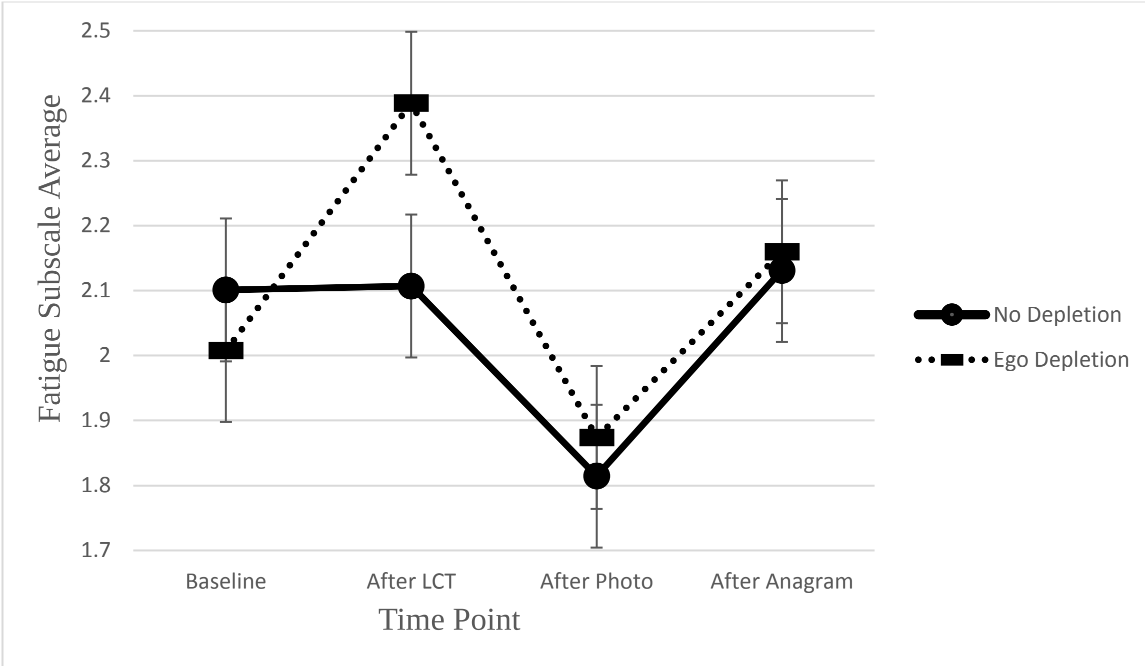

Figure 10. Average POMS Fatigue Subscale score by Depletion Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

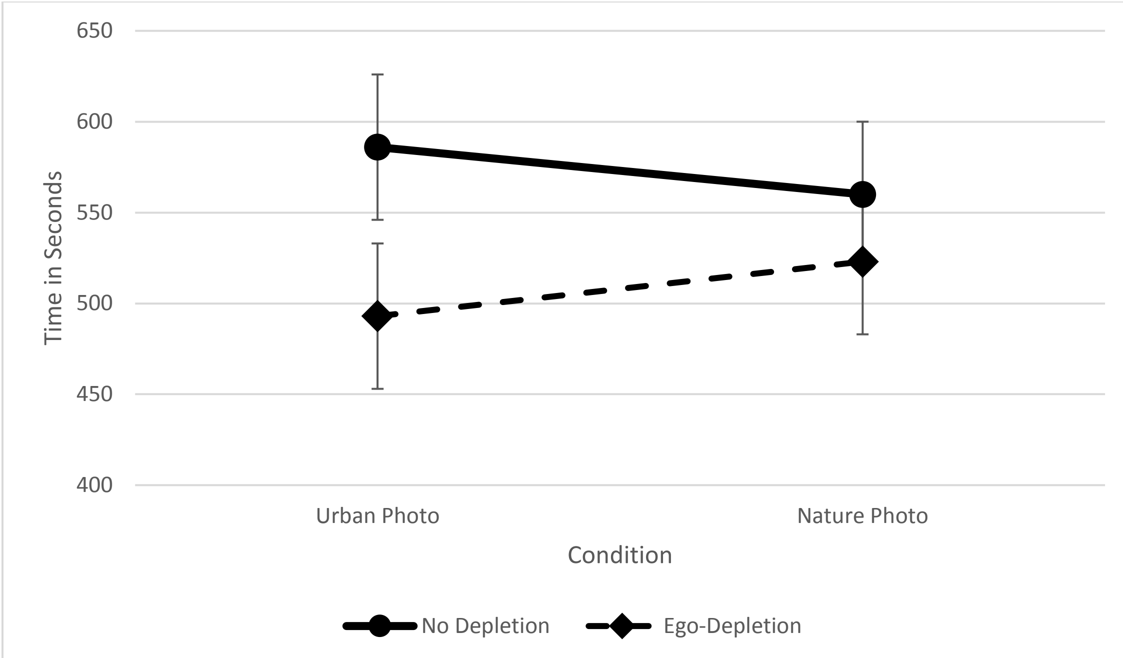

Figure 11. Time spent on unsolvable anagram task by condition. Error bars denote one standard error around the mean.

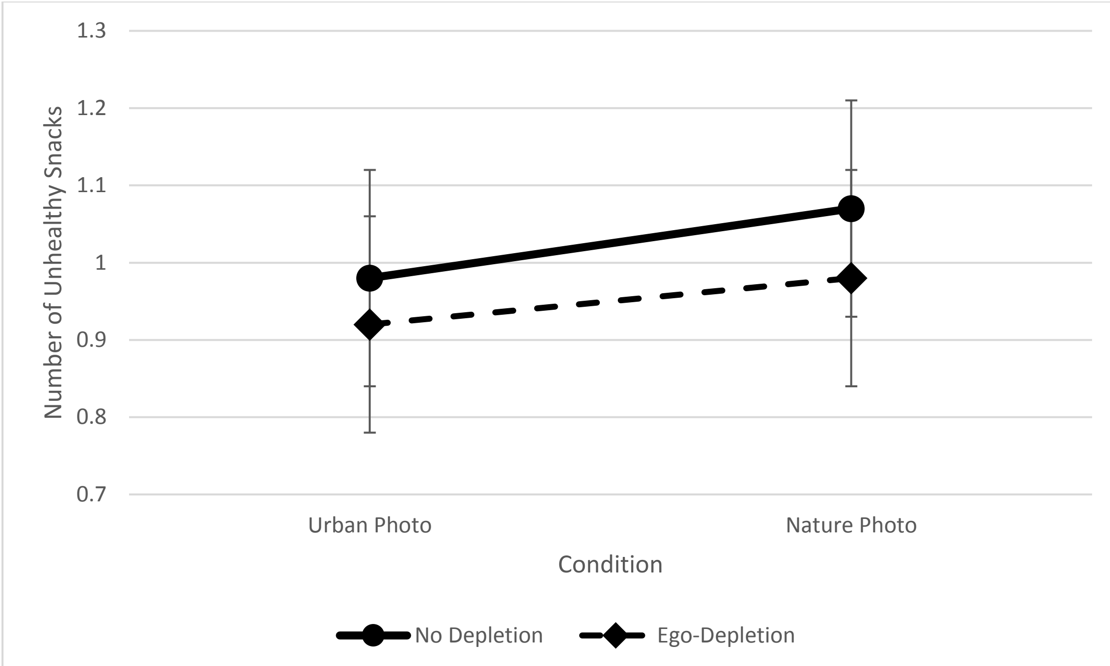

Figure 12. Number of unhealthy snacks chosen in the health decision task by condition. Raw means are presented for ease of interpretation. Error bars denote one standard error around the mean.

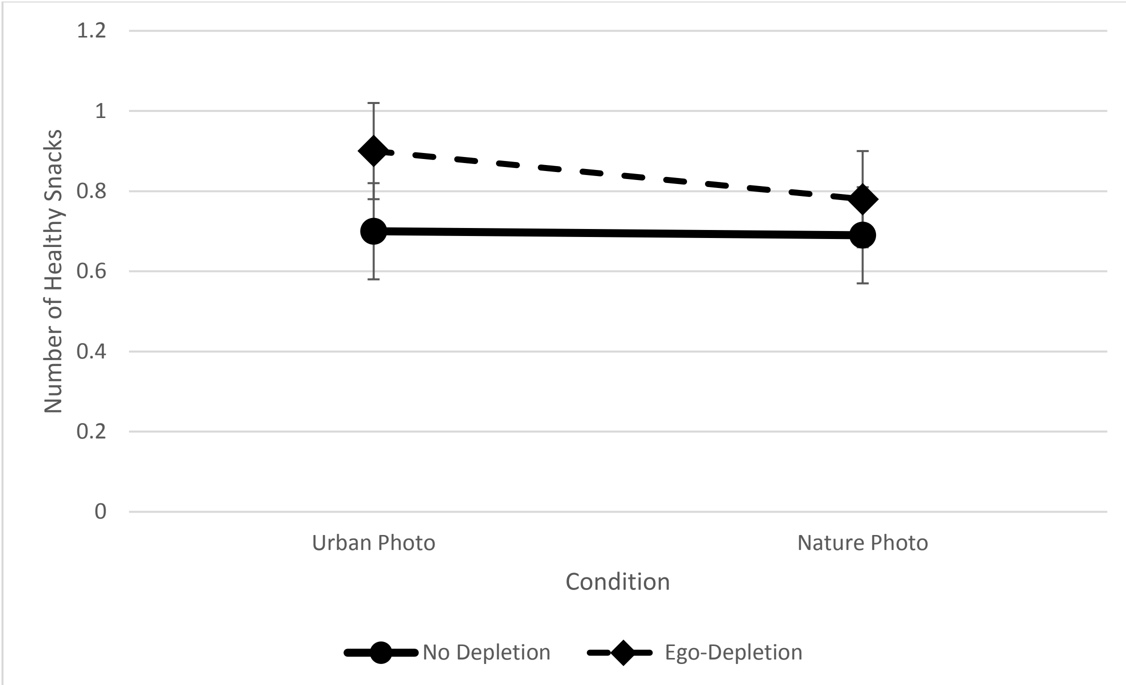

Figure 13. Number of healthy snacks chosen in the health decision task by condition. Raw means are presented for ease of interpretation. Error bars denote one standard error around the mean.

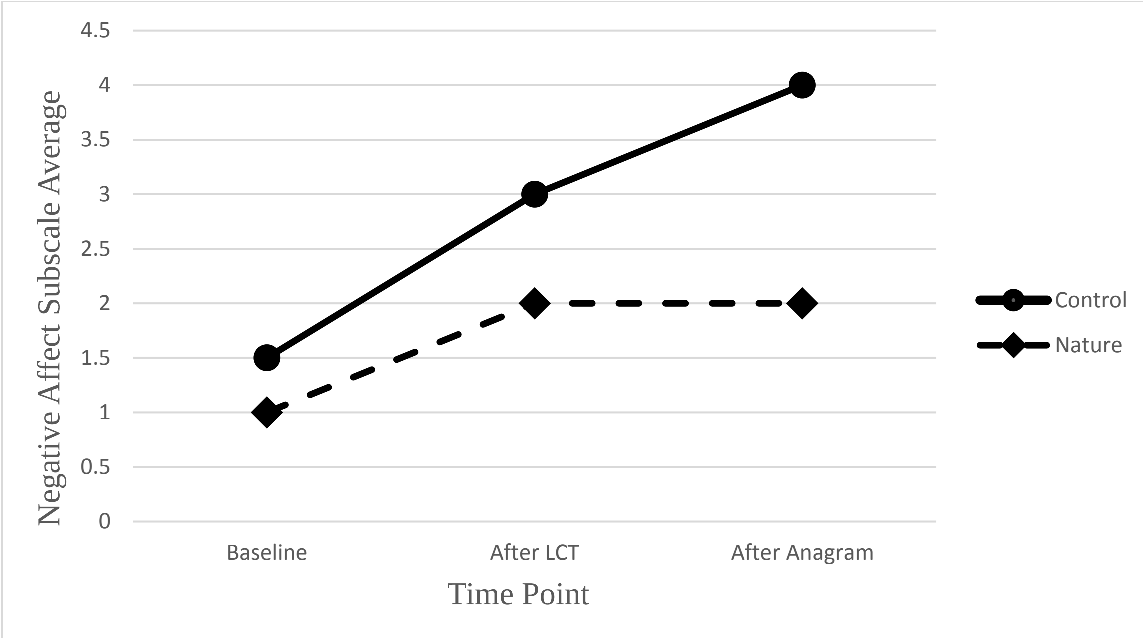

Figure 14. Hypothesized interaction of Condition and Time for negative affective states. LCT = letter crossing task.

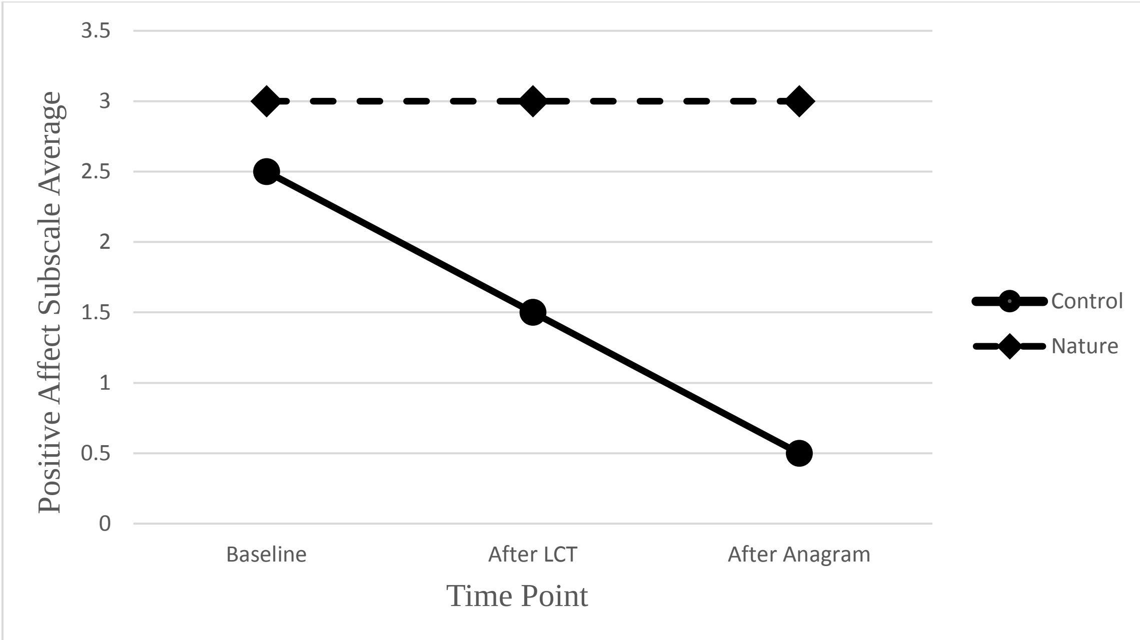

Figure 15. Hypothesized interaction of Condition and Time for positive affect. LCT = letter crossing task.

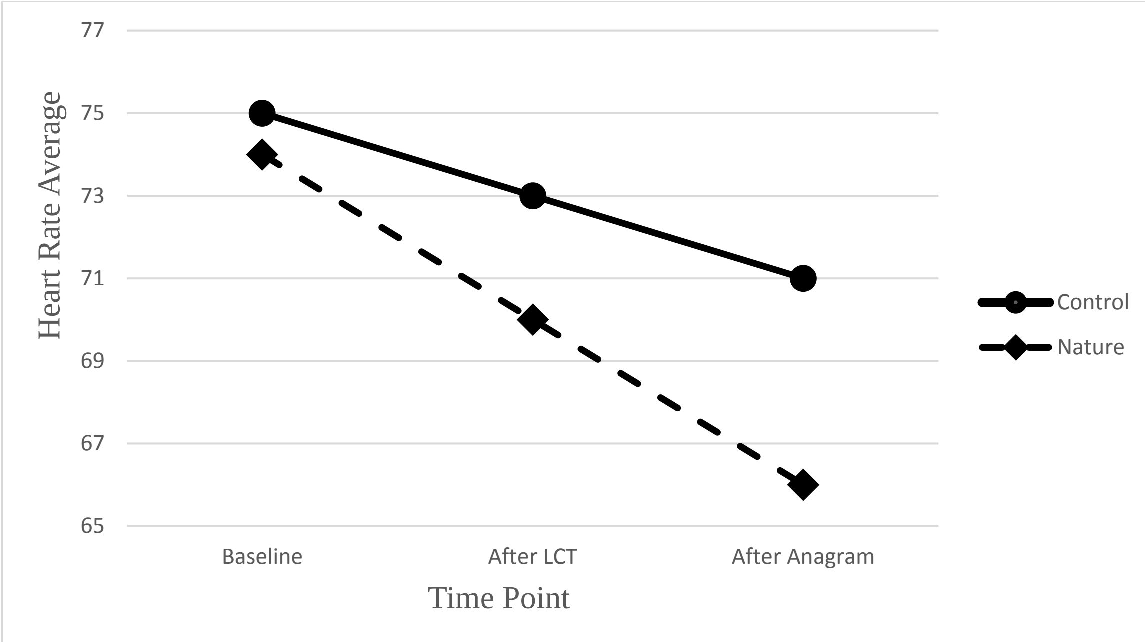

Figure 16. Hypothesized interaction of Condition and Time for heart rate. LCT = letter crossing task.

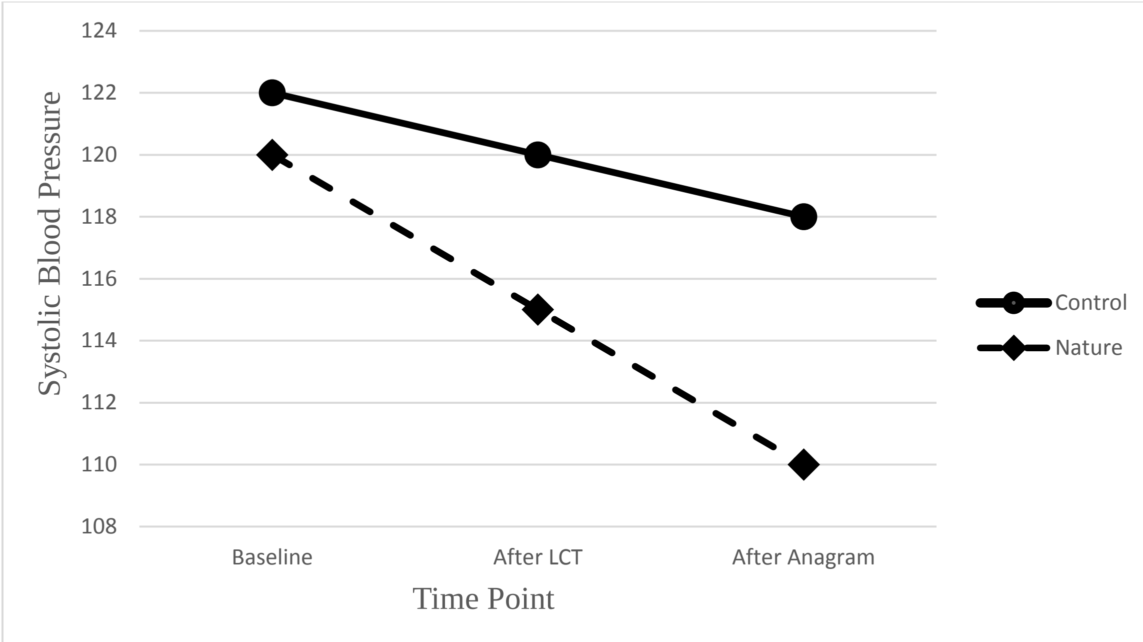

Figure 17. Hypothesized interaction of Condition and Time for systolic blood pressure. LCT = letter crossing task.

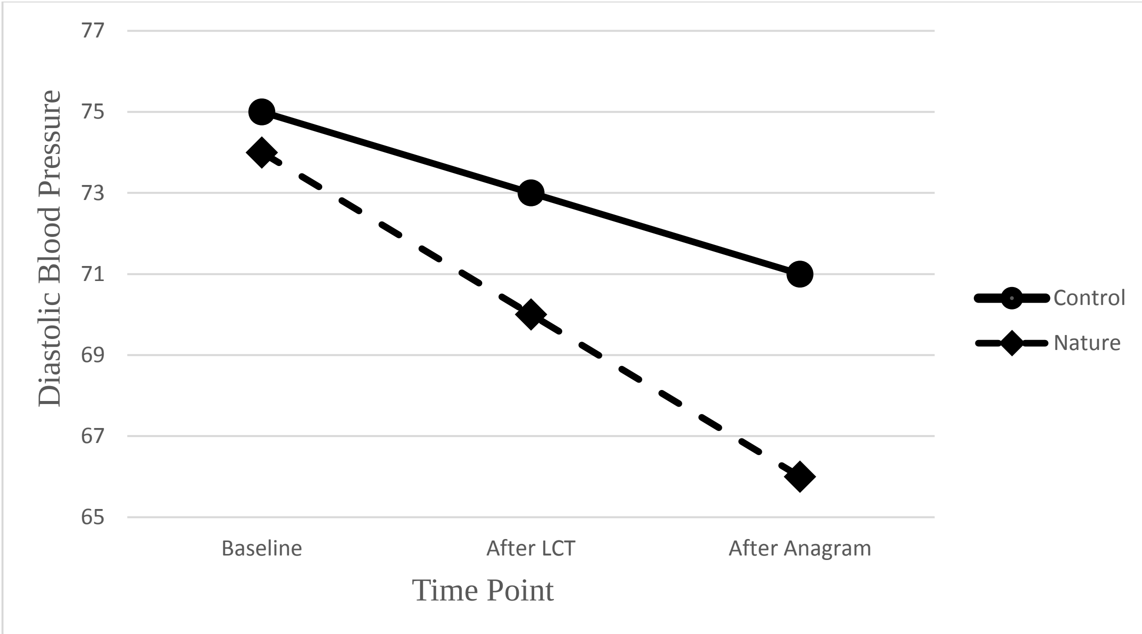

Figure 18. Hypothesized interaction of Condition and Time for diastolic blood pressure. LCT = letter crossing task.

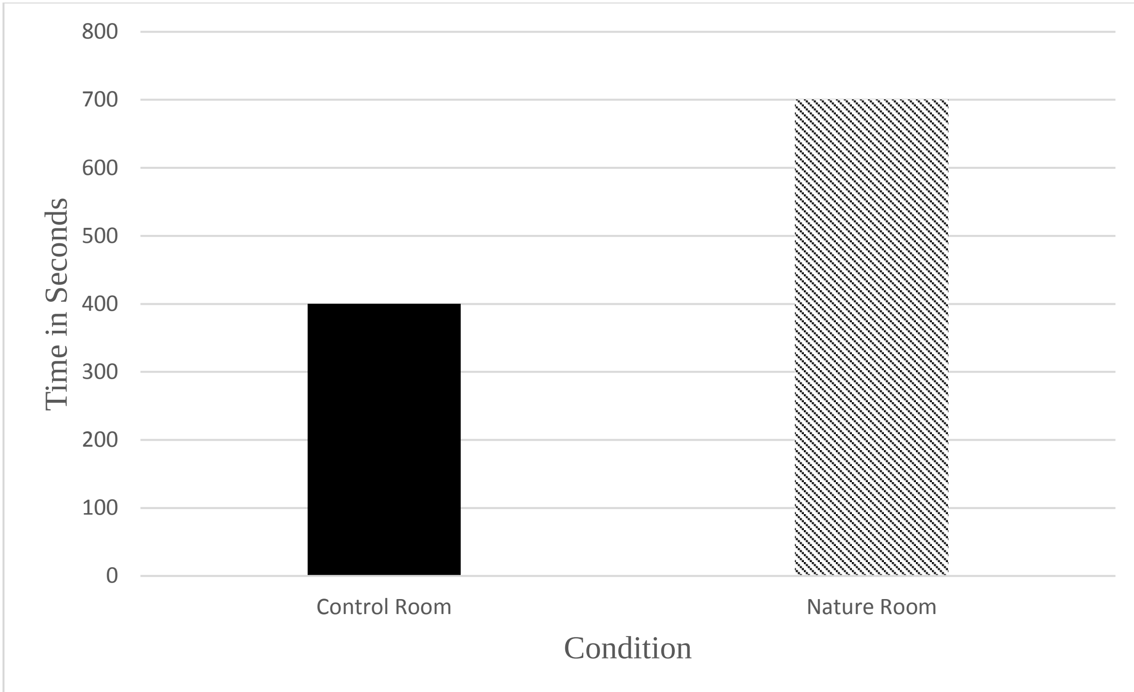

Figure 19. Hypothesized main effect of Condition on average time spent on anagram task.

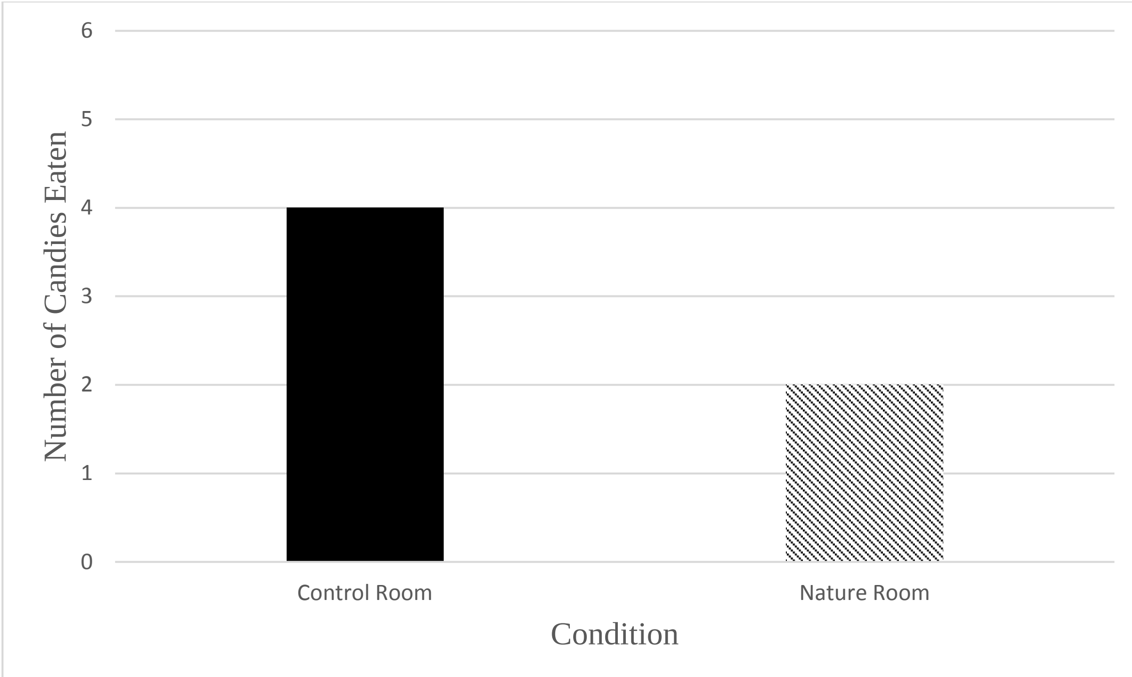

Figure 20. Hypothesized main effect of Condition on number of candies eaten.

Participant Flow Through Study Two

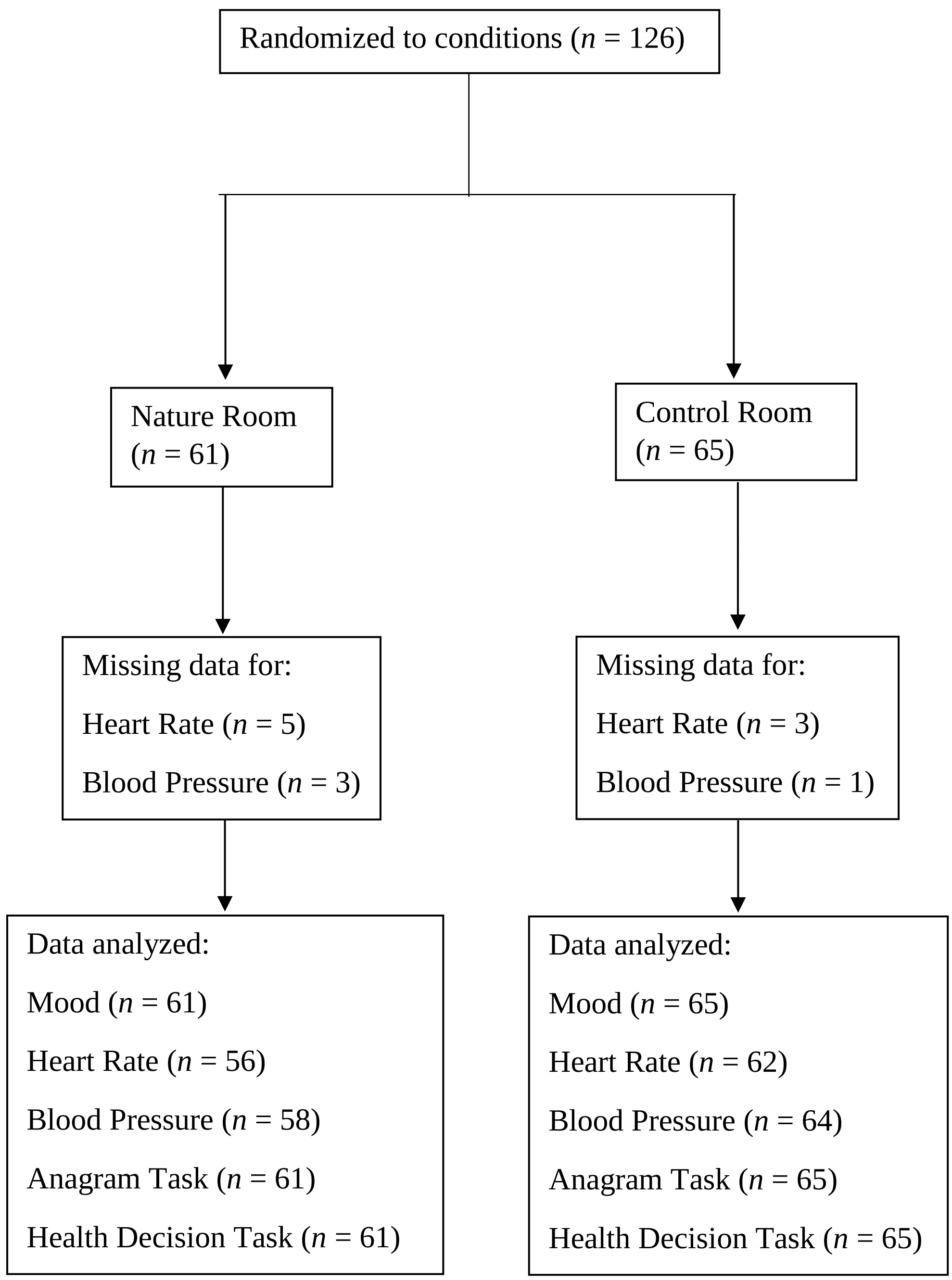

Figure 21. Flow diagram of participants through study two.

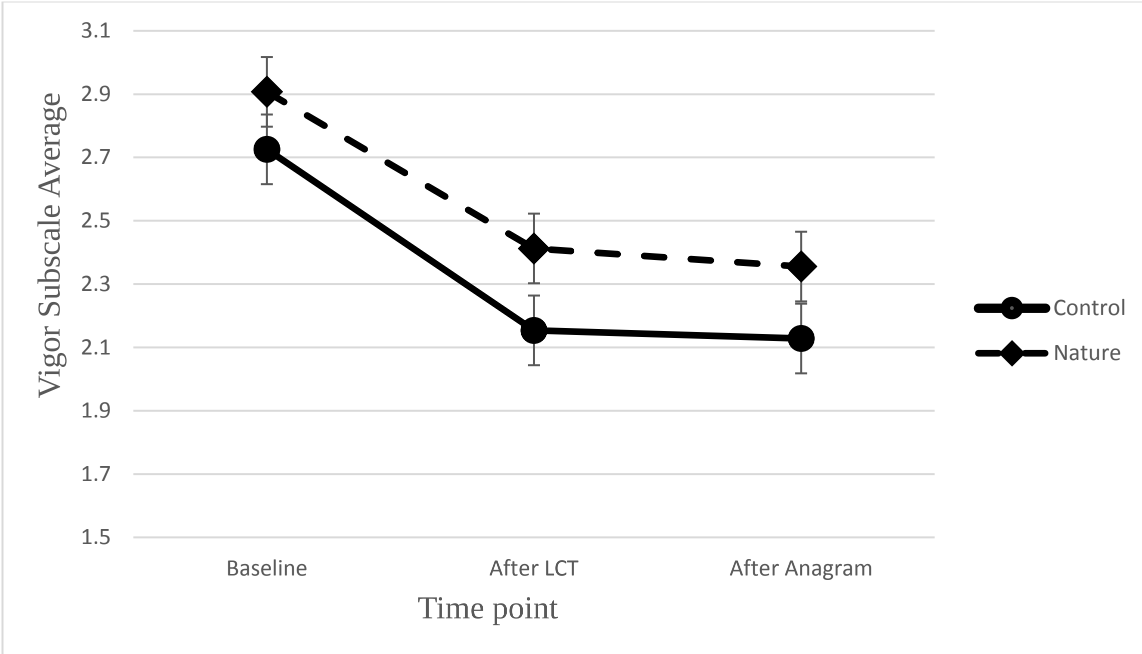

Figure 22. Average POMS Vigor Subscale score by Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

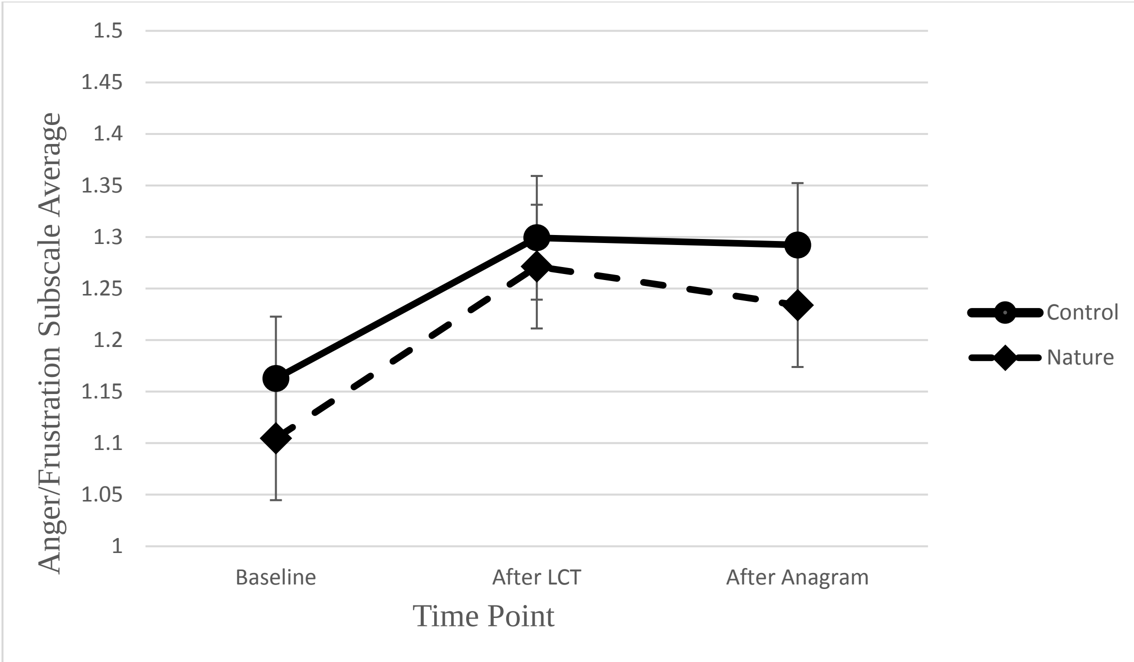

Figure 23. Average POMS Anger/Frustration Subscale score by Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

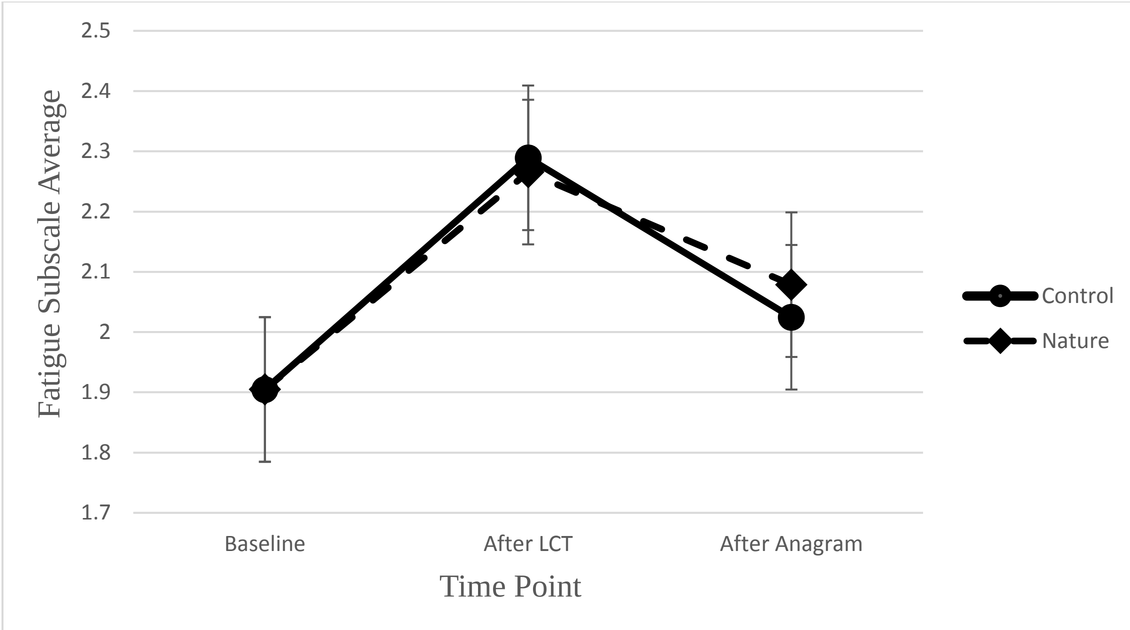

Figure 24. Average POMS Fatigue Subscale score by Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

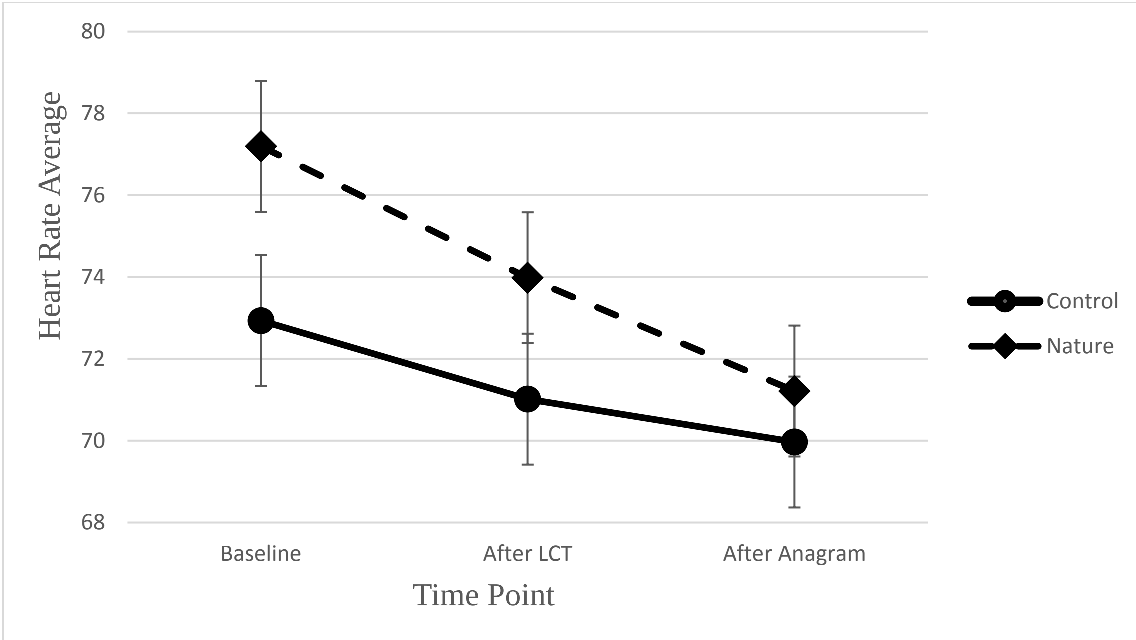

Figure 25. Average heart rate by Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

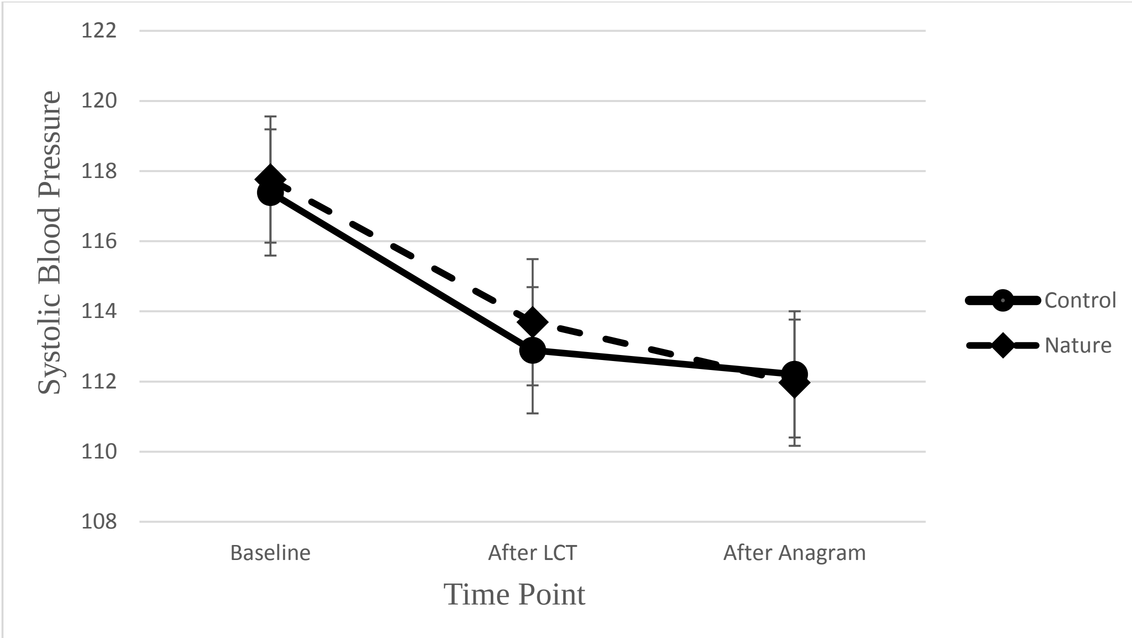

Figure 26. Average systolic blood pressure by Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

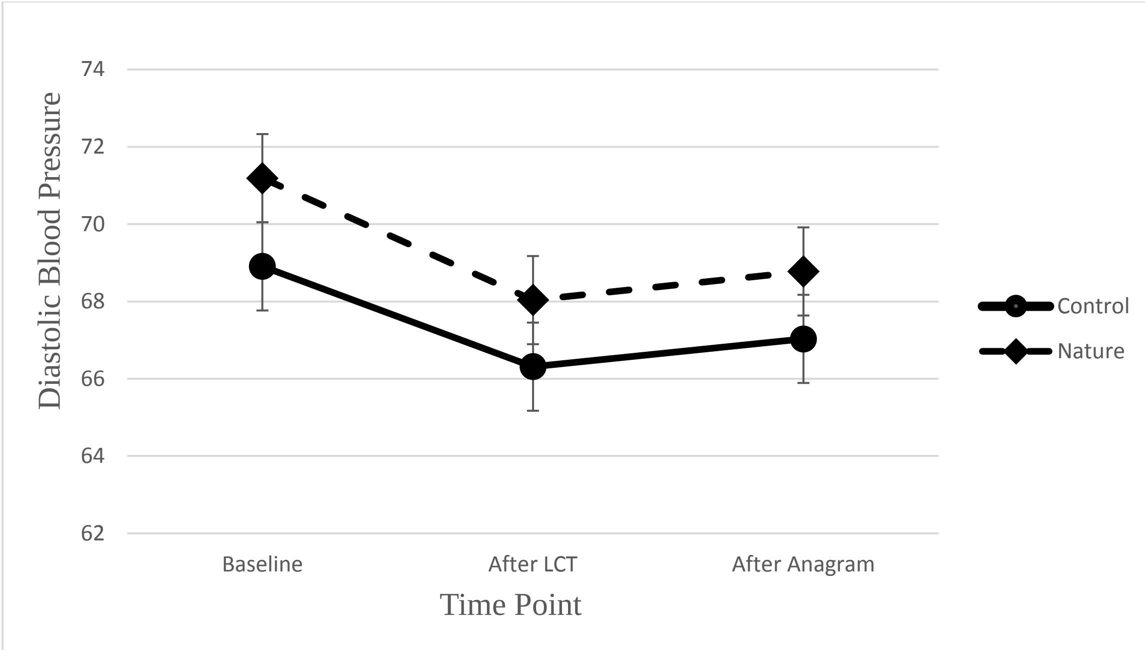

Figure 27. Average diastolic blood pressure by Condition over Time. LCT = letter crossing task. Error bars denote one standard error around the mean.

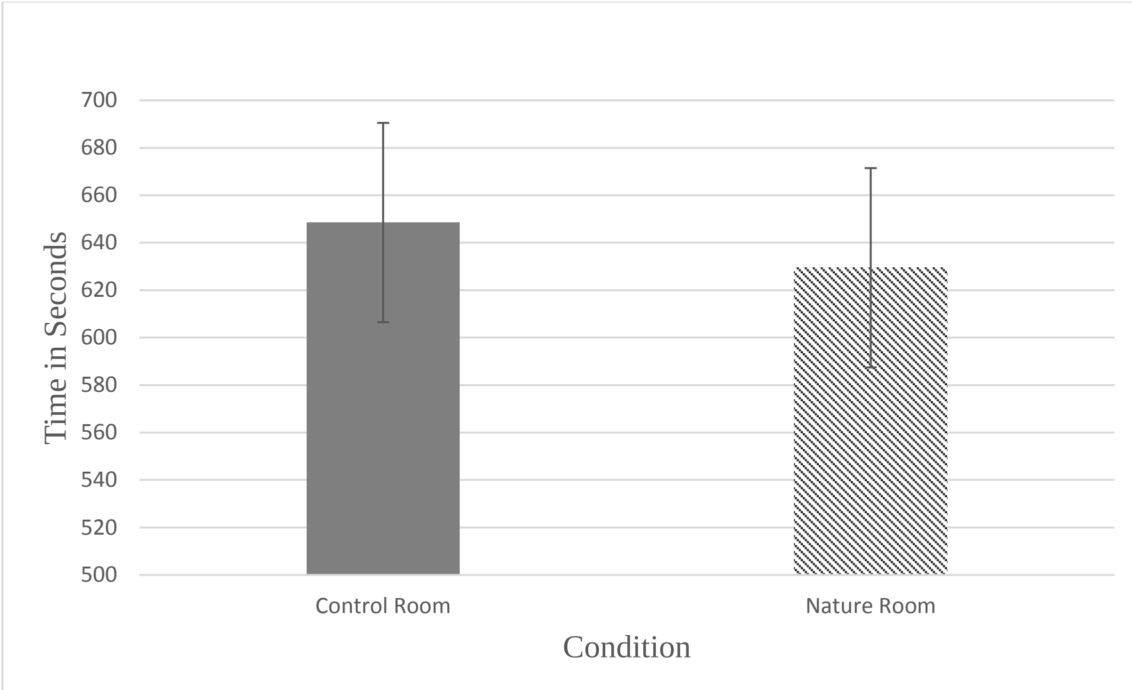

Figure 28. Average time spent on Anagram Task by Condition. Error bars denote one standard error around the mean.

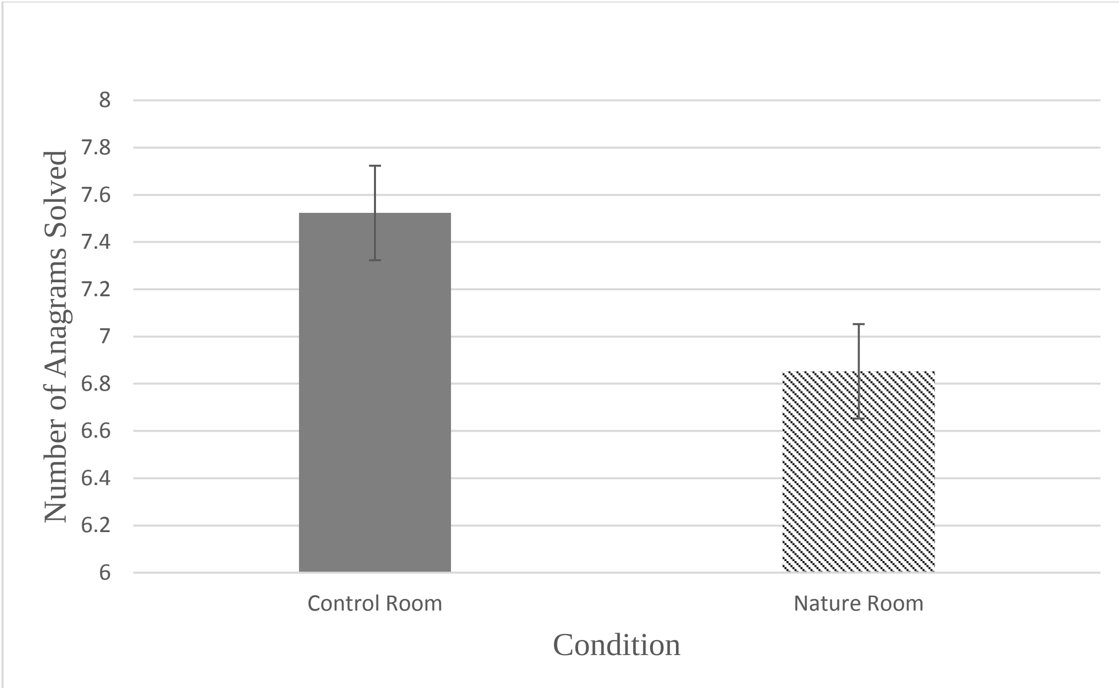

Figure 29. Average number of anagrams solved by Condition. Error bars denote one standard error around the mean.

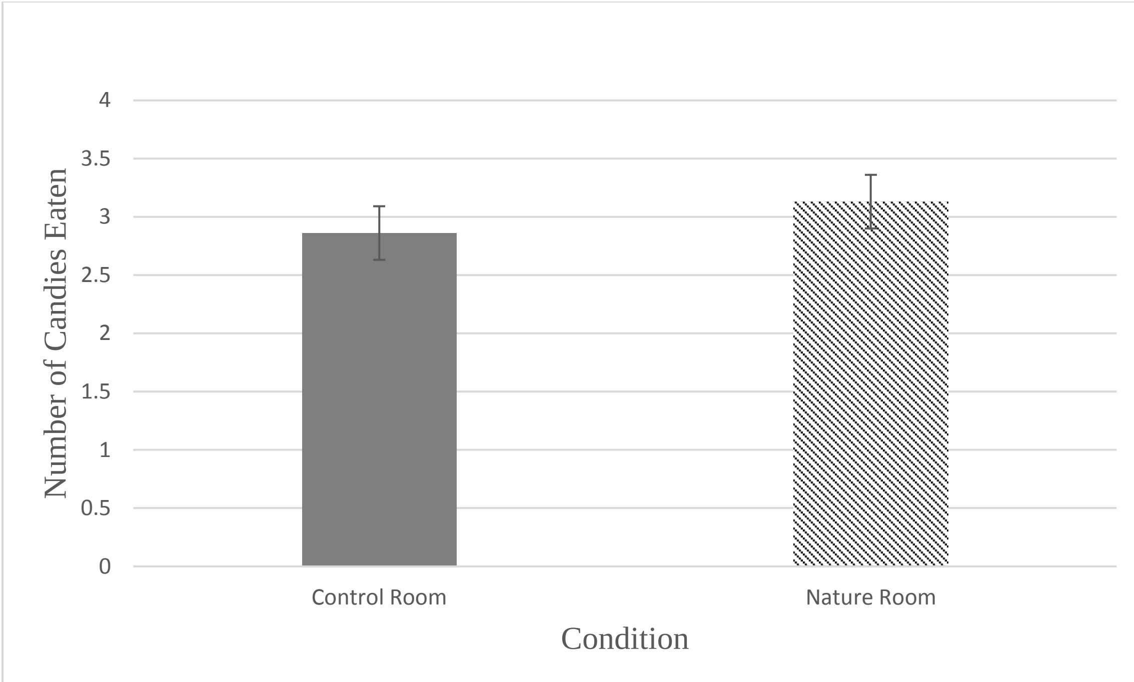

Figure 30. Average number of candies eaten by Condition. Raw means are presented for ease of interpretation. Error bars denote one standard error around the mean.

Appendix A: Trait Anxiety Inventory

A number of statements which people have used to describe themselves are given below. Read each statement and, using the scale below, circle the appropriate number that indicates **how you <u>generally</u> feel.** There are no right or wrong answers, just give the answer that seems to describe **how you <u>generally</u> feel.**

	Almost Never	Sometimes	Often	Almost Always
1. I feel pleasant…………………………….	1	2	3	4
2. I tire quickly……………………...………	1	2	3	4
3. I feel like crying……………………...……	1	2	3	4
4. I wish I could be as happy as others seem to be…………..…	1	2	3	4
5. I am losing out on things because I can't make up my mind soon enough………………	1	2	3	4
6. I feel rested……………………...………	1	2	3	4
7. I am "calm, cool and collected" …………	1	2	3	4
8. I feel that difficulties are piling up so that I cannot overcome them……………………...	1	2	3	4
9. I worry too much over something that doesn't really matter………………………..	1	2	3	4
10. I am happy……………………...……….	1	2	3	4
11. I am inclined to take things hard…………	1	2	3	4
12. I lack self-confidence…………………….	1	2	3	4
13. I feel secure……………………….……….	1	2	3	4
14. I try to avoid facing a crisis or difficulty…	1	2	3	4
15. I feel blue……………………...………..	1	2	3	4
16. I am content……………………...…….	1	2	3	4
17. Some unimportant thought runs through my mind and bothers me……………………..	1	2	3	4
18. I take disappointments so keenly that I can't put them out of my mind…………….	1	2	3	4
19. I am a steady person……………………..	1	2	3	4
20. I get in a state of tension or turmoil as I think over my recent concerns and interests....	1	2	3	4

Appendix B: Connectedness to Nature Scale

Please answer each of these questions in terms of *the way you generally feel*. There are no right or wrong answers. Using the following scale, in the space provided next to each question simply indicate as honestly and candidly as you can what you are presently experiencing.

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree

____ 1. I often feel a sense of oneness with the natural world around me.

____ 2. I think of the natural world as a community to which I belong.

____ 3. I recognize and appreciate the intelligence of other living organisms.

____ 4. I often feel disconnected from nature.

____ 5. When I think of my life, I imagine myself to be part of a larger cyclical process of living.

____ 6. I often feel a kinship with animals and plants.

____ 7. I feel as though I belong to the Earth as equally as it belongs to me.

____ 8. I have a deep understanding of how my actions affect the natural world.

____ 9. I often feel part of the web of life.

____ 10. I feel that all inhabitants of Earth, human and nonhuman, share a common 'life force.'

____ 11. Like a tree can be part of a forest, I feel embedded within the broader natural world.

____ 12. When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature.

____ 13. I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.

____ 14. My personal welfare is independent of the welfare of the natural world.

Appendix C: Dutch Eating Behavior Questionnaire – Restrained Eating Subscale

Using the following scale, please indicate in the space provided next to each question your response.

1	2	3	4	5
Never	Seldom	Sometimes	Often	Very Often

____ 1. If you have put on weight, do you eat less than you usually do?

____ 2. Do you try to eat less at mealtimes than you would like to eat?

____ 3. How often do you refuse food or drink offered because you are concerned about your weight?

____ 4. Do you watch exactly what you eat?

____ 5. Do you deliberately eat foods that are slimming?

____ 6. When you have eaten too much, do you eat less than usual the following days?

____ 7. Do you deliberately eat less in order not to become heavier?

____ 8. How often do you try not to eat between meals because you are watching your weight?

____ 9. How often in the evening do you try not to eat because you are watching your weight?

____ 10. Do you take into account your weight with what you eat?

Appendix D: The Profile of Mood States – Short Form

On a scale from 1 to 5, with 1 being 'not at all' and 5 being 'extremely,' please indicate the extent to which each emotion describes how you feel RIGHT NOW:

1	2	3	4	5
Not at all				Extremely

_____ Unhappy	_____ Angry	_____ Confused
_____ Sad	_____ Peeved	_____ Unable to concentrate
_____ Blue	_____ Annoyed	_____ Bewildered
_____ Hopeless	_____ Grouchy	_____ Forgetful
_____ Discouraged	_____ Resentful	_____ Uncertain
_____ Miserable	_____ Bitter	
_____ Helpless	_____ Furious	_____ Worn out
_____ Worthless		_____ Fatigued
	_____ Tense	_____ Exhausted
_____ Lively	_____ On edge	_____ Weary
_____ Active	_____ Uneasy	_____ Bushed
_____ Energetic	_____ Restless	
_____ Cheerful	_____ Nervous	
_____ Full of pep	_____ Anxious	
_____ Vigorous		

Appendix E: Letter Crossing Tasks

Non-Depletion (Control) Version

In this executive function task, you will be presented with passages from a scientific journal article and asked to follow rules related to the crossing out of letters. For example, the block of text below follows the rule of crossing out all occurrences of the letter 'x.'

Expression of the type I transmembrane glycoprotein CD44 has recently been recognized as a molecular signature for stem cells of various cancers, including those of the breast, the prostate and the colon. Once engaged, CD44 is internalized and translocated to the nucleus, where it binds to gene promoters and upregulates pro-tumorigenic gene expression. Importantly, nuclear CD44 requires acetylated STAT3 as a binding partner to the promoters of genes. The nuclear CD44– acetylated-STAT3 complex generates CSC-like cells by reprogramming the transcriptome, thereby contributing to colon cancer progression[127]. Although our understanding of the precise mechanisms that underlie CD44–STAT3-mediated transcriptome reprogramming is incomplete, acetylated STAT3 is known to modulate gene expression in human cancer cells[128,129], which is probably a crucial regulator of the biological function of this protein complex.

Now try this yourself. Please cross out (i.e., draw a line through) all occurrences of the letter 'x' in the following passage:

The Janus kinase (JAK)–signal transducer and activator of transcription (STAT) pathway was originally discovered in the context of interferon-α (IFNα)-, IFNγ- and intereukin-6 (IL-6)-mediated downstream signalling1–3. Of the seven members of the STAT protein family, STAT3 and STAT5 have been demonstrated to be the most important for cancer progression4–6. They are not only crucial for transducing signals from numerous receptor and non-receptor tyrosine kinases that are frequently activated in cancer cells, but they are also transcription factors that regulate the expres-sion of a wide range of genes5,7,8, thereby contributing to tumour progression. Although both STAT3 and STAT5 contribute to tumour cell proliferation and survival, a notable feature of STAT3 as a promising target for cancer therapy is that it also has a crucial role in stromal cells, including immune cells, which are recruited to the tumour microenvironment to promote tumour progression9–15. Importantly, STAT3 activation also functions as a potent immune checkpoint for multiple antitumour immune responses7,9,10,13,14.

Although the crucial role of STAT3 in both tumour cells and the tumour microenvironment is evident, gaps remain in our understanding of links between upstream regulators and JAK–STAT3 signalling. STAT3 is mainly considered to be a direct transcription factor. Nevertheless, recent studies demonstrate that STAT3 also regulates gene expression through epigenetic mechanisms, such as DNA methylation and chromatin modulation. Recent studies also highlight the importance of STAT3 in cancer through regulating mitochondrion functions. In addition to its known roles in promoting tumour cell proliferation, survival, tumour invasion, angiogenesis and immunosuppression, JAK–STAT3 signalling has recently been shown to have central roles in inflammation-mediated cancer, obesity and/or metabolism, cancer stem cells (CSCs) and pre-metastatic niche formation7,16–21.

Although abundant evidence suggests that STAT3 is an ideal target for cancer therapy, to date, effective therapeutic interventions to inhibit STAT3 and to generate potent antitumour effects in the clinic remain to be further explored and developed. The lack of efficacious therapeutics is in large part due to the challenge of directly targeting STAT3 (which lacks its own enzymatic activity), and in part due to the complexity of its biology in cancer — specifically its numerous activators and its diverse biological functions. Consequently, it is essential to have a comprehensive understanding of the biology surrounding STAT3 to develop effective approaches to inhibit this pathway for the treatment of cancer.

For the following two pages of text, please continue to cross out all occurrences of the letter 'x.'

New pathways regulating JAK–STAT3 in cancer

IL-6 and IL-6 family cytokines. IL-6 is the most well-known traditional activator of STAT3 (REFS 34–36). IL-6 exerts its biological effects through binding to IL-6 receptor-α (IL-6Rα) on the cell surface. Receptor engagement by IL-6 induces conformational changes, triggering the formation of a hexameric signalling complex comprising a gp130 (also known as IL-6Rβ) homodimer plus two IL-6–IL-6Rα heterodimers. These events result in activation of JAKs that are constitutively associated with a proline-rich, membrane-proximal cytoplasmic domain of gp130. Activated JAKs, in turn, mediate phosphorylation of gp130, leading to the recruitment and activation of cytosolic STAT3, which then translocates into the nucleus (FIG. 1). Other IL-6 family members, including IL-11, leukaemia inhibitory factor (LIF), ciliary neurotrophic factor (CNTF), oncostatin M (OSM) and IL-31, also activate receptors that transduce signals through JAK–STAT3 .

Although a crucial role of IL-6 in promoting JAK–STAT3 in cancer has been well established, multiple recent studies have expanded and/or identified additional important functions of this signalling pathway.

IL-6 family cytokines, such as IL-6 and IL-11, produced mainly by myeloid cells37,38, regulate diverse inflammatory processes, such as autoimmune diseases, rheumatoid arthritis and obesity39–43, suggesting that they have an essential role in balancing pro-inflammatory and anti-inflammatory responses. Moreover, activation of IL-6 signalling, as well as some of the family members of IL-6, is strongly associated with tumour progression and poor prognosis in patients with many types of solid tumours, including breast, lung and prostate cancers and multiple haematopoietic malignancies18,40,44–51. Most notably, IL-6 signalling, mainly via JAK–STAT3 in epithelial cells and immune cells, is able to promote inflammation, which in turn promotes oncogenesis44,45,52–55 (BOX 1). For example, persistent JAK–STAT3 activation by IL-6 and IL-11 induces a chronic inflammatory state in the intestine, affecting intestinal epithelial cell turnover, leading to increased incidence of gastric tumorigenesis42,56.

LIF, another IL-6-class cytokine, has also been recently shown to be crucial for JAK–STAT3 activation in several types of cancers, such as nasopharyngeal carcinoma, glioblastoma and pancreatic ductal adenocarcinoma57. In nasopharyngeal carcinoma, increased levels of LIF in serum correlate with local recurrence and poor radiosensitivity58, and dysregulated LIF is responsible for the activation of the JAK–STAT3 pathway during stem cell-mediated tumour progression59. Of particular interest, LIF levels in glioma stem cells (GSCs) are tightly controlled by transforming growth factor-β (TGFβ) signalling, suggesting that crosstalk between TGFβ and LIF–JAK–STAT3 is essential for GSC-mediated tumour development59. Despite this contribution of IL-11 and LIF to tumour development, IL-6 is still perhaps the most important driver of JAK–STAT3 activation in diverse tumours. This notion is further supported by recent findings that IL-6 expression can be induced by well-known oncogenes, including *BCR–ABL* and

RAS, as shown in leukaemia and skin cancer[60,61]. These newly recognized roles of well-defined oncoproteins in activating JAK–STAT3 through upregulating IL-6 expression also suggest that STAT3 may be able to serve as a crucial target to block the cancer-promoting effects of these oncogenes.

GPCRs. GPCRs are not traditionally associated with JAK–STAT3 activation. Recently, several GPCRs have been described as STAT3 activators, contributing to cancer progression[32,33]. Moreover, GPCR-mediated STAT3 activation has been shown to require JAKs[32,33]. Activation of STAT3 by adrenoreceptors results in the induction of IL-6 production and its receptor activation and signalling[62], indicating that GPCR signalling can crosstalk with IL-6 signalling. GPCRs can also upregulate the release of inflammatory mediators that activate STAT3. As an example, JAK–STAT3 activation in normal and malignant myeloid cells induced by chemokine BV8 (also known as prokineticin 2) upregulates the production and release of BV8, resulting in increased leukaemia cell survival[33,63–65].

Sphingosine-1-phosphate receptor 1 (S1PR1) is another GPCR, which responds to the signalling lipid metabolite S1P[66–68]. S1P–S1PR1 signalling promotes tumour cell survival and resistance to chemotherapy in various tumour cells[69–74]. In malignant cells and immune cells, as well as endothelial cells in the tumour stroma, expression of S1PR1 is upregulated[17,32,72,75–77]. S1P is produced by sphingosine kinase 1 (SK1), the expression of which is elevated in tumour cells[78–81]. Importantly, S1P–S1PR1 signalling activates STAT3 via the GPCRs $G\alpha_i$ and $G\alpha_o$, as well as JAK2 (REF. 32). This in turn upregulates expression of S1PR1, thereby forming an amplification loop in tumour cells[32].

Other studies also identify S1PR1–STAT3 signalling in linking chronic intestinal inflammation to the development of colitis-associated cancer (CAC)[76]. S1P contributes to nuclear factor-κB (NF-κB) activation, leading to increased production of IL-6, STAT3 activation and CAC incidence *in vivo*, suggesting that S1P–S1PR1 amplifies STAT3 activation during inflammation-associated tumour development[76]. S1P–S1PR1 signalling has an important role in the development of T cells and B cells[82,83]. Recent studies have highlighted the crucial role of S1PR1 signalling in maintaining persistent STAT3 activation in immune cells in the tumour microenvironment[32,33,76]. S1PR1–STAT3 signalling in myeloid cells facilitates the formation of a pre-metastatic niche, leading to increased metastasis[17]. Furthermore, the S1PR1–STAT3 axis is intrinsic to regulatory T cells.

Ego-Depletion (Difficult) Version

In this executive function task, you will be presented with passages from a scientific journal article and asked to follow rules related to the crossing out of letters. For example, the block of text below follows the rule of crossing out all occurrences of the letter 'e.'

Abstract | The Janus kinases (JAKs) and signal transducer and activator of transcription (STAT) proteins, particularly STAT3, are among the most promising new targets for cancer therapy. In addition to interleukin-6 (IL-6) and its family members, multiple pathways, including G-protein-coupled receptors (GPCRs), Toll-like receptors (TLRs) and microRNAs were recently identified to regulate JAK–STAT signalling in cancer. Well known for its role in tumour cell proliferation, survival, invasion and immunosuppression, JAK–STAT3 signalling also promotes cancer through inflammation, obesity, stem cells and the pre-metastatic niche. In addition to its established role as a transcription factor in cancer, STAT3 regulates mitochondrion functions, as well as gene expression through epigenetic mechanisms. Newly identified regulators and functions of JAK–STAT3 in tumours are important targets for potential therapeutic strategies in the treatment of cancer.

Now try this yourself. Please cross out (i.e., draw a line through) all occurrences of the letter 'e' in the following passage:

The Janus kinase (JAK)–signal transducer and activator of transcription (STAT) pathway was originally discovered in the context of interferon-α (IFNα)-, IFNγ- and intereukin-6 (IL-6)-mediated downstream signalling1–3. Of the seven members of the STAT protein family, STAT3 and STAT5 have been demonstrated to be the most important for cancer progression4–6. They are not only crucial for transducing signals from numerous receptor and non-receptor tyrosine kinases that are frequently activated in cancer cells, but they are also transcription factors that regulate the expression of a wide range of genes5,7,8, thereby contributing to tumour progression. Although both STAT3 and STAT5 contribute to tumour cell proliferation and survival, a notable feature of STAT3 as a promising target for cancer therapy is that it also has a crucial role in stromal cells, including immune cells, which are recruited to the tumour microenvironment to promote tumour progression9–15. Importantly, STAT3 activation also functions as a potent immune checkpoint for multiple antitumour immune responses7,9,10,13,14.

Although the crucial role of STAT3 in both tumour cells and the tumour microenvironment is evident, gaps remain in our understanding of links between upstream regulators and JAK–STAT3 signalling. STAT3 is mainly considered to be a direct transcription factor. Nevertheless, recent studies demonstrate that STAT3 also regulates gene expression through epigenetic mechanisms, such as DNA methylation and chromatin modulation. Recent studies also highlight the importance of STAT3 in cancer through regulating mitochondrion functions. In addition to its known roles in promoting tumour cell proliferation, survival, tumour invasion, angiogenesis and immunosuppression, JAK–STAT3 signalling has recently been shown to have central roles in inflammation-mediated cancer, obesity and/or metabolism, cancer stem cells (CSCs) and pre-metastatic niche formation7,16–21.

Although abundant evidence suggests that STAT3 is an ideal target for cancer therapy, to date, effective therapeutic interventions to inhibit STAT3 and to generate potent antitumour effects in the clinic remain to be further explored and developed. The lack of efficacious therapeutics is in large part due to the challenge of directly targeting STAT3 (which lacks its own enzymatic activity), and in part due to the complexity of its biology in cancer — specifically its numerous activators and its diverse biological functions. Consequently, it is essential to have a comprehensive understanding of the biology surrounding STAT3 to develop effective approaches to inhibit this pathway for the treatment of cancer.

During the past few years, many unexpected new roles of the JAK–STAT3 pathway in cancer and the underlying mechanisms by which this pathway is activated and exerts its cancer promoting effects have emerged. Traditionally, the JAK–STAT3 pathway has been thought to be activated primarily by cytokines and growth factors. Several recent studies have identified Toll-like receptors (TLRs), such as TLR9 and TLR4, as important activators of the JAK–STAT3 pathway[22–24]. STAT3, in turn, upregulates the expression of certain TLRs in malignant cells, thereby promoting tumour progression[25,26]. A major role of microRNAs (miRNAs) in cancer has also emerged, and several of these miRNAs have been shown to be crucial for regulating the JAK–STAT3 pathway[27–31]. Several G-protein-coupled receptors (GPCRs) have also been described to regulate STAT3, through JAK and SRC family kinases[32,33].

For the following three pages of text, please cross out occurrences of the letter 'e.' However, this time two additional rules apply:

1) Anytime an 'e' is directly followed by another vowel, as in 'beauty,' do not cross out the 'e.'

2) Anytime a vowel appears two letters before an 'e,' as in 'vowel,' do not cross out the 'e.'

New pathways regulating JAK–STAT3 in cancer

IL-6 and IL-6 family cytokines. IL-6 is the most well-known traditional activator of STAT3 (REFS 34–36). IL-6 exerts its biological effects through binding to IL-6 receptor-α (IL-6Rα) on the cell surface. Receptor engagement by IL-6 induces conformational changes, triggering the formation of a hexameric signalling complex comprising a gp130 (also known as IL-6Rβ) homodimer plus two IL-6–IL-6Rα heterodimers. These events result in activation of JAKs that are constitutively associated with a proline-rich, membrane-proximal cytoplasmic domain of gp130. Activated JAKs, in turn, mediate phosphorylation of gp130, leading to the recruitment and activation of cytosolic STAT3, which then translocates into the nucleus (FIG. 1). Other IL-6 family members, including IL-11, leukaemia inhibitory factor (LIF), ciliary neurotrophic factor (CNTF), oncostatin M (OSM) and IL-31, also activate receptors that transduce signals through JAK–STAT3 .

Although a crucial role of IL-6 in promoting JAK–STAT3 in cancer has been well established, multiple recent studies have expanded and/or identified additional important functions of this signalling pathway.
IL-6 family cytokines, such as IL-6 and IL-11, produced mainly by myeloid cells37,38, regulate diverse inflammatory processes, such as autoimmune diseases, rheumatoid arthritis and obesity39–43, suggesting that they have an essential role in balancing pro-inflammatory and anti-inflammatory responses. Moreover, activation of IL-6 signalling, as well as some of the family members of IL-6, is strongly associated with tumour progression and poor prognosis in patients with many types of solid tumours, including breast, lung and prostate cancers and multiple haematopoietic malignancies18,40,44–51. Most notably, IL-6 signalling, mainly via JAK–STAT3 in epithelial cells and immune cells, is able to promote inflammation, which in turn promotes oncogenesis44,45,52–55 (BOX 1). For example, persistent JAK–STAT3 activation by IL-6 and IL-11 induces a chronic inflammatory state in the intestine, affecting intestinal epithelial cell turnover, leading to increased incidence of gastric tumorigenesis42,56.

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Other studies also identify S1PR1–STAT3 signalling in linking chronic intestinal inflammation to the development of colitis-associated cancer (CAC)76. S1P contributes to nuclear factor-κB (NF-κB) activation, leading to increased production of IL-6, STAT3 activation and CAC incidence *in vivo*, suggesting that S1P–S1PR1 amplifies STAT3 activation during inflammation-associated tumour development76. S1P–S1PR1 signalling has an important role in the development of T cells and B cells82,83. Recent studies have highlighted the crucial role of S1PR1 signalling in maintaining persistent STAT3 activation in immune cells in the tumour microenvironment32,33,76. S1PR1–STAT3 signalling in myeloid cells facilitates the formation of a pre-metastatic niche, leading to increased metastasis17. Furthermore, the S1PR1–STAT3 axis that is intrinsic to regulatory T cells promotes tumour regulatory T cell migration to and accumulation in tumours, leading to inhibition of antitumour CD8+ effector cells77. Intriguingly, in the tumour periphery, S1PR1 inhibits regulatory T cell migration, even in the same mouse in which S1PR1 facilitates tumour regulatory T cell accumulation77. Evidently, both JAK–STAT3 and S1P–S1PR1 have a crucial role in normal physiology, as well as in cancer.

This link between JAK–STAT3 and S1P–S1PR1 raises the possibility that STAT3 may promote cancer through certain dysregulated lipid signalling pathways. The finding that S1P–S1PR1 signalling activates STAT3 and NF-κB also illustrates an important point: even though numerous stimuli and pathways contribute to cancer progression, many of these ultimately require transcription factors to exert their tumour-promoting effects. Consequently, the few transcription factors that are known to be crucial for cancer are ideal targets for cancer therapy84. However, targeting transcription factors that lack enzymatic activity for cancer treatment remains challenging. The discovery that GPCRs, such as S1PR1, activate JAK–STAT3 and/or SRC–STAT3, as well as NF-κB, implies the use of drugs against the GPCRs to block the effects of STAT3 and NF-κB.

TLRs. Recent studies have identified a crucial role for TLR signalling pathways in contributing to STAT3 activation and tumour development in both mouse and human cells (FIG. 1). In inflammation-associated colon cancer, increased TLR4 expression in intestinal epithelial cells induces STAT3 activation, which promotes colon tumour growth *in vivo*24. Importantly, TLR4–STAT3 signalling correlates with clinical stage in human colon adenocarcinoma24. TLR4 also contributes to lymphomagenesis through upregulation of IL-6 and miR-21 (REF. 85). In addition to TLR4, TLR7 ligation induces loss of expression of tumour suppressor genes through STAT3 activation, which accelerates pancreatic cancer progression86. A crucial role of TLR–STAT3 signalling in cancer progression is also supported by the finding that TLR7 elicits potent cancer-promoting inflammation in the stroma during pancreatic cancer development86.

Systemic deletion of *Tlr2* in mice suppresses the development of CAC, and TLR2 expression is highly elevated in tumour tissues and strongly associated with poor survival in patients with gastric cancer, which is correlated with STAT3 activation25. The reduction of CAC incidence in mice that systemically lack *Tlr2* is probably due to the importance of TLR2 in mediating inflammation, which is crucial for the development of CAC. TLR2-mediated tumorigenesis does not require activation by its own ligand; instead, it upregulates IL-6, which activates STAT3 and increases proliferation of the intestinal epithelium25. In contrast to the oncogenic role of TLR2 in CAC, a protective role of ligand-induced TLR2 against the development of CAC has also been shown87. It remains unclear whether these discrepancies stem from inherent differences in the experimental approaches.

Elevated TLR9 expression in tumours predicts worse survival in glioblastoma88. TLR9 also activates STAT3, creating a potent checkpoint or a brake for antitumour immune responses89. How TLR9 signalling exerts its oncogenic influence in tumour cells through STAT3 was recently explored. Recent studies show that TLR9 is highly expressed in GSCs. Activated STAT3 binds to the *Tlr9* promoter and contributes to TLR9 expression in GSCs. Upon TLR9 engagement with CpG oligodeoxynucleotides (ODNs), JAK2 undergoes recruitment by Frizzled 4 (FZD4) and becomes activated, linking CpG–TLR9–FZD4 signalling with subsequent STAT3 tyrosine phosphorylation26.

The recent findings that certain TLRs activate STAT3 in tumours provide a potential mechanism by which infection or inflammation enhances oncogenesis, at least in some settings. At the same time, upregulated expression of several TLRs, through JAK–STAT3 activation, mimics certain inflammatory reactions, without the presence of their cognate ligands.

miRNAs and JAK–STAT3 regulation. Reciprocal interactions of miRNAs and JAK–STAT3 are also emerging as having surprisingly important roles in regulating cancer-promoting inflammation, as well as oncogenesis (FIG. 2). In breast epithelial cells and breast cancer stem-like cells, interaction of miRNA let-7 and IL-6–STAT3 provides a negative-feedback loop in regulating inflammation-mediated cellular transformation. Enforcing SRC expression in breast epithelial cells suppresses let-7 expression, which results in higher levels of IL-6 (REF. 27). High levels of IL-6 expression by direct activation of IL-6 transcription and indirect inhibition of let-7 miRNA might be required to ensure STAT3 phosphorylation and entry into the nucleus. Additionally, persistent activation of STAT3 in breast cancer cells perturbs the expression of let-7 and miR-200 families, leading to metastasis of tumour cells through alterations of transcription factors and oncoproteins involved in the epithelial-to-mesenchymal transition (EMT) process28. While the importance of IL-6 in promoting tumour cell migration through the induction of EMT has been shown90, IL-6-triggered EMT in breast cancer cells may be a consequence of STAT3 activation, as STAT3 inhibition effectively reverses the mesenchymal phenotype and restores the expression of let-7 and miR-200 families *in vitro*28.

Changes in miRNA expression profiles, including let-7 families, are emerging as a mechanism for regulating chemoresistance in several types of cancer cells. For example, increasing let-7a expression led to resistance of human squamous-cell carcinoma and hepatocellular carcinoma (HCC) cells to doxorubicin and paclitaxel91. However, other studies have found a correlation between let-7 expression and sensitivity to certain chemotherapeutic compounds. In patients with chemotherapy-resistant ovarian cancer, let-7i expression is downregulated, and reintroduction of let-7i sensitizes resistant ovarian cancer cells to platinum-based chemotherapy92. Let-7b and let-7c directly repress cisplatin-induced IL-6–STAT3 activation in tumour cells, and let-7 expression in oesophageal tumour tissues predicts favourable response to cisplatin-based chemotherapy29. Moreover, miRNA array analysis studies using doxorubicin- or fulvestrant-resistant MCF-7 human breast cancer cells have revealed that let-7 is upregulated in doxorubicin-resistant cells93, whereas it is downregulated in fulvestrant-resistant cells94. Whether STAT3 activation determines let-7-associated sensitivity or resistance to these drugs requires further investigation. Nevertheless, these studies suggest that let-7–IL-6–STAT3 signalling is a potential biomarker for assessing therapeutic response in some human cancer cells.

Interestingly, miR-135a also regulates the JAK–STAT3 pathway (FIG. 2). Gene target analysis shows that miR-135a can inhibit STAT3-induced pro-survival gene expression and induce apoptosis in lymphoma and gastric cancer30. Expression of another miRNA, miR-26a, is downregulated in HCC tissues. Patients with high levels of miR-26a have a better prognosis with longer overall survival and time to recurrence, suggesting that miR-26a can be a prognostic marker for HCC95. Importantly, miR-26a mainly suppresses IL-6 expression in HCC cells, leading to inhibition of JAK–STAT3 signalling, as well as its downstream target genes involved in cell proliferation and cell cycle progression. In addition, miR-337-3p sensitizes lung cancer cells to paclitaxel by inhibiting STAT3 (REF. 31), suggesting that these miRNAs can be used to boost therapeutic efficacy of current chemotherapy through targeting STAT3 (FIG. 2). These extensive examples of how miRNAs regulate JAK–STAT3 oncogenic potential suggest that miRNAs can mediate an epigenetic switch to enable cells to make rapid transitions between non-transformed and transformed states without permanent genetic alterations.

The miRNA–STAT3 regulatory circuits within non-transformed stromal cells are also important in tumour progression. For example, miR-17-5p and miR-20a inhibit STAT3 expression in myeloid-derived suppressor cells (MDSCs) in the tumour microenvironment. Tumour-associated MDSCs express lower levels of miR-17-5p or miR-20a than do MDSCs from the spleen of naive mice. Transfection of MDSCs with miR-17-5p or miR-20a alleviates the immunosuppressive function of MDSCs96, suggesting that these miRNAs can potentially be used for cancer immunotherapy (FIG. 2). Most importantly, some miRNAs, such as miR-21 and miR-29a, can function as ligands to TLRs in immune cells, triggering a TLR-mediated pro-metastatic inflammatory response97. These miRNAs are released from cancer cell-derived exosomes, bind to TLRs in immune cells in the microenvironment, and thereby modulate production of cancer-promoting inflammatory cytokines. STAT3 is a transcriptional regulator of miR-21, which implies that JAK–STAT3 can affect the tumour microenvironment through cancer-secreted miRNAs.

Additionally, miRNAs released by tumour cells are packaged into microvesicles and delivered to neighbouring stromal cells in the tumour microenvironment (FIG. 2). For example, tumour cell-derived miR-9 strongly induces endothelial cell migration and tumour angiogenesis by inhibiting suppressor of cytokine signalling 5 (SOCS5) in endothelial cells, which leads to JAK–STAT3 activation98. Thus, tumour-derived miRNAs participate in mediating signalling networks between tumour cells and stromal cells during tumour development, highlighting a crucial role of miRNAs in modulating the tumour microenvironment.

Notably, this regulation is of an epigenetic nature, as it implies changes in the gene expression programme in the tumour microenvironment without direct modification or mutations of specific genes.

JAK–STAT3 in pre-metastatic niche formation. Although a crucial role of JAK–STAT3 in cancer cell proliferation, survival, tumour immunosuppression, angiogenesis and metastasis has been well documented, recent studies further indicate the importance of JAK–STAT3 in the formation of pre-metastatic niches in future metastatic sites17 (FIG. 3). These pre-metastatic niches, which consist of immune cells, including those of myeloid origin, are implicated in providing a sanctuary for disseminated tumour cells, allowing them to colonize and form metastases17. It is not entirely unexpected that immune cells such as myeloid cells in the tumour microenvironment can provide cytokines, growth factors and other molecules to support tumour cells. However, if the future metastatic sites are too hostile for tumour cells to colonize, an intriguing question is why myeloid cells have an apparently superior capacity to proliferate and resist apoptosis, thereby facilitating outgrowth in secondary tumour sites.

Myeloid cells in future metastatic sites, under the influence of tumour-produced factors, exhibit increased proliferation and survival17. Of particular importance, both the production of tumour-derived factors that promote metastasis and the outgrowth of myeloid cells in distant sites are dependent on the S1PR1–JAK2–STAT3 signalling axis17 (FIG. 3). Like in transformed cells, myeloid cells gain increased proliferation and survival capacity through upregulated expression of genes underlying growth in a STAT3-dependent manner. Consequently, inhibiting this STAT3 pathway abrogates formation of and suppresses established pre-metastatic niches, effectively reducing tumour metastasis17. A correlation between STAT3 activity and the number of pre-metastatic niches was also found in tumour-free lymph nodes of patients with various types of cancer17,99. These findings suggest that targeting S1PR1–JAK–STAT3 signalling may be an effective therapeutic strategy for the prevention and treatment of tumour metastasis.

Inflammation, obesity, diabetes and cancer. A crucial role of JAK–STAT3 in cancer inflammation has been well documented7,39,40. One recent study demonstrated that IL-6–JAK2–STAT3 signalling in the liver exacerbates metabolic stress-induced inflammation in obese mice, accelerating the incidence of HCC18. Increased IL-6 in the hepatic microenvironment upregulates STAT3 activity through JAK2 activation, which is required for development of the malignant hepatic phenotype18. Blocking IL-6 in diet-induced obese mice or treating obese mice with the JAK2 inhibitor AG490 suppresses hepatic inflammation as well as tumour growth through STAT3 inhibition18. Moreover, *Il6*−/− mice that were fed on a high-fat diet (HFD) showed reduced fat accumulation in the liver18, suggesting that targeting the IL-6–JAK2–STAT3 pathway may prevent the development of an environment that increases the risk of obesity-induced HCC. IL-6–STAT3 signalling in colon epithelial cells is also important for the development of obesity-associated colon cancer100. These results suggest that activation of the JAK–STAT3 pathway in epithelial cells can promote development of obesity-associated cancer through the activation of inflammatory immune responses (FIG. 3).

STAT3 activity in T cells promotes obesity as well as insulin resistance16. In HFD-fed mice, blocking STAT3 signalling in T cells decreases local adipose tissue inflammation, reducing obesity and insulin resistance16, further demonstrating that STAT3 is a molecular nexus between inflammation and obesity (FIG. 3). This study also illustrates a link between type 2 diabetes and STAT3 activation, which indirectly suggests that type 2 diabetes could enhance cancer development via STAT3 signalling. Supporting this hypothesis are recent findings with metformin, a front-line drug for treating type 2 diabetes. Metformin lowers the risk of cancer incidence in patients with diabetes101–103, and treatment of triple-negative breast cancer (TNBC) cells with metformin selectively targets STAT3 and induces apoptosis104.

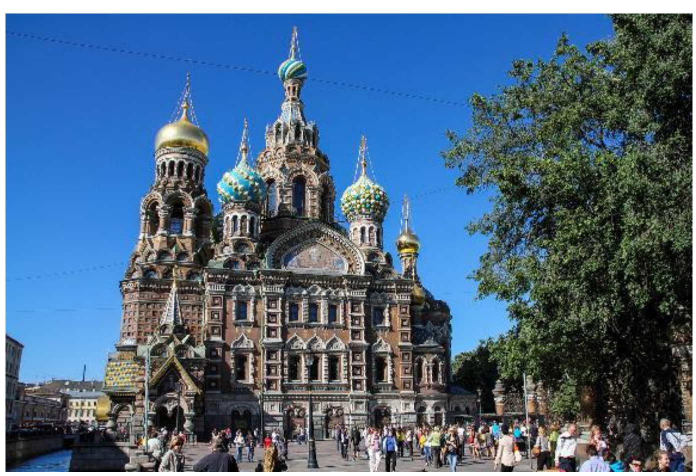
Appendix F: Photo Questionnaire

Would you like to visit the place in: (circle answer)

Photo 1?	Yes	No	Already Have	Photo 16?	Yes	No	Already Have
Photo 2?	Yes	No	Already Have	Photo 17?	Yes	No	Already Have
Photo 3?	Yes	No	Already Have	Photo 18?	Yes	No	Already Have
Photo 4?	Yes	No	Already Have	Photo 19?	Yes	No	Already Have
Photo 5?	Yes	No	Already Have	Photo 20?	Yes	No	Already Have
Photo 6?	Yes	No	Already Have	Photo 21?	Yes	No	Already Have
Photo 7?	Yes	No	Already Have	Photo 22?	Yes	No	Already Have
Photo 8?	Yes	No	Already Have	Photo 23?	Yes	No	Already Have
Photo 9?	Yes	No	Already Have	Photo 24?	Yes	No	Already Have
Photo 10?	Yes	No	Already Have	Photo 25?	Yes	No	Already Have
Photo 11?	Yes	No	Already Have	Photo 26?	Yes	No	Already Have
Photo 12?	Yes	No	Already Have	Photo 27?	Yes	No	Already Have
Photo 13?	Yes	No	Already Have	Photo 28?	Yes	No	Already Have
Photo 14?	Yes	No	Already Have	Photo 29?	Yes	No	Already Have

Photo 15? Yes No Already Have Photo 30? Yes No Already Have

Appendix G: Urban Photos




DON'T
BELIEVE THE
LIBERAL
MEDIA!
Kodak

Appendix H: Nature Photos

Appendix I: Unsolvable Anagram Task

For this task you will be asked to solve anagrams. Anagrams are groups of letters that can be rearranged into words. For example:

ACLADIR – can be rearranged to spell ‘RADICAL’

ITWHEG – spells ‘WEIGHT’

VETIIFUG – spells ‘FUGITIVE’

Below are six anagrams. Work on them for as long as you want, and when you want to stop just notify the experimenter.

EERIVCE ___________________

KDNITE ____________________

BALGME _____________________

UTAFIE ______________________

DNOEIG _______________________

AESIDUD _______________________

Appendix J: Demographic Questionnaire

1. What is your age in years? _______________

2. What is your gender (circle one)? Male Female Other

3. With which ethnic group do you primarily identify? Please circle one.

Hispanic Asian White Black Native American Pacific Islander Inuit
Other __________

4. If you identify with more than one ethnic group, what is the second? Please circle one (if applicable).

Hispanic Asian White Black Native American Pacific Islander Inuit
Other __________

5. Is English your first language? Yes No

6. Please describe, in your own words, what you think this study was about in the space below.

7. Sometimes when people take part in these studies, they think that the researchers are looking at something unknown to participants. Did you have any thoughts along those lines? If so, what do you think the researchers were looking for?

Appendix K: Anagram Task for Study Two

For this task you will be asked to solve anagrams. Anagrams are groups of letters that can be rearranged into words. For example:

SETB – can be rearranged to spell ‘BEST’

AER – spells ‘ARE’ and ‘EAR’

VETIIFUG – spells ‘FUGITIVE’

Below are twelve anagrams. Work on them for as long as you want, and when you want to stop just notify the experimenter.

UMD ________________	BALGME ________________
XFO ________________	ITWHEG ________________
LBLA ________________	ACLADIR ________________
CRHA ________________	ESMNEIS ________________
BAREZ ________________	ONOPRHA ________________
TINAP ________________	MEDRICTOA ________________

Appendix L: Taste Test Writing Task

For this task, we are testing a new method of assessment for personality traits. We think certain traits may be revealed by examining how people describe experiences and sensations. On the table in front of you is a bowl of candy. You may help yourself to as much as you would like. Please be aware that some candies may contain nuts or gluten.

While you are eating, please describe in the space below the sensations you are experiencing as best as you can. This can be strictly related to taste or can include other bodily sensations and perceptions while eating as well. There are no right or wrong answers; we are interested in your unique experience. You may eat as much candy as you would like to aid in your descriptive process.

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