GARDENING MODIFIES THE PATTERNS OF BRAIN ACTIVATION AND ENHANCES THE MENTAL HEALTH PROFILE OF HEALTHY WOMEN

By

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To gardeners everywhere

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Research in the field of people-plant interactions has long sought to demonstrate the therapeutic effects of interacting with plants that is often innately felt by a majority of the population. However, many studies have relied solely on self-report or observational data, and there has been very little research aimed at understanding the neurological bases that could explain the therapeutic benefits of interacting with plants. This study used *f*unctional *M*agnetic *R*esonance *I*magining (fMRI) to assess changes in the patterns of brain activation resulting from a group-based gardening intervention. The resulting data were used to explore linkages that may exist with the mental health therapeutic benefits associated with gardening. Five self-report psychometric assessments were used to quantify the mental and physical health-related therapeutic benefits accruing from a group-based gardening treatment intervention in a population of 12 healthy adult women. The treatment group received a six-week gardening program that involved working with plants and learning gardening skills, while the control group of 11 women received no intervention of any kind.

The two groups were evaluated at baseline and again following the completion of the gardening treatment using self-report questionnaires assessing general physical

and mental health, perceived stress, depressive symptomatology, anxiety, and mood, and fMRI brain scans to evaluate brain activation patterns.

The results showed a significant improvement in the self-reported mental health status of the treatment group comparing pre- to postintervention. Perceived stress, anxiety, total mood disturbance, and depressive symptomology were also significantly reduced in the treatment group. The control group demonstrated no changes in self-reported mental health.

Functional MRI results revealed unique patterns of activation between the control and treatment group at the postintervention scan. The two groups did not exhibit any similar changes in brain activation from pre- to postintervention. Unique areas of decreased activation in the treatment group included the inferior frontal gyrus and the medial frontal gyrus. These results suggest that a gardening experience is linked with positive self-reported improvements in mental health and with unique changes in the patterns of brain activation, including the inferior and medial frontal gyrus.

CHAPTER 1
INTRODUCTION

Plants were abundant long before the dawn of hominid and human evolution some 7-8 million years ago, and down through the ages they have provided a plethora of benefits to humans. Among other things, we use plants for food, shelter, clothing, medicine and enjoyment (Coulter, 1913). These uses are obvious to all. However, plants have other uses that benefit humanity that have received far less recognition from society. One of these is the therapeutic benefit that plants bring to people. Researchers such as Rachel and Stephen Kaplan, Roger Ulrich, and E. O. Wilson have conducted studies that suggest that an innate, intimate connection exists between humans and plants. Their findings and conclusions suggest that people-plant interactions are generally beneficial to society, and essential to our individual as well as our collective wellbeing as a species (Kaplan and Kaplan, 1989; Ulrich, 1984; Wilson, 1984).

One of the most common ways that people actively interact with plants is through gardening. When asked why they garden, survey participants have given a variety of justifications, including stimulus avoidance, social interaction, intellectual stimulation, physical fitness, skills development, and expression of creativity (Ashton-Shaeffer and Constant, 2006). This data, along with other anecdotal and some empirical evidence, suggests that there is a reason for our desire for interaction with plants beyond their simple utilization as a food source. Many people will spend time walking in parks (Hartig et al., 2003; Maller et al., 2006), immersing themselves in nature (Park et al., 2010), or participating in communal gardening (Guitart, 2012) to glean their own self-perceived benefits of these experiences.

Along similar lines, the field of horticultural therapy seeks to capitalize on the beneficial effects of plants by using them and their by-products to help clients reach therapeutic goals. Horticultural therapy (HT) has been defined by the American Horticultural Therapy Association as “the engagement of a client in horticultural activities facilitated by a trained therapist to achieve specific and documented treatment goals” (Diehl, 2007, p.1). Another term commonly used in this field is therapeutic horticulture (TH) which is typically a less structured intervention that “uses plants and plant-related activities through which participants strive to improve their well-being through active or passive involvement” (Diehl, 2007, p.1). Common goals of these therapeutic programs include participants experiencing reduced stress and decreased symptoms of depression (Gonzalez, 2011), improved physical functioning (Beela and Reghunath, 2010; Verra et al., 2012), increased sociability (Son et al., 2004), improved self-esteem (Perkins, 2010), and even enhanced cognitive functioning (Berman et al., 2008). While the emphasis of the field of horticultural therapy is centered on improving quality of life (Diehl, 2007), the foundational research developing and supporting these broad therapeutic outcomes is surprisingly limited.

Quality of life is made up of many different facets including physical, mental, psychological, and social wellbeing. The World Health Organization (WHO), describes quality of life as being “a broad ranging concept affected in a complex way by the person's physical health, psychological state, level of independence, social relationships, personal beliefs and their relationship to salient features of their environment” (1997, p.1). The most common research in the field of people-plant relationships conducted to date has centered on the psychological effects of people interacting with plants. Studies have shown that elderly populations participating in therapeutic horticulture programs experience improvements in life mastery, self-rated happiness, self-rated health (Collins and O'Callaghan, 2008), positive affect (Gigliotti et al., 2005; Gigliotti and Jarrott, 2005), and sleeping patterns (Gonzalez and Kirkevold, 2014). Gonzalez and colleagues (Gonzalez et al., 2009, 2010, 2011) have demonstrated in multiple studies a reduction in depression symptoms for clinically depressed patients following a therapeutic horticulture program. Stress reduction is often reported when populations interact with plants either actively or passively (Clatworthy et al., 2013; Eriksson et al., 2011). However, quality of life measures often rely on self-report questionnaires which can be subject to validity problems (Baumeister and Vohs, 2007). Therefore, a need for more objective measures in the field of people-plant interactions is necessary to further validate the claims of the therapeutic nature of plants. By combining both qualitative and quantitative measurements, it is possible to effectively gather a wider range of conclusive results.

The development of *M*agnetic *R*esonance *I*maging (MRI) has helped to advance many of today's research inquiries. Researchers in the fields of medicine, psychology, and other human-subject related fields are able to employ MRI to look inside the body in a noninvasive way, and determine the effects of diseases, medications, and interventions on the body as well as the brain (Edelman and Warach, 1993; Rajan, 1997). Magnetic Resonance Imaging is simply defined as the "use of magnetic resonance to create images of objects such as the body. Currently, this primarily involves imaging the distribution of mobile hydrogen nuclei (protons) in the body" (Hendrick, 2005, p.1).

Of the many studies assessing the effects of gardening or engaging in gardening activities, virtually none have approached the subject with a focus on the patterns of brain activation using functional MRI (fMRI). After a thorough and comprehensive review of the world literature, only a few reports were found that employed the use of MRI to determine outcomes of a horticultural therapy intervention. The first study sought to examine the beneficial effects of horticultural therapy on brain function using fMRI in individuals that had suffered some form of cerebrovascular disease (Mizuno-Matsumoto et al., 2008). Many weaknesses were identified in this study, such as a very small population size (n=5), a diversity in the severity, location, and type of brain injury between each participant, and the implementation of non-uniform horticultural therapy programming given as an intervention. This study is not seen as experimentally robust for many reasons and, therefore, the findings are considered very preliminary at best.

A second study evaluated differences of a horticultural therapy intervention and a stress education intervention on a population suffering from post-traumatic stress disorder (PTSD) following the Great East Japan earthquake also known as the Tohoku earthquake of 2011. After an eight week intervention, the horticultural therapy group showed statistically significant decreases in salivary cortisol levels as well as increased regional gray matter volume of the left subgenual anterior cingulate cortex and left superior frontal gyrus when compared with the stress education group (control). The results gathered in this study appear to only use the anatomical information from MRI and did not use functional MRI to quantify changes in patterns of brain activity (Kotozaki et al., 2015).

While writing this thesis, a study was published that compared a group of participants taking a nature walk to a matched group taking an urban walk using self-reported rumination and brain blood perfusion scans which determine changes in regional blood flow. Participants completed a self-reported rumination questionnaire and underwent a preintervention MRI brain scan. Following a 5 km walk along either a busy city street or through a natural area, participants completed the postintervention self-reported rumination questionnaire and underwent a second brain scan at the MRI facility. The results showed a significant decrease in self-reported rumination for the nature walk group, but not the urban walk group. A decrease was also observed in the blood flow to the subgenual prefrontal cortex for those individuals in the nature walk group, but not in the urban walk group (Bratman et al., 2015).

A significant shortcoming in research in the field of horticultural therapy exists. Because therapeutic improvements are associated with interacting with plants, many researchers have sought to employ those benefits to aid in the recovery of those with disabilities, diseases, or injuries. As a result, little research has been done to establish the effects of people-plant interactions with a wellness population. Research demonstrating the effects of people-plant interaction on a healthy population could shed new light on the impacts of interaction with plants on the general public, and those who do not need any recovery or rehabilitation from a disease or injury. Such results could offer a baseline of evidence to show that people-plant interactions can affect every person and be beneficial for any individual regardless of the degree of their wellness.

The purpose of this study is to demonstrate the effects of gardening activities on the self-reported physical and mental health of participants from a wellness population, and to determine whether an associated neurological response can be revealed by functional Magnetic Resonance Imaging.

The objectives of this study are to:

1. Use psychometric assessments to evaluate the therapeutic impacts of the group-based gardening intervention on study participants' self-report general health, perceived stress, depression symptomatology, anxiety, and mood states profile of a wellness population consisting of only women.

2. Use functional MRI to determine the effects of a group-based gardening program intervention on the patterns of brain activation of the study participants.

3. Search for linkages between the patterns of brain activation and quantified therapeutic benefits.

In this study, we demonstrate a novel changes in the patterns of brain activation and improved mental health status in the gardening group that suggest a neurological basis for some of the therapeutic benefits derived from engaging in group-based gardening activities. The present findings may extend to a variety of people-plant interactions resulting in a wide array of therapeutic benefits.

CHAPTER 2
LITERATURE REVIEW

This literature review will explore publications essential to the development of the research project described herein. This research project was inspired by the fact that for 100 years the practice of horticultural therapy has rested upon the belief there are genuine therapeutic benefits to be accrued from its application. First, there will be a brief exploration of the origins of people-plant interactions. Second, there will be a more comprehensive look at the therapeutic effects of human interactions with plants. The final portion will explore diagnostic tools that can be used to assess the effects of interactions with plants; these tools include psychometric assessments, and a more novel approach of neural imaging using functional Magnetic Resonance Imaging.

Origin and Theories of People-Plant Interactions

The most prominent of all interactions that people have with plants is the use of plants for food. Plants are essential to our survival as a species, as well as to the survival of nearly all other animal and microbial life on earth, because plants, through photosynthesis ultimately, provide for the capture and transformation of energy from the sun into heterotrophically-usable forms of energy crucial for biological growth, maintenance and reproduction. Plants have long shaped the behavioral patterns and the genetic composition (Perry et al., 2007) of humans, as *Homo sapiens* originally migrated according to the availability of plant and animal foods. The domestication of plants and rise of agriculture ≈12,000 years ago initiated a type of “domestication” of *Homo sapiens* as we settled into an agrarian lifestyle to cultivate crops for higher yields, and a much more stable and abundant food supply (Doebley et al., 2006).

Plants and humans appear to be intricately intertwined as they have co-evolved. As humans have eaten different plants or parts of plants, changes in diet have caused shifts in human biology that are predicated on modifications within the human genome or how the patterns of gene expression are changed. For example, a shift in the staple plant in the human diet caused an analogous shift in the enzymes produced by the human body needed for the breakdown of this new staple plant (Perry et al., 2007). Perry and his colleagues found that the copy number of the salivary amylase gene (AMY1) was increased in a population that had both a high-starch diet and an increased level of salivary amylase proteins. Populations having a lower amount of starch in their diet (such as rainforest hunter-gatherers or pastoralist who eat mostly fish) did not have elevated levels of AMY1 or salivary amylase proteins. This research demonstrates a co-evolution of humans with plants as a shift in the plants in the diets of certain populations influenced AMY1 copy number within their genomes. Turnbaugh and his colleagues (2009) have found similar results when analyzing the effects of diet on the microbiome of living organisms. Changes from a low-fat, plant polysaccharide diet to a high-fat/high-sugar diet shifted the structure of the gut microbiota, affected the use of certain metabolic pathways, and altered gene expression of the microbiome. If the human genome and our gut microbiome can be influenced by changes in plant-based diets, perhaps the mental health of humans could be similarly linked to interactions with plants. In fact, the human need for plants appears to extend well beyond the need for pure physical sustenance. Several studies have expanded our understanding on how interactions with living organisms and particularly plants can meet human needs in the realms of psychological, cognitive, and social well-being (Gonzalez et al., 2011; Ulrich, 1984; Wang and MacMillan, 2013).

Several researchers have explored the evolutionary advantages of close attention to plants and attempted to explain the innate attraction that man has to natural and biotic environments. One theory that has been developed by E. O. Wilson suggests how the evolution of people and the biotic/natural world together has resulted in our current attraction to living organisms. His theory, termed “biophilia”, is simply defined as “the innately emotional affiliation of human beings to other living organisms” (Kellert and Wilson, 1995, p.20). Wilson has proposed that this affiliation is ingrained in humans and cannot be conditioned out. Biophilia is an unconscious predisposition that keeps humans and other living organisms intertwined to the advantage of both parties (Wilson, 1984). Wilson and Kellert include research conducted by Ulrich to defend this theory in their book *The Biophilia Hypothesis* (Kellert and Wilson, 1995). Ulrich and his colleagues have found that stress recovery, as measured by muscle tension, blood pressure, and heart beat rate is significantly reduced when research subjects are exposed to natural environments as opposed to urban environments (Ulrich et al., 1991). Other studies also support this finding that viewing natural scenes is better for stress recovery than viewing plant-free urban scenes (Kaplan et al., 1972; Park et al., 2010; Wohlwill, 1976).

Ulrich developed his own theory on plant-people evolutionary interactions, the “psycho-evolutionary theory”, which focuses on the stress-recovery effects of nonthreatening natural environments. He postulates that the ability of an individual to recover quickly from stressors and threats in the environment contributes to the survival and fitness of that individual. Therefore, nonthreatening natural scenes, which cause a quick recovery from stress by lowering heart rate, increasing positive feelings, and reducing negative feelings, are innately attractive to humans (Ulrich et al., 1991; Ulrich and Parsons, 1992).

The Attention Restoration Theory is another complimentary theory that attempts to determine the reason for people's positive relationship to the natural environment. Kaplan and Kaplan are the champions of this model which focuses on the influence of nature on directed attention. Kaplan and Kaplan utilized concepts about voluntary and involuntary attention from the writings of William James (James, 1892) to help formulate their theory. Voluntary attention inherently requires effort and work. However, involuntary attention, as described by James, is something that requires no effort and simply attracts focus naturally. Inspired by this concept, Kaplan noted that voluntary attention can be exhausted if it is relied upon too heavily. However, Kaplan also observed that nature can serve to concurrently engage involuntary attention and restore voluntary attention (Kaplan, 1995; Kaplan and Kaplan, 1989). Kaplan theorizes that because being in a natural environment does not demand any specific focus, the mind can be free to wander to other things in self-reflection or contemplation. This time and space for involuntary attention then allows voluntary attention to be restored and used again later, thereby reducing the negative impacts of prolonged voluntary attention (Herzog et al., 1997; Kaplan and Kaplan, 1989).

While the rationale for the underlying cause of our innate and beneficial attraction to the natural world remains unclear, research has demonstrated that interactions with plants can have physiological, psychological, and cognitive benefits to humans. These benefits have been recorded with many different populations: healthy individuals (Hawkins et al., 2011; Park et al., 2014), the elderly (Kojima and Kunimi, 2013; Tseng et al., 2007), young children (Beela and Reghunath, 2010), patients with dementia (Detweiler et al., 2009; Lee and Kim, 2008), stroke (Kim et al., 2003), depression (Gonzalez et al., 2009, 2010, 2011), those recovering from temporary injury and illness (Davis, 2011; Park and Mattson, 2009), individuals with intellectual disabilities (Lee, 2010), and many others. This suggests that the therapeutic benefits of horticulture may be available to almost any population.

Physiological Benefits

Physiological measurements are used to analyze how well a body is functioning. Therefore, measures of physiological factors such as heart rate, cortisol levels, sleeping patterns, and even pain levels can be useful tools in determining the effect of active or passive engagement with plants on a person's physical well-being. One of the most widely cited studies to date that clearly demonstrates the therapeutic nature of plants and/or natural landscapes is a study conducted by Ulrich in 1984. This study compared two groups recovering from gall bladder surgery in the same hospital, one with a view from the window of a stand of deciduous trees and the other with a view from the window of only a brick wall. This highly controlled study with little variation between the two groups discovered that those who had a view of nature took fewer doses of moderate to strong pain medication, had fewer negative notes on their nurse observation records, and were discharged faster than the group with the view of the brick wall. Other studies further support this finding such as the study by Park and Mattson (2009) which showed that patients who were recovering from a thyroidectomy and had plants in their rooms reported lower pain, anxiety, and fatigue levels, as well as less of a need for analgesics, than patients with no plants in their rooms. Those with plants also had a shorter hospitalization, a higher satisfaction rate, and more positive feelings about their hospital rooms. Similar results were also found in a study of patients recovering from appendectomy surgery (Park and Mattson, 2008). Surprisingly, having physical plants is not always necessary to reap the therapeutic benefits of their presence: when a view of real nature is not possible, a simulated view can be a potential alternative. Vincent et al. (2010) demonstrated that showing participants nature images while inducing pain in a simulated hospital room decreased sensory pain responses compared to neutral or hazardous images.

Passive interaction with plants in an outdoor setting is also practiced for its beneficial effects, such as in the Japanese art of Shrin-yoku or “forest bathing.” Salivary cortisol and pulse rate decreased in a statistically significant manner for a group of Japanese men who walked through a forest setting when compared to a group of men walking through an urban setting. Variability in heart rate of the forest walking group was also significantly lower than those in the urban setting (Lee et al., 2011).

Hands-on activities, such as gardening, are one of the most common ways people enjoy the benefits of plant interactions. A study by Lee and Kim (2008) saw positive effects of indoor gardening on a group of dementia patients. Twenty-three patients participated in an indoor gardening program during which each individual cared for one plant over four weeks and learned basic skills such as planting, watering, harvesting and cleaning. The participants experienced significant improvements in wake-up after sleep onset, nap, nocturnal sleep time, and nocturnal sleep efficiency. Another study found that dementia patients who spent time in a wander garden had a lower risk of falls and a significant reduction in scheduled antipsychotic medication usage (Detweiler et al., 2009).

Cortisol, a biological marker (proxy) of stress levels, has been shown to decrease when research subjects are in a garden environment. Rodiek (2002) showed that the mean cortisol level for those conducting an activity in an outdoor garden was significantly lower (by about two and a half times) than a group performing an identical activity indoors. Cortisol levels were also significantly reduced in a group of individuals with intellectual disabilities when they participated in various horticultural activities such as planting flowers, creating a topiary, and pressing flowers over a one week period (Lee, 2010).

The evidence is clear that positive physiological changes can be experienced when individuals and groups interact with plants and nature. Even more so, research shows that there are cognitive benefits to human-plant interaction.

Cognitive Benefits

Because of the influence of Kaplan’s Attention Restoration Theory, many studies surrounding nature and cognitive abilities are centered on attention, mental fatigue, and memory tasks. For instance, Berman et al. (2008) had two groups walk down either a busy street or a path lined with trees in an arboretum. The group that had walked through the row of trees had higher cognitive performance during a backwards digit span task after the walk. Another study suggests that children with Attention Deficient Disorder (ADD) could potentially benefit from the attention restoring aspects of nature. When asked to rate the severity of their child’s ADD symptoms after playing in an outdoor natural setting as opposed to another setting (such as indoors), parents reported a lower severity in ADD symptoms and increased attentional functioning ratings (Taylor et al., 2001). Those struggling with depression also typically struggle with attentional capacity. Gonzalez et al. (2010) measured a statistically significant increase in the attention capacity (using the Attentional Function Index) of a group of 28 individuals with clinical depression after they participated in a therapeutic horticulture intervention for twelve weeks. Attention capacity measured by the Attentional Function Index included factors such as planning, following a train of thought, and concentrating on details.

Dementia and general mental decline are other cognitive health conditions that have been addressed through participation in therapeutic horticulture activities. Because the elderly population is particularly vulnerable to cognitive decline, the cognitive benefits from interactions with plants are especially evident for this group. After participating in a variety of horticultural activities for three months, a healthy elderly population showed improvement in cognitive skills as tested by an arithmetic test (Kojima and Kumimi, 2013). Dementia patients, who by nature of their disease suffer severely from memory loss and cognitive decline, have exhibited positive improvements in orientation, memory, calculation, attention, and semantic word fluency (as measured by the Hasegawa Dementia Scale) after a simple gardening program. Twenty three dementia patients demonstrated these results after participating in an indoor gardening program for four weeks that included planting fast growing edible plants, caring personally for their plants, and harvesting at the end of the treatment period. Every participant had a significant increase in their Hasegawa Dementia Scale score, a measure of improvement, when pre and postintervention scores were compared (Lee and Kim, 2008).

When evaluating the effects of plants on cognition, the task being used to determine cognitive effects is important. Shibata and Suzuki have performed multiple studies on healthy students (2001, 2002, 2004), and have noticed different effects of indoor ornamental plants on different types of cognitive tasks. Their results have shown a positive influence on creative tasks (i.e. asking the participant to generate as many alternative words for an item as they can), but not on routine tasks such as sorting or association. One study suggests that the density of the plant foliage should also be considered as too many plants can decrease productivity. A moderate amount of plants (10 plants/7% of total cubic office space) had a greater influence on increasing productivity than a setting with a high density of plants (22 plants/18% of total cubic office space) (Larsen et al., 1998). Creativity has been shown to improve after immersion in a wilderness setting. Atchley and colleagues (2012) used the Remote Associates Test to determine the creative thinking and problem-solving skills of 56 adults before and after a 4-day backpacking wilderness immersion program. The results showed participants had higher scores post hike when compared to their initial scores before the outdoor hike.

Cognition is a complex concept that has many components to consider when evaluating the outcome of a test and experiment. The same is true for psychological health. The following section will further demonstrate the wide range of studies that have been performed in many different areas of psychological health in the context of people-plant interactions.

Psychological Benefits

The most frequently reported benefits from human-plant interactions are psychological in nature. Though many anecdotal reports exist regarding the stress-reducing, mood-changing, and depression-alleviating benefits of working with plants, it is important for researchers to empirically quantify these psychological effects. Two of the most commonly utilized measures of the psychological state are observational reports and self-report instruments. Researchers have employed many of these types of psychosocial instruments to measure the elements that contribute to participant well-being, including anxiety, depression, self-confidence, mood, and self-perceived health.

Mood is one area of psychological well-being that has been shown to be affected by both active and passive interactions with plants and nature. One of the most convincing studies to date demonstrated that mood can be positively affected with just one session of horticultural therapy. A group of cardiopulmonary inpatients in need of rehabilitation were split into two groups experiencing either a patient education class or a horticultural therapy session. The horticultural therapy session included a guided tour of a greenhouse and gardens followed by a planting activity where participants divided and potted a house plant. The group that received the one session of horticultural therapy experienced a significant reduction in total mood disturbance (as measured by the Profile of Mood States self-report psychometric assessment instrument) and heart rate, while the control group showed no significant changes in mood state or heart rate (Wichrowski et al., 2005). Additional studies have reported similar positive effects on mood when participants were exposed to outdoor nature environments or horticulture programs (Detweiler et al., 2008; Kotozaki, 2014; Lee et al., 2011; Van den Berg and Custers, 2011).

Measurements of mood are closely associated with those of stress and anxiety. Stress and anxiety are known to lead to other detrimental side effects on the body, and because of this, some countries will even treat a stress-related disorder as a clinical disorder and prescribe medical treatment. Several studies suggest that a plant-interaction intervention is a viable means for treating those with elevated stress and stress-disorders (Adevi and Martensson, 2013; Eriksson et al., 2011; Hawkins et al., 2011; Sahlin et al., 2015). Van den Berg and Custers (2011) reported that acute stress can be significantly reduced through a gardening activity. Their study showed that acutely-stressed gardening participants had a greater reduction in stress than control participants that were asked to read popular magazines for the same duration of time. Those who participated in gardening after a stress-inducing Stroop task (Stroop, 1935) exhibited significantly decreased stress, as measured by cortisol levels and fully recovered positive mood (determined using the Positive and Negative Affect Schedule also known as PANAS). In contrast, the reading group had a further decline in positive mood after reading, as well as a less significant change in cortisol levels. This finding suggests that plant-centered activities could provide even greater stress-alleviating benefits than some other leisure activities such as reading.

Anxiety measures, often coupled with stress measures, have also been used in an effort to quantify the effects of plants and an outdoor environment on a person's psychological state. Similar results have been reported for anxiety reduction as for stress reduction (Gonzalez et al., 2011; Park and Mattson, 2009; Sahlin et al., 2015; Verra et al., 2012; Weng and Chiang, 2014;). As stress levels and anxiety rise in an individual, the incidence of depression can also be elevated. Gonzalez and her colleagues have done several studies to determine the effects of a therapeutic horticulture program on individuals with clinical depression. In a group of studies occurring from 2009-2011, Gonzalez repeatedly found a significant reduction in depression levels throughout a therapeutic horticulture intervention and even a persistent reduction in depression at a three-month follow up. Her results are confirmed by the results of other researchers also studying depression and with similar interventions (Austin et al., 2006; Edwards et al., 2013; Hwang et al., 2007; McCaffrey et al., 2010).

While reducing the negative aspects of psychological health is an important aspect to improving well-being, increasing positive aspects, such as self-esteem, satisfaction, mastery, and happiness, are also important to the health of an individual. Improved self-perceived quality of life is a common goal of any intervention attempting to affect the psychological well-being of a population. Collins and O'Callaghan (2008) used an indoor horticulture program to explore changes in participants' quality of life. Mastery, self-rated health, and happiness were all significantly increased from pre- to postintervention assessments. Other studies have shown self-reported increases in job satisfaction (Dravigne et al., 2008), self-esteem (Beela and Regunath, 2010; Lee et al., 2007), purpose in life (Lee et al., 2007), and socialization (Wang and MacMillan, 2013).

Types of Interactions

The many studies discussed above reveal just how diverse the outcomes of interactions with plant life can be. It should be noted that these interactions with plants and structured interventions have taken many forms. Reported benefits have been published for interventions that utilize the therapeutic properties of plants both actively and passively. Active interactions typically include indoor gardening (Collins and O'Callaghan, 2008; Lee and Kim, 2008), outdoor leisure gardening (Hawkins et al., 2011), and formal horticultural interventions such as therapeutic horticulture (Gonzalez et al., 2009; Gonzalez et al., 2011) and horticultural therapy (Beela and Regunath, 2010). Passive interactions include seeing images or views of nature or plants (Dravigne, 2008; Ulrich, 1984; Vincent et al., 2010), actually being immersed in nature (Atchley et al., 2012; Lee, 2011), enjoying a cultivated outdoor garden (Detweiler et al., 2009; Rodiek, 2002), and the presence of indoor plants in a home, work, or recovery setting (Bringslimark et al., 2009; Park and Mattson, 2008, 2009). While all of these studies are diverse in their structure, type of person-plant interaction(s), length of engagement, population being studied, and sampling and assessment methods, the common thread that connects these interventions is the utilization of the inherently therapeutic nature of plants and biotic life. When taken together, the totality of this body of research reveals the general therapeutic benefits of people-plant interactions, and validates the notion that there is a human need for interactions with plants for overall well-being. The inherent diversity in the sampling of the studies summarized above renders meta-analysis comparisons between studies virtually impossible. This fact suggests that concerted efforts should be considered for a set of standardized studies that begin to characterize the relative efficacy of uniformly designed therapeutic interventions across different populations.

Horticultural Therapy

One field that has sought to capitalize on the therapeutic nature of active interaction with plants through a formalized therapeutic intervention is the field of horticultural therapy. Horticultural therapy started developing as a field in the 1950s when both Rhea McCandliss and Alice Burlingame began pioneering the use of horticulture as therapy. McCandliss became one of the first professional horticultural therapists while working with Dr. Karl Menniger at the Menninger Foundation in Topeka, Kansas. Around this same time, Alice Burlingame used her expertise in the fields of occupational therapy, psychiatry, landscape architecture, and greenhouse production to establish the first horticultural therapy program with National Garden and Farm Bureau volunteers in Michigan (Relf, 2006). An earlier and less formal indication of the use of gardening for therapeutic reasons was suggested by psychiatrist Benjamin Rush whose records of patients in mental asylums suggested that working in a garden may be therapeutic. While widely referenced in the horticultural therapy literature, mention of patients working in a garden is very brief in Rush's book, being only a fraction of a sentence, but does give an early and clear indication of the use of a garden setting for rehabilitation, even if the focus at the time was on the physical activity provided by the task of gardening (Rush, 1812). When soldiers returned from World War I, the use of horticulture to aid in their recovery and transition home became a common practice in rehabilitation hospitals as countless veterans participated in gardening programs put on by garden club volunteers (Shoemaker and Diehl, 2012).

Currently, horticultural therapy is practiced around the globe and is organized in the United States by the American Horticultural Therapy Association (AHTA). The AHTA has created a formal definition for horticultural therapy which states that horticultural therapy (HT) is "the engagement of a client in horticultural activities facilitated by a trained therapist to achieve specific and documented treatment goals" (Diehl, 2007, p. 1). While formal horticultural therapy programs are scarce in the United States, a more common, though less formalized, intervention type exists in the form of therapeutic horticulture (TH). In this case, TH: "uses plants and plant-related activities through which participants strive to improve their well-being through active or passive involvement" (Diehl, 2007, p.1). Both of these intervention modalities seek to establish goals for a client in the program and use plant-related activities to aid the client in achieving those goals. HT and TH programs can be found in rehabilitation centers (hospitals, occupational and physical therapy clinics, and prisons), residential facilities (assisted-living communities and nursing homes), and community settings (schools and community gardens). The inherent therapeutic nature of plants is at the core of these interventions, and is typically harnessed to help clients achieve results that may not be attainable through the use of a traditional intervention or therapy alone.

While existing research suggests impressive therapeutic benefits of interaction with plants, many areas still need to be developed and substantiated using empirical evidence from peer-reviewed clinical research. Several major questions exist which require further research, including:

- What are the best activities to include in a HT intervention?
- Which populations can benefit most from these interventions?
- What length of time is ideal for adequate or for optimum results?
- How much are the inherent non-horticultural components of a HT program (such as social stimulation and physical exercise) contributing to the therapeutic outcome and success?

Many of the horticultural therapy studies performed to date have suffered from limited resources, small populations, and uncontrolled variables. Unfortunately, this has limited the power and credibility of these studies in various ways. Many reports give little information on the specifics of the horticulture intervention used in the research and, thus, hinder a complete assessment and repeatability of the study. No standardization exists for which assessments and instruments should be used to evaluate outcomes (including quality of life, depression, stress, health, etc.). This precludes the ability to compare results across studies. Additionally, there remains a glaringly large gap in the field of data: precious little of the research to date uses clear, objective measures to gather quantitative results to demonstrate the positive effects of people-plant interactions. Many studies which indicate positive results have relied heavily on subjective measures that cannot clearly demonstrate a measurable effect with the scientific rigor needed to establish the credibility of the field of horticultural therapy (Relf, 2012). The field of horticultural therapy is also one that is inherently interdisciplinary as it intertwines the areas of horticulture, psychology, neuroscience, and medicine as well as many others. High quality research studies require expertise from multiple disciplines. Therefore, the unique combination of disciplines needed to accomplish research studies in horticultural therapy can pose challenges when designing and executing research that requires a multidisciplinary team with the necessary skills and expertise to accomplish high quality research.

Psychometric Assessments

Because horticultural therapy seeks to help people reach desired therapeutic goals and improve quality of life, it seems to fall naturally under the social, behavioral, and medical science fields. A common tool used to evaluate the impact of an intervention in these fields is the psychometric assessment. Self-reported questionnaires, one type of psychometric assessment, can measure various psychological and behavioral aspects of an individual to quantify changes that have occurred as a result of an intervention or other remedy. These tools are particularly useful because they can aid in quantifying aspects of health that would otherwise be intangible (Fernandez-Ballesteros, 2004). However, use of self-reported questionnaires should be approached with caution because they can be distorted by multiple factors as described by Baer et al. (2003). These include negative impression management, positive impression management, random responding, and acquiescence. These distortions do not invalidate results gained from these assessment tools, but it does mean that investigators employing this methodology need to be aware of bias and account for them when administering questionnaires and analyzing data (Fernandez-Ballesteros, 2004).

Research in the field of people-plant interactions has made use of a wide variety of self-report questionnaires. While no standard assessment instruments have been prescribed or regularly utilized in the field of horticultural therapy, there are a few assessment instruments that have been used commonly in social science and medical outcomes research that are, or would be appropriate. Some common instruments for assessing self-reported physical health, mental health, and mood for a general population include the 36-item Short Form (SF-36) health survey, Perceived Stress Scale (PSS), Beck Depression Inventory (BDI), Profile of Mood States (POMS), and the Spielberger State-Trait Anxiety Inventory (STAI).

The SF-36, cited over 24,000 times (Ware and Sherbourne, 1992), is a well-known and widely used tool that reports both the general physical and mental health of the sampled individuals and is one of the most common tools used in research to report the health-related quality of life in a population (Coons et al., 2000). Research investigating the impact of gardening on the health of the elderly has used this tool (Hawkins et al., 2011; Wang et al., 2013) as well as similar research reporting the effects of people-plant interactions on general health (Verra et al., 2012).

As noted in the previous sections of this literature review, areas of health that are apparently affected by plant-related activities can be stress, depression and anxiety. The Perceived Stress Scale has been shown to be a valid and reliable measure of self-appraised stress in an individual's daily experiences (Cohen et al., 1983). Both nature and horticulture related research has demonstrated effective use of this instrument to determine self-perceived stress (Gonzalez et al., 2009, 2010, 2011; Hawkins et al., 2011; Willert et al., 2014).

Closely related to stress is the occurrence of anxiety. The Spielberger State-Trait Anxiety Inventory was created in 1983 and has been widely used as a self-report instrument to assess levels of anxiety (Spielberger et al., 1983). Because it is an important component of health and wellness, anxiety reduction has been a factor analyzed in horticultural therapy and related research (Gonzalez et al., 2011; Kelley and Coursey, 1997; Li et al., 2012; Park and Mattson, 2008, 2009; Rodiek, 2002). Because of STAI's proven reliability over many years and across many types of social science and medical research, this instrument is an especially appropriate tool for measuring and evaluating the outcomes of interactions with plants on anxiety and mental well-being.

The Beck Depression Inventory (Beck et al., 1996) is an instrument that is not typically used for a clinical diagnosis of depression, but has demonstrated the ability to predict the diagnosis of a major depressive disorder (Arnau et al., 2001), and is a useful tool to determine the depressive symptomatology of individuals in a population. The BDI has been used to determine if a therapeutic horticulture intervention is able to alleviate depressive symptomatology and has revealed favorable results (Gonzalez et al., 2009, 2010, 2011). Nature-assisted therapy has also made use of this tool in quantifying effects of therapeutic outdoor adventures on depression symptoms (Kelley and Coursey, 1997).

Psychological distress, a component of mental health, can be measured in part by the Profile of Mood States (POMS) (McNair et al., 1981; Shacham, 1983). The POMS is a Likert-scale self-report instrument that evaluates the total mood disturbance of an individual and can be used to evaluate changes in mood over time (Curran et al., 1995). Mood measures offer a unique benefit compared to the instruments mentioned above because they can report not only on changes in negative affect, but also on positive affect of an individual's mental health. Vigor and friendliness are two subscales on the POMS that are used to measure positive mood. Therefore, the positive impacts of interactions with plants are evaluated as well as the commonly measured alleviation of a poor mental health condition. Current research in the therapeutic horticulture field has made use of this measure for determining effects on mood (Jo et al., 2013; Lee et al., 2011; Li et al., 2012; Park et al., 2010; Vincent et al., 2010; Wichrowski et al., 2005;)

While each of these measures mentioned above do offer informative results when used independently, the use of all of these measures together can further reinforce the results of a given intervention's effectiveness to reflect actual therapeutic benefits. The aspects that these measures report on often overlap and the repetition of measured findings throughout the various instruments can strengthen results. Therefore, many of these instruments can be used to validate each other and create a multi-method approach to measure the impact of an intervention (Nyenhuis et al., 1999).

Functional Magnetic Resonance Imaging

Coupling multiple self-report measures with the use of biochemical, physiological, neurological, and health/well-being markers is a robust approach to validating the results of a people-plant intervention. The use of functional magnetic resonance imaging (fMRI) in the field of behavioral, neuro-, and social sciences has rapidly increased since its development in the early 1990s (Logothetis, 2008). Functional Magnetic Resonance Imaging is a technique that has aided the research field in understanding neuronal functioning in relation to a given task or intervention (Howseman and Bowtell, 1999). Basic Magnetic Resonance Imaging (MRI) incorporates the use of a strong magnetic field and high frequency radio waves to create structural images of the object being scanned. When the head of a subject is placed inside a MRI scanner, the hydrogen nuclei in the subject's body (located in the water and blood inside the body) will align with the magnetic field of the MRI scanner. At the start of a structural brain scan, a radio frequency (RF) pulse is used to excite the hydrogen nuclei and their spin axis orientation is displaced. After the displacement, the spin undergoes a relaxation back to the lower energy state, a process called precession that produces a measurable amount of radio frequency (Larmor frequency) signal at the resonant frequency associated with the spin flip. The radio signals can be measured by receivers in the scanner and that information is processed into an image. Hydrogen nuclei in different tissues and regions return to their normal spins at different rates, allowing the scanner to distinguish this information among tissues. The time for the population of nuclei with higher energy spin to return towards an equilibrium state is designated T1. Thus, this process is termed T1 or Spin-Lattice and represents a longitudinal relaxation, or relaxation in the z-direction. The lattice is the environment surrounding the nucleus, including other molecules in the sample containing the nucleus of interest. T2 or “Spin-Spin” is a transverse relaxation, or relaxation in the x-y plane. T2 represents the distribution energy throughout the system while T1 reflects dissipation of energy to the surrounding environment. Pulses are repeated and the distribution of the magnetic resonance signal throughout the brain is recorded by the scanner to then create a map of the brain structure. This provides information for the size, shape and location of various tissues in the brain as well as any anomalies present in the anatomical structure of an individual’s brain (Sands and Levitin, 2004).

Functional brain imaging can also be conducted in a MRI scanner to create the images that display changes in brain activation. The Blood-Oxygen Level Dependent (BOLD) method is one of the most prevalent ways that research has developed to determine these changes in activation. While inside of a MRI scanner, a subject will be asked to perform a task such as viewing an image or clicking buttons to answer questions. During the execution of this task, certain areas of the brain are becoming active while other areas will be less active. Active areas will require more oxygen because active neurons and cortical areas are requiring more energy in the form of ATP. The red blood cells that transport oxygen (the iron atoms in hemoglobin) have magnetic properties, and when hemoglobin is not transporting oxygen (deoxyhemoglobin), it is paramagnetic. The weak magnetic properties of the deoxyhemglobin act as “nature’s own intravascular paramagnetic contrast agent” (Kim and Ugurbil, 1997; p. 229). Deoxyhemoglobin will be found in areas of the body utilizing oxygen and can be used to indicate activation areas of the brain (Kim and Ugurbil, 1997).

Blood flow in the brain is not uniformly equal, but is highly locally controlled in response to oxygen and carbon dioxide levels. When neurons become locally active, the demand for oxygen in the cortex goes up and the level of oxygen in the cells and their surroundings decreases. The level of deoxyhemoglobin rises while that of oxyhemoglobin falls. Carbon dioxide levels also rise as glucose is more rapidly metabolized to meet the increased energy demands of active neurons. Physiologically, the brain will respond by redirecting blood flow to the active area of the brain bringing more glucose, oxygen, and oxyhemoglobin. A brief lag of 2-6 seconds occurs between the neuronal activation and the blood flow increases delivering surplus oxyhemoglobin, and draining away deoxyhemoglobin. The large shift of deoxy- to oxyhemoglobin in the localized activity area is what is imaged in fMRI BOLD. The large shift disturbs the magnetic field around deoxyhemoglobin. This disturbance creates a signal that can be detected by the scanner and can be used to track the changes in oxygenated blood flow and activation in corresponding parts of the brain. The BOLD signal is then acquired and is used to create functional images in the brain. This BOLD signal is acquired throughout a scanning session where a subject may be asked to perform different tasks or view different images. The changes in the BOLD signal can be used to determine the effects of the task on the activation of the various areas of the brain (Buxton, 2013).

Functional MRI Studies

Functional MRI has been used in recent years to determine what areas of the brain are activated when a research subject experiences different stimuli that would provoke various reactions or feelings. Of particular interest for this study is the research involving the areas of stress, anxiety, depression, and mood because these are commonly studied factors in the field of people-plant interactions. Insight into the neural functioning of a person as they experience these feelings and mental states could be useful in also targeting the effects of plant-related interventions on neuronal activity.

Emotional responses of individuals can be obtained by allowing research participants to view positive and negative stimuli and track their responses through fMRI. Mak et al. (2009) conducted this type of study on a group of twelve females and demonstrated that there are a few shared areas of activation when viewing both positive and negative pictures (left superior and lateral frontal regions) and other regions that are only activated by either positive stimuli (prefrontal regions and the left insula) or negative stimuli (left orbitofrontal gyrus, the left superior frontal gyrus, and the anterior cingulate gyrus). Males and females typically differ in their processing of stimuli and commonly show differences in activation areas when viewing the same stimuli (Garn et al., 2009; Hofer et al., 2006; Klein et al., 2003). Therefore when appropriate, fMRI studies should be gender specific to control for this variable. The idea that the right hemisphere is essential for the processing of emotion has been a prevalent theory. However, a meta-analysis of 106 PET and fMRI studies have shown that this theory is not supported by the literature and both sides of the brain are equally activated in emotion related tasks (Murphy et al., 2003). Both of the studies mentioned above demonstrate the crucial need for fMRI to inform and shape our theories about which areas of the brain are involved for certain tasks and how this is affected by gender/race/disease and other variables. By careful repeated research, we can start to identify patterns and create well-informed theories of the function that various areas of the brain play during different tasks, mental states, and neurological pathologies. Not only has neurological research been able to shed light on emotion and brain activation, but more and more studies have demonstrated the ability to see correlations between disorders and activation levels in the brain. Disorders such as depression and anxiety have been studied and revealed insightful results. Women with major depressive disorders have smaller hippocampal volumes than non-depressed women. This loss in volume was also found to correlate with the length of time that a subject experienced depression throughout their life (Sheline et al., 1999). A meta-analysis of anxiety disorders revealed that patients with a social anxiety disorder and specific phobia have hyperactivation in the amygdala and insula, areas often correlated with negative emotion responses. Patients with PTSD did not show this same activation, but instead "showed hypoactivation in the dorsal and rostral anterior cingulate cortices and the ventromedial prefrontal cortex—structures linked to the experience and regulation of emotion" (Etkin and Wager, 2007,p. 1476). Chronic stress has also demonstrated a decreased response in the medial prefontal cortex when given information about monetary gains and losses. Treadway and colleagues (2013) suggest that these results demonstrate that chronic stress can have harmful effects on areas related to cognition. Understanding where chronic stress can modify or damage brain activation can give insight into vulnerability when individuals experience this and related conditions. Such information can give valuable insight into the diagnosis of diseases and disorders and could be useful in quantifying the effect of an intervention on both brain structure and activation.

Functional MRI and Interactions with Plants

While there is relatively little literature that directly analyzes the effect of plant interactions on the brain, there are a few studies that could give insight into areas that could be influenced by interactions with plants. There are multiple ways to experience interactions with plants via the senses. Sight, smell, touch, and even taste are typically involved when interacting with plants and natural stimuli. Functional MRI studies have reported an effect of viewing natural stimuli compared to other neutral and positive stimuli. One study found that images of the sky produced activation in the same areas of the brain as other positive stimuli while both types of stimuli differed from negative stimuli (Pati et al., 2014). Typical components of natural environments are its perceived beauty by the viewer, and the fact that natural environments are often outdoors. Two separate studies have investigated these aspects and found that there is a difference in activation areas when viewing beautiful stimuli (including landscapes) versus neutral or ugly stimuli (Kawabata and Zeki, 2004), and there is also a difference when looking at outdoor versus indoor images (Henderson et al., 2007). Both results could be considered components when attempting to discern the effects of interactions of seeing plants on brain activation. Smell is an important part of experiencing plants as their volatile organic compound emissions can produce positive and negative emotions. Gradenhorst et al. (2007) conducted an fMRI study that included the smelling of a pleasant odor of jasmine, an unpleasant odor of indole, and a mixed smell of both of these scents while subjects were in the MRI scanner. The results revealed the processing of pleasant versus unpleasant odors occurred in two different areas of the brain as well as the ability to process both smells simultaneously in a mixed odor. Finally, the ingesting of plants can also have effects on the brain. One study found an increase in activity in the dorsolateral prefrontal cortex of participants who ingested a green tea extract when compared to a control group who did not. This area of the brain is important in mediating working memory and perhaps suggests a memory enhancing effect of green tea consumption (Borgwardt et al., 2012).

As evidenced by the limits of the studies described above, research has yet to explore the foundation of what impact direct interactions with plants may have on brain activation. While we can quantify some of the areas where activation occurs when smelling flowers, eating plant-based food, or looking at nature in general, this information is not enough to provide any solid basis for the beneficial influence of human interactions with plants. One study that was previously mentioned in the introductory chapter has attempted to analyze brain activation following a horticultural therapy intervention (Mizuno-Matsumoto et al., 2008). Five subjects who suffered from cerebrovascular disease were given a one month horticultural therapy intervention that varied with each individual in an attempt to aid in their rehabilitation. During pre- and postintervention fMRIs, subjects were shown images of pleasant and unpleasant facial expressions and healthy and dying forest landscapes. These images were used to determine differences in brain activation before and after the gardening intervention. The authors concluded that the visual area, inferior temporal gyrus, the motor area, sensory area, the prefrontal area and the inferior and middle temporal gyrus and other areas showed increases in activation resulting from the horticultural therapy program. These activation areas were unique when compared to literature describing areas that are activated as a result of a traditional rehabilitation program for individuals recovering from cerebrovascular disease. However, the very limited population size, the use of a historical control group, variation in the severity and locations of the participants' injuries, and the non-uniform intervention provided to the participants cast serious doubt on the significance of the findings. The brain activation areas described in the study might be used for future reference in people-plant interaction and fMRI studies, but should not be used for strict reference as the population had inherent brain trauma and similar results may not be seen in other populations (Mizuno-Matsumoto et al., 2008).

Two other studies are also worth describing for their use of brain scans in quantifying the effects of putative interactions with plants. Kotozaki and her colleagues (2015) evaluated the changes in brain structure for participants with PTSD following a horticultural therapy intervention. Fifty-four women (ages 23-55) who had survived the Great East Japan earthquake in 2011, and were diagnosed with mild PTSD were selected for the study. After being randomly assigned to either a stress education control group or a horticultural therapy treatment group, participants engaged in their assigned intervention once a week for eight weeks. The HT group attended one hour sessions where they learned horticulture skills such as planting seeds, caring for plants, and harvesting. The participants in this group were also required to care for their plants every day for 15 minutes and record this daily interaction. The stress education class included eight sessions that lasted for one hour each week. Video lectures focused on areas such as stress mechanisms in the body, psychology of stress, and management techniques. Data was collected at pre- and post- intervention time points from both groups in the form of psychological measures, salivary cortisol levels, and brain scans. The psychological measures included general health and well-being inventories, post-traumatic symptomology measures, positive and negative affect measure, profile of mood states, and a post-traumatic growth inventory. Cortisol levels were determined using a saliva sample to test for salivary cortisol and salivary alpha amylase. High resolution T1-weighted structural images were collected to analyze changes in anatomical brain structure. The results showed significant increases for the HT group in positive affect scores and post-traumatic growth scores, but not in the stress education group. Further, the results also indicated statistically significant decreases in post-traumatic symptoms for the HT group as determined by the psychological measures. Similar results were found with the salivary cortisol measurements. The HT group had significantly reduced cortisol levels when compared to the stress education group. Brain scans indicated that the HT group had a significant increase in the regional grey matter volume when compared to the stress education group.

Another recent study used a different type of brain scan to quantify the effects of interaction with nature. Bratman and his colleagues (2015) gathered a sample of 38 healthy participants and randomly assigned them to either an urban walk group or a nature walk group. Participants walked about 5 kilometers along either a busy city road or a path through a natural area. Participants were evaluated on their rumination levels before and after the walk using the Reflection Rumination Questionnaire (Trapnell and Campbell, 1999). Participants also underwent an MRI before and after the walk to acquire T1-weighted structural images, perfusion weighted data, and proton density maps to determine changes in blood flow in various areas of the brain. The neuroimaging method used was arterial spin labeling (ASL) in which regional cerebral blood flow (rCBF) was measured passing through regions of interest. Rumination was chosen as a measurement because of its association in the development of depression for many diagnosed individuals. Also, rumination has been shown to result in changes in brain activity in the subgenual prefrontal cortex, therefore determining the brain area to be focused on for this MRI portion of this study. The findings showed statistically significant decreases in self-reported rumination in the nature walk group, but not for the urban walk group following the completion of the walk. Also, blood flow decreased in the subgenual prefrontal cortex as measured by the blood perfusion scan for the nature walk group but not for the urban walk group, findings that were statistically significant. This study suggests that walks through natural areas could contribute to positive mental health outcomes. This study also opens doors to new questions that would prompt the study of the influence of plants and nature on other areas of well-being.

After a thorough review of the literature, it appears that no research has been published that examined the effect of active plant interactions on brain activation when measured by functional MRI. There is a critical need in the current field of research for studies that can provide quantitative results that can provide a baseline for further investigation. Functional MRI offers an opportunity to launch the research field of people-plant interactions into rapid movement and provide substantiation for the use of horticulture as therapy. If a plant-based intervention can be determined to be beneficial using a study that produces clear and objective results on the neural activity of a population, additional studies could be performed to determine the most effective components of the intervention. Variables such as the length of time of a single interaction, how often the interaction should be repeated, the environment where the interaction should occur, the types of plants and specific horticultural activities that should be used and even the populations most affected cannot be explored unless there is adequate groundwork of data on which to build. Laying the foundation in a research field cannot be taken lightly. It is of utmost importance to the establishment and growth of a research field related to therapies. This study seeks to begin laying that foundation by providing research to objectively demonstrate the effect of interactions of plants on the self-reported quality of life and the brain activation patterns of a healthy population of women. Connecting therapeutic benefits with altered patterns of brain activation is a first step towards understanding the mechanism(s) of how interactions with plants leads to improved health and/or quality of life.

CHAPTER 3
METHODOLOGY

Overview

The experimental design for this thesis research sought to test the effects of engaging in group-based gardening on brain network activation and the mental health profile in a healthy, wellness group of participants. A treatment group participated in a series of gardening sessions over a six week period and data was collected before, during, and after the intervention. A control group received no interventional treatment (they simply continued with their daily routine), but had similar data collected over the same period of time. Patterns of brain activation for the control and treatment groups were acquired using functional Magnetic Resonance Imaging pre- and postintervention. Participant physical and mental health status was documented using five specific standard self-report questionnaires. A set of standard statistical tests was used to analyze the results from the datasets to determine the impacts of the gardening intervention on the participants. A detailed description of each aspect of the study follows.

Participants

Twenty-three healthy women were recruited from the local community to participate in the treatment and control groups. Recruitment occurred mainly through printed flyers that were placed on community bulletin boards in local businesses, schools, and around the University of Florida campus. Other recruitment methods used included print ads in newspapers, online social media, radio ads, word of mouth, and Health Street (a local resource designed to connect researchers to potential research subjects). The experimental design, all procedures, and the data collected, secured, and analyzed in the study were approved by the Institutional Review Board (IRB) at the University of Florida (UF IRB201400425) prior to beginning the experimental stage of the research. The study and its protocols were also registered at ClinicalTrails.gov (ID number: NCT02225847) in August of 2014. Following the IRB-approved protocols, participants were consented, screened, selected, and enrolled in the study based on their meeting all eligibility requirements for participation. Each participant who completed the study received a total of $100 in Visa gift cards as compensation. Eligibility requirements were as follows: 1) adult woman between the ages of 26-49, 2) right-handed, 3) not pregnant, 4) not in any stage of menopause or post-menopausal 5) not claustrophobic, 6) eligible to receive an MRI, 7) not allergic to plants or plant parts, 8) nonsmoker, 9) in good health with no disabilities or diseases that affect quality of daily life, 10) minimal gardening experience, and 11) no prior problems with abuse of drugs and/or alcohol. Written consent was obtained from each participant after the procedures of the study were fully explained in accordance with IRB requirements. MRI eligibility was determined using the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) Facility screening form for patients being scanned in the Philips 3T scanner. The form was used to screen for the presence of metal in the body as well as health and medical procedure history to ensure safety of the participant while in the MRI scanner.

Women were the target population for this study because of theorized gender differences that exist when interacting with plants. A number of studies support this idea (Behe et al., 1999; Relf et al., 1992; Todorova et al., 2004; Ulrich, 1981), and have demonstrated that women have a more favorable attitude toward plants compared to men. The use of fMRI to quantify the effects of the study intervention also contributed to the selection of a single gender. Gender has been shown to influence brain activation patterns when men and women are asked to view the same stimuli (Frank et al., 2010; Klein et al., 2003; Smeets et al., 2006; Wrase et al., 2003). This experimental variable was eliminated by studying a population of women only.

Recruitment and Group Assignment

Twelve women were recruited for the treatment group and eleven for the control group. The women recruited to the treatment group agreed to undergo a six week basic gardening program. During this six week period, the control group did not participant in any form of intervention, but were asked to continue their regular daily activities.

The placement of participants into the control and treatment group was done in a non-random fashion. Participants were allowed to self-select a group depending on their willingness and availability to commit to the requirements of the study. After hearing study details, most interested volunteers indicated a desire to be a part of the gardening treatment group. These women understood the time commitment, and decided to be screened and assessed for enrollment in the treatment group. These volunteers were consented and enrolled in the study. However, some women, after hearing the time commitment for the treatment group, decided this was not feasible for their schedule or had some other conflict. These individuals were then offered the option to participate in the control group for the study. The women who felt they could commit to participation as a control subject were screened and assessed for possible assignment into this group. Those volunteers meeting all eligibility requirements were consented and enrolled in the study.

After the gardening treatment group reached an enrollment goal of 12 women, all subsequent candidates were offered the opportunity to participate as control subjects if they met all eligibility requirements. Women who met the initial eligibility requirements and were willing to participate as control subjects were screened, assessed, and consented for enrollment in the control group.

Two factors played into the enrollment assignment process: 1) It was crucial that the treatment group be adequately enrolled to ensure that the study could begin on schedule and be completed before the seasonal change would occur during the treatment intervention (creating an unfavorable environmental condition in the greenhouse impacting personal comfort), and 2) all subjects in the gardening group needed to be scanned within a very narrow window of time (about one week before and after the start and end of the treatment intervention). Appointment times available at the MRI scanning facility were very limited and scheduling appointments early was important to ensure all scans were completed in the allotted time interval. Members of the control group (not experiencing a formal intervention) could be enrolled on a rolling basis and complete study requirements during any 7-8 weeks of the 4 month period that the study procedures were taking place. This meant that enrollment of the members of the control group was not initially prioritized or randomly assigned, and occurred largely after the treatment group was sufficiently enrolled. Ultimately, it was not possible to enroll a 12th eligible control participant in the same general time frame of the experimental phase of the study.

During the recruitment phase, 101 calls were received with interest in participation, 34 women were consented and screened, and 24 women were enrolled in the study (1 test subject for fMRI protocol staging and 23 subjects total in the treatment and control group).

Because this is a pilot study and no previous research exists to provide information on an ideal sample size, other fMRI pilot studies (Baron-Cohen et al., 2006; Cao et al., 1998; Leidy et al., 2011), and recommendations from experienced professionals were used to determine a minimally adequate sample size. This study was not blinded for either the researchers or the participants due to the roles the principal investigator and study coordinator had in leading and assisting in the gardening sessions.

Gardening Intervention

The gardening intervention given to the treatment group was conducted over six weeks and included twelve one-hour sessions. The sessions occurred twice a week in the late afternoon. Participants selected the treatment session days that best fit their personal schedules, either Monday/Wednesday or Tuesday/Thursday. Sessions were designed by the study staff and reviewed by a professionally registered horticultural therapist (co-principal investigator). The study coordinator implemented the sessions aided by the study's principle investigator (PI), and occasionally a student assistant. There were no other individuals that worked with the study subjects during the treatment sessions.

Gardening sessions were conducted in a completely accessible greenhouse located on the medical campus of the University of Florida campus where temperature and ambient conditions could be more easily controlled than under outdoor conditions. The greenhouse is a structure that measures 2,700 square feet. A small 950 square foot air-conditioned head house is located on the east side of the structure. The west side of the greenhouse has a small area for the storage of greenhouse materials. The walls of the greenhouse are glass and permit a view of a natural garden space to the north and east. On the south and west sides of the building, medical facilities, research buildings, roads, and parking areas are visible. The greenhouse has nine growing benches that were moderately full of plants throughout the treatment period. An internal shade cloth mounted just below the glass ceiling was typically drawn overhead in the greenhouse during the treatment sessions to reduce the temperature in the working space. Cooling in the greenhouse was provided by thermostatically-controlled modular fan-driven evaporative coolers that helped to keep the greenhouse at a comfortable temperature and humidity during the gardening sessions. During warmer days, additional air movement in the gardening session work area was provided by overhead fans mounted on the upper structure of the greenhouse. Information about the temperature and ambient conditions was recorded at the beginning and end of each session. Temperatures inside the greenhouse ranged from 21º to 27ºC (70º to 81ºF) during the gardening sessions having an average temperature of 24ºC (mid 70ºs F). Percent humidity in the greenhouse ranged from high 60s to low 80s. The outdoor temperature and environmental conditions were most often noted to be mild or warm and either sunny or partly cloudy. Only one session occurred during rainy conditions. The gardening sessions occurred from February 23rd to April 9th, 2015 from 5:00 pm to 6:00 pm. It should be noted that daylight savings time started during this interval on March 7th. At the start of the intervention, lights needed to be turned on when the sun was setting during the sessions. However, after daylight savings time began, lights were not necessary at any point as the greenhouse had plenty of sunlight during the sessions. Average day length at the beginning of the gardening program was about 11.5 hours with sunset occurring at approximately 6:30 pm. By the end of the program, the average day length was approximately 12.5 hours and sunset had shifted to 7:45 pm.

Before the participants arrived at the greenhouse for each session, the study coordinator prepared the session activity by assembling all necessary materials and placing them on a greenhouse bench near the activity area. All session materials for the study were kept in a storage area in the back of the greenhouse facility or brought to the greenhouse and set up before a session would begin.

Participants were asked to provide their own transportation to the greenhouse for each session and some participants drove their personal vehicle while others walked from their offices on the University of Florida campus. Participants recorded the time they arrived and left the greenhouse on a sign-in sheet at the beginning and end of each session. The study coordinator and PI greeted the participants upon arrival. Once the group had all arrived, the study coordinator briefly described the activities that would be done that day and any necessary background information. The study coordinator often gave a demonstration of the task (such as how to plant seeds or take a cutting appropriately) before the participants were allowed begin on the task. The participants performed all activities at tables where they could sit or stand as they completed their tasks. Participants worked in groups for many activities and were encouraged to converse with the study coordinator, PI, and each other during each session. Participants also asked questions during this time and were guided in their task as needed. At the end of a session, participants assisted in cleaning the activity area before they were dismissed (See Table 3-1). Plants that needed time to grow and establish were kept on a greenhouse bench in the Wilmot Gardens Greenhouse. Participants were allowed to take home all plant materials they personally had worked on by the end of the study. De-identified notes were recorded by the study coordinator and PI following the completion of each session. Unsolicited comments and preferences expressed by participants were recorded as well as notable group interactions, relative degree of engagement, and enjoyment/enthusiasm that occurred throughout the session.

The program repeated four basic types of activities throughout the sessions, but varied the types of plants and materials used. The four types of sessions were 1) propagule planting, 2) vegetative propagation, 3) transplanting, and 4) simulated harvest/sensory stimulation. Each of these types of sessions occurred three times throughout the study and included activities such as planting seeds, taking cuttings of herbs, transplanting succulents into a container arrangement, and harvesting/tasting microgreens and other Florida-grown vegetables (see Table 3-2 for full description of activities). The activities for all the individual sessions were designed to involve approximately the same level of physical, cognitive and social engagement to filter out differential competing effects in these aspect areas. Each participant received a booklet describing every activity in each session for their personal reference. Participants also received a free copy of *Florida Gardener's Handbook* by MacCubbin, Tasker, Bowden and Lampl'l (2012) that could serve as a general reference to support the activities taking place in the gardening sessions.

Members of the treatment group were asked to not engage in any other gardening activities, not look up gardening information online, or visit botanical gardens during the six week period of the gardening treatment intervention.

Health and Quality of Life Evaluations

The self-reported mental and physical health of the participants in both groups were assessed using five different instruments that were administered at selected times throughout the study. The five instruments included the SF-36 Health Survey instrument (Hays et al., 1993; Ware and Sherbourne, 1992), the Perceived Stress Scale (Cohen et al., 1983), the Beck Depression Inventory 2nd Edition (Beck et al., 1996), the Profile of Mood States 2 Adult Form (McNair et al., 1981; Shacham, 1983), and the State Trait Anxiety Inventory Forms Y-1 and Y-2 (Spielberger et al., 1983). These assessment forms were used to evaluate self-reported physical/mental health, perceived stress, depression symptomatology, mood, and anxiety, respectively. The licenses for the SF-36 Health Survey, Beck Depression Inventory 2nd Edition, and the Profile of Mood States 2 Adult Form were obtained from Quality Metric Incorporated, Pearson Education Inc., and Multi-Health Systems Inc.

A preassembled packet containing all five of the assessment instruments was completed by the treatment group at their initial orientation before their first gardening session (a preintervention baseline measure), and again at a wrap-up session following their last gardening session (a postintervention measure). The sessions where these instruments were completed occurred from 5:00 pm to 6:00 pm at the Wilmot Gardens Conference Center. Participants completed the self-report questionnaires together in the same room, spaced apart to insure plenty of personal space and privacy, and were asked to remain quiet as they worked through the questionnaires. Participants were given as much time as they needed to complete the assessments, and any questions that arose were answered by the study coordinator or PI. The self-report questionnaires were generally completed within 30 minutes. All participants also answered a self-report questionnaire that included demographic questions about their age, race, education, occupation, and marital status at their initial orientation time. Even though the participant population was a wellness group with no pre-identified health concerns, the completed Beck Depression Inventory assessments were promptly examined for evidence of self-harm and suicidal ideation that may require immediate professional intervention or referral for professional follow-up.

The control group completed the packet containing the five instruments and the demographic questionnaire within one week of their first MRI and again within one week of their second MRI depending on their availability within this window. Both pre- and post- assessments were scheduled for approximately the same time of day for each individual. Participants completed the self-report assessment forms in a private and quiet room by themselves, and were given as much time as needed to complete all instruments, which generally was within 30 minutes.

The Profile of Mood States 2 was administered on a weekly basis to the treatment group only following the conclusion of the 2nd, 4th, 6th, 8th, and 10th gardening sessions to provide a time-course of mood status during the treatment intervention. The assessment was typically completed within five minutes. The Beck Depression Survey 2nd Edition was administered to the treatment group following the conclusion of the 4th and 8th gardening sessions to provide additional information on the degree of depression symptomatology during the intervention. The assessment was usually completed within 5 minutes. These assessments were administered in the greenhouse where the gardening sessions occurred and usually were completed at the end of the session between 5:45 pm and 6:00 pm.

Functional Magnetic Resonance Imaging

Functional Magnetic Resonance Imaging (fMRI) was conducted on all subjects at the beginning of the study period (baseline) and again at the end. For the treatment group, subjects were scanned within a ten day window before their first gardening session and also within ten days following the final gardening session. The control group participants were enrolled on a rolling basis and pre- and post-scans were scheduled from early February to early May. Before and after scans for the control group were scheduled seven to eight weeks apart in order to correspond to the time interval between the preintervention and postintervention scans for the treatment group. The average time between the first and second scan for the treatment group was 58 days (range 51-63 days). The average time between the first and second scan for the control group was 54 days (range of 49-62 days). Before and after scans for each participant were scheduled for approximately the same time of day.

Whole brain imaging was conducted using a Phillips 3.0 Tesla MRI/S scanner located at the McKnight Brain Institute (MBI) at the University of Florida. The scanner was equipped with a 32-channel head coil for neuroimaging applications with significant gains in signal-to-noise ratio and acquisition speed. An ESys® system built by Invivo (Invivo Corporation, Gainesville, Florida) was used for presenting visual signals to participants during the functional MRI scans.

Study participants were called two to three days before their scanning appointment, and asked to refrain from smoking and consuming alcoholic beverages and other common drugs/stimulants (opiates, caffeine, cocaine and amphetamines) for the 24 hours prior to undergoing neuroimaging. Participants were also asked to refrain from exercise and sexual activity for at least 2 hours before their scanning appointment.

Based on convenience for the participants and parking availability, participants were either transported to the McKnight Brain Institute (MBI) from the PI's offices or were met at the MBI. Once at the Human Imaging Core at the MBI, the participants were asked to fill out a MRI screening form to ensure safety, and the study coordinator conducted a pregnancy test to confirm that the participant was not pregnant. None of the study participants tested positive for pregnancy at any of the pre- or postintervention scans. The study coordinator informed the participant of what to expect while in the scanner, and allowed time for her to ask questions before entering the scanning room. The 3T MRI technologist reviewed the MRI screening form and approved the participant to undergo the MRI scanning. The participant was given earplugs and headphones to block the noise of the scanner. Once inside the scanning room, the MRI technician positioned the participant's head within a standard RF head coil and moved the participant's upper body into the bore of the MR scanner in a supine position. Physiological measurements including breathing and heart rates were taken during the scan on each participant. The participant was made comfortable with a cushion under their legs and a blanket as needed. The average total time spent in the scanner for the participant was approximately 35 minutes. Before the functional imaging scans, high resolution structural images were acquired. The anatomical images were a three-dimensional T1-weighted scan using a MP-RAGE sequence (sagittal plane, TR/TE/TI = 7/3.2/2750 ms, flip angle = 8°; in-plane Field of View (FOV) = 240 mm x 240 mm;

imaging matrix 240 x 240; 170 contiguous sagittal slices with 1 mm slice thickness, 1x1x1 mm^3 isotropic voxels) (Table 3-3).

Changes in cerebral blood flow (CBF) is an established correlate of brain function. The noninvasive arterial spin labeling (ASL) technique uses arterial water to provide quantification of CBF with high signal to noise spatial and temporal resolution. ASL is safe to repeat over time and can be employed to track changes in CBF. ASL can produce absolute measurements of CBF dynamically and capture changes in blood flow in physiologically meaningful ways. Pseudo-continuous ASL is an intermediate technique that gives reliable perfusion images while retaining good signal to noise output without the need for long labeling pulses.

Anatomical scans were followed by a 5 minute Pseudo-continuous Arterial Spin Labeling (pCASL) blood perfusion scan (Jahng et al., 2014) to measure cerebral blood flow in a resting state (TR/TE = 4000/11 ms, Flip angle = 90°, in plane FOV = 230 mm x 230 mm, imaging matrix = 80 x 80, Isotropic voxels = 2.875 mm x 2.875 mm x 7 mm, slice number = 20, slice gap = 1 mm, slice thickness = 6 mm, ascending [1, 2, 3, 4…]).

Functional MRI BOLD

The final portion of the imaging protocol consisted of two separate replications or "runs" of the functional scan (TR/TE = 2243/30 ms, Flip angle = 90°, in plane FOV = 240 mm x 240 mm, imaging matrix = 80 x 80, Isotropic voxels = 3 mm x 3 mm x 3 mm, slice number = 42, slice gap = 0 mm, slice thickness = 3 mm, interleaved [1,7,13,19, ……]). During the functional imaging scan, participants passively viewed a set of visual stimuli in a random block-design paradigm consisting of three experimental categories of images: 1) a woman with plants, 2) a woman only (no plants in the image), and 3) plants only (no woman in the image) (See example images in Figure 3-1). The images from all of these categories were scrambled and pixelated to create neutral stimuli, with the same color content, but no recognizable information content that followed at the end of each block. A single block (32 secs) included four pictures of one type of stimulus, each shown for 4 secs (16 secs total) followed by the four scrambled images of the pictures most recently viewed (16 secs). Each run included 5 repetitions of each type of stimulus block, summing 15 blocks per run requiring about 8 minutes of viewing/scanning time. Two runs were viewed by the participant during each scanning session, but different images were used during every run and scan. There was a short break/rest between the two BOLD runs of 1-2 min. Blocks were shown in a randomized order and each picture (and its scrambled counterpart) was viewed only once by each participant over the entire experiment. Stimulus images were generated using E-prime software Version 2.0 (Psychology Software Tools, Sharpsburg, PA), and driven by a laptop computer. Participants viewed stimuli on an IFIS-SA presentation system (InVivo Systems, Gainesville, FL) using a Dell model 2100MP data projector, rear projection screen, and first surface mirror display system. Stimuli were projected at 1024 x 768 pixel resolution, visible to the participant through a mirror attached to the head coil that reflected images on the screen behind the scanner.

Information from the functional scans was collected from brain regions showing an increase of Blood Oxygen Level Dependent (BOLD) response when viewing the three categories of stimuli compared to the corresponding scrambled images that served to provide a neutral stimulus baseline. The high-resolution T1-weighted scan was used to provide a structural basis for brain segmentation and surface reconstruction. T1-weighted data was classified as gray matter, white matter (WM), and cerebrospinal fluid (CSF) using the unified segmentation approach. Functional scans were overlaid on the high-resolution reconstruction to identify regions of changes in BOLD. The E-prime software used to generate the stimuli images also recorded the order that images were shown to each participant for every run. The E-prime output file that was generated with this information was used to determine overlapping activation patterns with specific stimuli.

Statistical Analysis

Functional MRI data was pre-processed and analyzed using Statistical Parametric Mapping (SPM12, Wellcome Department of Cognitive Neurology, London, UK). Pre-processing included slice timing correction, motion correction, co-registration of functional images to the participant's anatomical scan, spatial normalization, and smoothing. Analysis of the fMRI data was accomplished using a standard whole-brain general linear model (GLM), 2-sample t-test, and paired t-test at a p-value $\leq$ 0.005 and voxel cluster size $\geq$ 10.

Scores calculated from the self-report questionnaires were analyzed using Excel, SPSS Statistics 23 software (IBM Corporation, Armonk, New York), and SAS JMP v11. Statistical tests utilized included paired t-tests, two-sample t-tests, F-tests for assessing equal variances, Pearson and Spearman correlation coefficients, and ANOVA when appropriate. The mean, median, standard deviation, standard error and confidence intervals were also determined for each data set. Mean separations with P-values $\leq$ 0.05 were considered statistically significant.

Table 3-1. Sequence timeline for the 12 experimental gardening activities sessions

Timeline	Session component
0 min	Arrival and sign-in
0-5 min	Gathering/individual check plant growth progress/greeting individuals and assembled group
5-15 min	Educational module/introduction to activity/demonstration of activity
15-55 min	Gardening activity/questions
55-60 min	Clean-up
60-70 min	Final clean-up/departure
70-90 min	Session review and record notes/observations (staff only)

Table 3-2. Gardening intervention activities

	Activity	Plants
Session 1	Planting herb seeds	Basil, borage, chives, dill, rosemary, and, thyme
Session 2	Cuttings of herbs/scented plants	Rosemary, thyme, oregano, tarragon, lavender, and scented geranium
Session 3	Transplanting to create a succulent container garden	*Kalanchoe* spp., *Crassula* spp., *Aloe* spp., *Echeveria* spp., and *Sedum* sp.
Session 4	Tasting herbs and herb flavors	Basil, borage, chives, dill, mint, oregano, parsley, rosemary, sage and thyme
Session 5	Cuttings/Divisions of herbaceous ornamentals	African violet, begonia, coleus cultivars, pothos, snake plant and spider plant
Session 6	Planting seeds of fast germinating vegetables	Radish, lettuce, microgreen seeds (arugula, garden cress, kale, radish, sorrel, and swiss chard)
Session 7	Transplanting to create a herb and scented plant container	Aromatic herbs from sessions 1 and 2; basil, borage, chives, dill, mint, oregano and thyme
Session 8	Planting bulbs, corms, and tubers	Iris, caladium, garlic, and potato
Session 9	Cuttings of tropical ornamentals	Croton, dracaena, hibiscus, pineapple, and schefflera
Session 10	Tasting microgreens and Florida vegetables	Bell pepper, broccoli, carrot, celery, collards, cucumber, onion, and microgreens from session 6
Session 11	Transplanting lettuce containers	Lettuce mix, arugula, and kale
Session 12	Tasting Florida fruits	Orange, mango, starfruit, peach, blueberry, and tomato

Table 3-3. Parameter settings for MRI scans

Parameter	Anatomical scan	Blood perfusion pCASL scan	Functional BOLD scan
TR	7 ms	4000 ms	2243 ms
TE	3.2 ms	11 ms	30 ms
TI	2750 ms	-	-
Flip angle	8°	90°	90°
In plane field of view	240 mm x 240 mm	230 mm x 230 mm	240 mm x 240 mm
Imaging matrix	240 x 240	80 x 80	80 x 80
Isotropic voxels	1 x 1 x 1 mm^3	2.875 mm x 2.875 mm x 7 mm	3 x 3 x 3 mm^3
Slice number	170	20	42
Slice gap	-	1 mm	0 mm
Slice thickness	1 mm	6 mm	3 mm

Figure 3-1. Example images of visual stimuli from fMRI paradigm design. A) example of a plant only image (Photo credit: Linda Baldwin), B) example of a women only image (Photo credit: Ariel da Silva Parreira), and C) example of a woman and plant image (Photo credit: Tyler Jones).

CHAPTER 4
RESULTS

This chapter reports on the results gathered in the gardening research study described in the previous chapters. The results are reported and analyzed within the framework of the following objectives:

- Use psychometric assessments to evaluate the therapeutic impacts of the group-based gardening intervention on study participants' self-report general health, perceived stress, depression symptomatology, anxiety, and mood states profile of a wellness population consisting of only women.
- Use functional MRI to determine the effects of a group-based gardening program intervention on the patterns of brain activation of the study participants.
- Search for linkages between the patterns of brain activation and quantified therapeutic benefits.

In order to achieve these objectives, participants self-reported the status of their wellbeing using five psychometric assessment instruments: the SF-36, the Perceived Stress Scale, the State Trait Anxiety Inventory, the Profile of Mood States, and the Beck Depression Inventory. These scales were chosen for their wide use in social, behavioral, and medical science research as well as their ability to assess certain areas of quality of life that may be influential and important even within a healthy population.

Functional magnetic resonance imaging (fMRI) of the brain was selected as a powerful noninvasive approach to assess neurocognitive changes, and for its recognized capabilities and wide use in social, behavioral, and neurosciences research. Functional MRI has the ability to quantify patterns of brain activation that are otherwise unknowable. Therefore, fMRI is a unique tool that could lend novel and informative research findings to the field of people-plant interactions.

Study Recruitment

The study recruitment and implementation of the gardening intervention was initially planned to begin in late fall of 2014 following the study's IRB approval in August of 2014. Recruitment efforts relied mostly on a strategy of posting flyers in local coffee shops, grocery stores, and community bulletin boards. Unfortunately, this effort was not effective in enrolling individuals to the study as less than 30 inquiry calls were received during the two month recruitment period, and only one volunteer was consented to the study. The study intervention was therefore rescheduled to the spring of 2015, and the fall marketing and recruitment effort was reevaluated, redesigned and greatly expanded.

The original IRB approved experimental design was planned to have a single population of study subjects to receive the gardening treatment intervention coupled with pre- and postintervention assessment of subject psychological profile and fMRI scan. The design was to have two experimental phases with one group of study subjects in the fall followed by a second group of equal number in the spring, each group receiving identical gardening interventions. This design was aimed at eliminating any possible seasonal change as an experimental variable. The original experimental design did not include a control population.

Given the failure to secure enough study subjects to begin the experiment in fall 2014, the experimental design was reconsidered, and it was decided to upgrade the study to include a control group of study subjects to rule out the potential for seasonal effects on the psychological profile and brain activation patterns of the study subjects over the duration of the experimental treatment intervention. During this reconsideration of the experiement, it was also decided to expand the age range of the studied population of 30-45 to a wider range of 26-49. A revision for restructuring the experimental design of the study was submitted to the UF IRB and was approved in December 2014.

Included in the study revision submitted to the IRB was an expanded recruitment strategy that included totally redesigned flyers with more appealing imagery and color combination to stand out and generate more interest in the target population (flyer attached in Appendix B), an expanded distribution and posting of flyers on and around the UF campus and in the surrounding community, the creation of a study Facebook page with links on how to find out more information about the gardening study, newspaper and radio public service ads and announcements. Additionally, the approved recruitment flyer was able to be sent to colleagues in the plant sciences to post and/or distribute to potential study eligible friends and family.

At the beginning of January, 2015, flyers were placed in the offices, clinics and hallways in the University of Florida medical plaza, veterinary school, and dental building, animal sciences, and other places on campus. After adding these flyer locations and other recruitment methods such as registering with Health Street, invoking Internet (Google Ads) and newspaper print ads, and creating social network postings (gardening study Facebook page) as approved in the study IRB revision, the interest in the study greatly increased to over one hundred calls and both the control and treatment groups were very nearly fully enrolled by the planned start of the experimental phase of the study in the last week of February. The goal was to enroll 24 participants to be equally divided between the control and treatment groups. A total of 23 participants were ultimately assigned; 11 to the control group and 12 in the treatment group.

Participant Information

Each enrolled participant completed an approved demographic information questionnaire at the start of the study (Table 4-1). While most demographic information reported appeared typical, two unique characteristics of this recruited population can be noted in the demographics of income and education. The women recruited to the study appear to have both high levels of education, and a high income range. This may have been a result of recruiting heavily on the campus of the University of Florida and surrounding community where individuals who are highly educated and fall into a higher income bracket are concentrated by nature of the type of work found at a major research university. Demographic characteristics of the control and treatment groups were assessed to determine whether any factor may have influenced any of the parameters of the psychological profile. For this assessment, demographic information was coded into two groups and included the domains of age (36 and below/37 and above), race (Caucasian/non-Caucasian), marital status (married/single), income (below Florida median income/above Florida median income), and education level (19 years or less/20 years or more). A multiple linear regression model ($p < 0.05$) was used to determine the effects of sociodemographic differences on the results of the psychometric assessment scores. It was found that there was no significant effect for any of the demographic variables on the scores from each of the psychometric assessments.

Psychological Measures

The following paragraphs detail the results from the self-report instruments that were completed by each participant. Normative values collected from other studies are compared to this study's results listed in Table 4-2. Mean values for the scores for the five assessments for this study's total preintervention population were very comparable to the normative values reported in the literature for the five assessment instruments for adult women. This suggested that as a study population, the participants appeared to approximate expected norms for a wellness population.

Results in the following section are presented as percent change. References for mean scores for each assessment can be found in Table 4-3.

SF-36 Health Survey

The SF-36 Health Survey instrument assesses both physical and mental health domains. The SF-36 is used to determine self-perceived changes in general physical and mental health that have occurred within time horizons of the previous month and previous year. Components of the physical score are physical functioning, role-physical, bodily pain, and general health. The mental health component of SF-36 includes the sub-domains of social functioning, role-emotional, mental health, and vitality.

Baseline or preintervention scores for the control and treatment groups were not significantly different for the physical health domain of SF-36. However, the control group exhibited a 5% improvement in the physical health score, $p < 0.01$, $t = 2.23$, from preintervention to postintervention assessment, while the treatment group showed no significant change (Figure 4-1).

The scores for SF-36 mental health report at baseline for the control and treatment groups were found to be significantly different ,$p < 0.05$, $t = 2.11$. Interestingly, this is a pattern that will be repeated and evident across nearly all psychological profiling assessments conducted in this study. It is a result that will establish that the two groups were not identical with respect to psychological status at the outset of the experimental phase of the study, and that the treatment group participants had an overall poorer psychological profile than the control group. The control group showed no significant change from preintervention to postintervention assessments. In marked contrast, the treatment group displayed a 19% increase (improvement) in mental health scores which suggests a therapeutic improvement for overall mental health ,$p < 0.05$, $t = 2.20$ (Figure 4-2). In effect, the intervention improved the mental health score of the treatment group fully equal to that of the control group.

Perceived Stress Scale (PSS)

The Perceived Stress Scale is a tool that indicates the self-perceived degree of stress that an individual feels over a time horizon of the previous month. The ten question instrument has a Likert-scale rating of areas such as “feeling out of control” and “ability to cope with stressors”. While it does not ask for an indication of the number or type of stressful events, the PSS instead measures the “experienced” stress levels of an individual (Cohen et al., 1983).

The PSS scores at preintervention for the control and treatment groups were statistically different at the outset of the study. The treatment group exhibited elevated levels of perceived stress compared to the control group ,$p < 0.05$, $t = 2.08$,. The control group showed no significant change in mean PSS scores from preintervention to postintervention of the experimental phase of the study. In marked contrast, the treatment group displayed a 49% decrease in perceived stress from pre- to post-treatment measurements ,$p < 0.01$, $t = 2.20$ (Figure 4-3).

State Trait Anxiety Inventory (STAI)

The State-Trait Anxiety Inventory (Forms Y-1 and Y-2) measures self-reported State anxiety and Trait anxiety. State anxiety is a reflection of the levels of anxiety being experienced at the moment the assessment is being administered. In contrast, Trait anxiety is an indication of the overall or general level of anxiety felt by an individual. State anxiety measures transient levels of anxiety, while Trait anxiety reports a predisposition toward feeling anxious (Speilberger et al., 1983).

Preintervention scores for the treatment group were significantly higher than the control group in both State and Trait anxiety measures ,$p < 0.05$, $t = 2.08$; $p < 0.01$, $t = 2.11$,. When comparing pre- and postintervention mean scores, the control group showed a slight increase in the State score and a slight decrease in the Trait score, however, neither were statistically significant changes in either the State or Trait anxiety scores. On the other hand, the treatment group exhibited a 25% decrease in the mean score for State anxiety ,$p < 0.01$, $t = 2.23$, and a 16% decrease in the mean score for Trait anxiety ,$p < 0.05$, $t = 2.20$, from preintervention to postintervention (Figure 4-4). The treatment group postintervention score was reduced to a level that was slightly lower than the control values for the State anxiety. Similar to the State anxiety, the Trait anxiety score was reduced to a level below that of the pre- and postintervention controls, although as noted above the mean score was not statistically separated from either the pre- and postintervention control.

Profile of Mood States (POMS)

The Profile of Mood States 2 reports total mood disturbance (TMD) and seven different mood subdomains including: anger, confusion, tension, friendliness, depression, fatigue, and vigor. An increase in the TMD score indicates a negative change in mood, while a decrease in TMD reflects an improvement in mood. Preintervention TMD scores between the control and treatment groups revealed no statistical difference. Further, the control group registered no change in TMD score from pre- to postintervention. As seen with measures from other assessments for psychological conditions, the treatment group displayed a 23% decrease in TMD scores from preintervention to postintervention measurements ,$p < 0.01$, $t = 2.20$ (Figure 4-5). Similar to the postintervention score seen for the Trait anxiety score above, the TMD mean score for the postintervention treatment group was below that for the control group both pre- and postintervention. Some of the change in TMD score for the treatment group appeared to result from significant reductions in anger, confusion, fatigue, and tension scores along with a significant increase in vigor and friendliness scores ,$p < 0.05$, $t = 2.20$. Interestingly, depression was the only subdomain component of the TMD that did not significantly change for the treatment group from pre- to postintervention.

The POMS survey was administered to the treatment group every week throughout the 6 week gardening intervention to assess and reveal the cumulative impact on mood changes over the progression of the gardening sessions. Overall scores gathered over the six weeks reflect a consistent decrease in TMD (Figure 4-8). ANOVA analyses of the pre-, post-, and intermediate scores collected at weeks 1-6 supported the results of the paired t-test that demonstrated a significant change from the preintervention TMD score to the postintervention TMD score ,$p < 0.05$. No other intermediate scores for TMD (week 2, 3, 4, or 5) were shown to be significant when compared to the preintervention score using the one-way ANOVA test. Regression analysis of the TMD time-course revealed a log-rhythmic function with a correlation coefficient $r=0.9593$, p-value < 0.01.

Beck Depression Inventory (BDI)

The Beck Depression Inventory second edition scores the depressive symptomology using a self-reported assessment. Factors that are evaluated in this assessment include somatic symptoms such as tiredness, changes in eating habits, and crying as well as cognitive symptoms such as feelings of worthlessness or sadness. Scores from the BDI can be used to indicate whether the depression symptomology is minimal, mild, moderate, or severe.

The preintervention mean score for the treatment group was significantly higher than the control group ,$p < 0.05$, $t = 2.17$. Throughout the course of the study, no statistically significant change was observed in the BDI scores for the control group, although the postintervention mean score was increased by 17%. Most striking, the treatment group showed an 89% decrease in BDI scores from pre- to postintervention sampling points ,$p < 0.01$, $t = 2.20$ (Figure 4-6). This magnitude of decrease (89%) in the BDI score was matched when the four highest scoring individuals of the preintervention treatment group were excluded and the resultant pre- and postintervention mean scores based on the eight remaining individuals in the group. This unexpected result showed the treatment uniformly affected the entire group, and not just those individuals that had recorded high BDI scores.

Similar to the POMS, the BDI was administered additional times to the treatment group during the gardening sessions. The BDI was administered every two weeks with sampling points collected at weeks 2 and 4 in addition to pre- and postintervention assessments. The overall change over the course of the 6 weeks revealed a steady decline in the BDI scores (Figure 4-9). An ANOVA test of the data reinforced the findings of the paired t-test which demonstrated a significant change from pre- and postintervention for the treatment group ,$p < 0.05$. While the two intermediate scores (week 2 and 4) were not statistically separated from the pre- and postintervention mean scores, regression analysis yielded a log-rhythmic function with an $r = 0.9743$, $p < 0.05$.

Functional MRI Results

Before pre-processing the dataset and analyzing data, it was identified that the second run of a BOLD scan for one individual was corrupted and was removed from the dataset. All other individual scans were included. Because two nearly identical BOLD runs were performed at each scan, the two runs were combined to create one dataset for each scan (preintervention and postintervention) for every individual.

Individual scans were analyzed using the General Linear Model to create brain activation maps. Analysis was done on the whole brain level and did not specifically target preconceived regions of interest. Activation patterns were analyzed using this method for each type of stimulus displayed during the passive viewing task. The three types of stimuli, which included plants only, women only, and women interacting with plants, were each contrasted to the neutral scrambled images also displayed during functional scans. Activation maps, therefore, demonstrate the contrast between the activation patterns of the stimulus type and its scrambled counterparts. All areas that are equally activated when viewing both the stimulus and the scrambled image are not shown on the maps. The only areas that are represented are any locations that show different areas and/or intensities in activation levels.

The activation maps for all individuals were combined into one mean activation map for the treatment and control groups respectively. This was done for each stimuli type. Activation patterns were overlaid onto a study-specific brain template. Group patterns were analyzed using a paired t-test to contrast preintervention and postintervention scan within the control and treatment group. A 2 sample t-test was used to compare the activation areas between the treatment and control group using preintervention scans and again for the two groups using postintervention scans.

The following reports of activation patterns displaying changes across time and groups assumes a p-value $\leq$ 0.005 uncorrected and a contiguous voxel cluster size of at least 10 voxels. This threshold was chosen to balance both type-one and type-two errors (Lieberman and Cunningham, 2009). This is a pilot study which has no previous research to guide regions of interest (ROI), and therefore, a more moderate threshold might reveal some ROIs that might otherwise be missed. Specific details of all steps and parameters used can be found in the appendix .

Preintervention

Control and treatment groups displayed significant differences in their activation patterns at preintervention. The treatment group displayed greater activation compared to the control group in several regions of the brain while viewing each stimulus type. When viewing images of plants only, the treatment group exhibited increased activation compared to the control group in areas such as the occipital lobe, midbrain, lingual gyrus, insula, cuneus, and inferior parietal lobe. While viewing women only, the treatment group displayed increased activation in the cerebellum anterior lobe, lentiform nucleus, and the right cerebrum. The treatment group showed increased activation compared to the control group while viewing women interacting with plants in the areas of the fusiform gyrus, lingual gyrus, cuneus, and right cerebrum. A full description of these areas is given in Table 4-4. Coordinates listed in all tables are given in the standard Montreal Neurological Institute (MNI) space. Images displaying these differences on a study-specific brain template are found in figures 4-10 through 4-12.

Postintervention

The control and treatment group also displayed significant differences in activation at postintervention scans. These results revealed increased activation in some areas for the treatment group, but this was also true for the control group in other areas. When viewing plants only, the control group had greater activation in the parietal lobe. The treatment group had greater activation in the cingulate gyrus and parietal lobe. During viewing of women only images, the control group displayed increased activation in the right cerebellum. The treatment group displayed increased activation in the temporal lobe, inferior frontal gyrus, occipital lobe, and superior frontal gyrus. While viewing the images of women interacting with plants, the control group showed greater activation in the inferior frontal gyrus while the treatment group exhibited greater activation in the cuneus. Full descriptions of these areas are listed in Table 4-5. Figures 4-13 through 4-15 should be referenced for images displaying these differences in activation.

Treatment Group Change Over Time

The change over time in the activation patterns of the treatment group were obtained by contrasting the preintervention and postintervention scans. Decreases in activation levels at the postintervention scan appear to be the most common result revealed by the data. When viewing plants only, the middle and superior temporal gyrus had decreased activation at the postintervention scan. The parietal lobe had increased activation at the postintervention scan. While viewing women only, decreased activation was displayed in the declive, parahippocampal gyrus, right, cuneus, and precuneus. Increased activation was recorded in the middle frontal gyrus. Participants viewing women interacting with plants demonstrated decreased activation in the fusiform gyrus, frontal lobe, inferior frontal gyrus, posterior cingulate cortex, and medial frontal gyrus. Increased levels of activation were present in the temporal lobe and insula. Table 4-6 summarizes the details of this information. Figures 4-16 through 4-18 show images of these changes over time.

Control Group Change Over Time

The control group displayed patterns of increased activation while viewing plants and women only, but decreased activation while viewing women interacting with plants when comparing pre- and postintervention scans. The areas with increased activation while viewing plants only included superior frontal gyrus, inferior frontal gyrus, superior temporal gyrus, parietal lobe, middle frontal gyrus, inferior parietal lobe, medial frontal gyrus, and the precentral gyrus. When viewing women only, the only change was an increase in activity in the superior frontal gyrus. Viewing women interacting with plants demonstrated decreases in activation in the medulla, posterior lobe, pyramis of vermis, anterior cingulate, and cingulate gyrus. Table 4-7 displays the details of these regions. Figures 4-19 through 4-21 also show these changes in the control group over time.

Table 4-1. Participant demographics

Parameter	Treatment group	Control group	Total
Population size	12	11	23
Race			
White	10	8	18
African-American	1	0	1
Asian	0	2	2
Other	1	1	2
Ethnicity			
Hispanic/Latino	2	4	6
Non-Hispanic/Latino	10	7	17
Age (in years)			
Mean	34	39	37
Standard error	2.3	2.3	1.7
Range	26-48	27-48	26-48
Income (in dollars)			
Mean	86,000	103,000	94,000
Standard error	24,000	33,000	20,000
Range	0-300,000	16,000-400,000	0-400,000
Marital status			
Married	6	7	13
Single	6	4	10
Education (in years)			
Mean	18	20	19
Standard error	0.5	0.7	0.5
Range	16-22	16-22	16-22

Table 4-2. Comparison of adult normative values for the five psychological assessments used in this study and values obtained in this study population.

Assessment	Normative value	Source
SF-36 Health Survey		
	52-55	Maruish and DeRosa, 2009
	46-55*	This study
Perceived Stress Scale		
	20*	Cohen and Williamson, 1988
	16*	Cohen and Janicki-Deverts, 2012
	17*	This study
State Trait Anxiety Inventory (State/Trait)		
	38/40	Crawford et al., 2011
	33/36	Nyenhuis et al., 1999
	31/36*	This study
Profile of Mood States		
	40-59	Heuchert and McNair, 2012
	49*	This study
Beck Depression Inventory		
	6	Crawford et al., 2011
	7	Nyenhuis et al., 1999
	9*	This study

Note: Values listed for this study have been computed on the basis of the preintervention scores for all study participants. *Sampled population was women only.

Table 4-3. Mean and (standard error) values for psychological assessment scores

Assessment	Control	Treatment
SF-36 health survey		
Preintervention physical	54.3 (1.4)	56.9 (1.5)
Postintervention physical	57.0 (1.1)	57.4 (1.4)
Preintervention mental	50.1 (2.0)	41.3 (3.6)
Postintervention mental	50.0 (3.2)	49.3 (3.7)
Perceived stress scale		
Preintervention	13.3 (2.2)	20.3 (2.5)
Postintervention	11.5 (2.6)	9.5 (2.2)
State trait anxiety inventory		
Preintervention state	27.3 (1.6)	35.2 (2.8)
Postintervention state	28.7 (2.9)	27.1 (1.6)
Preintervention trait	29.5 (1.6)	41.5 (3.0)
Postintervention trait	27.6 (1.3)	34.9 (3.2)
Profile of mood states		
Preintervention	45.5 (2.3)	52.3 (2.5)
Postintervention	45.2 (3.1)	40.3 (2.3)
Beck depression inventory		
Preintervention	4.5 (0.9)	13.8 (3.5)
Postintervention	5.3 (2.0)	1.5 (0.8)

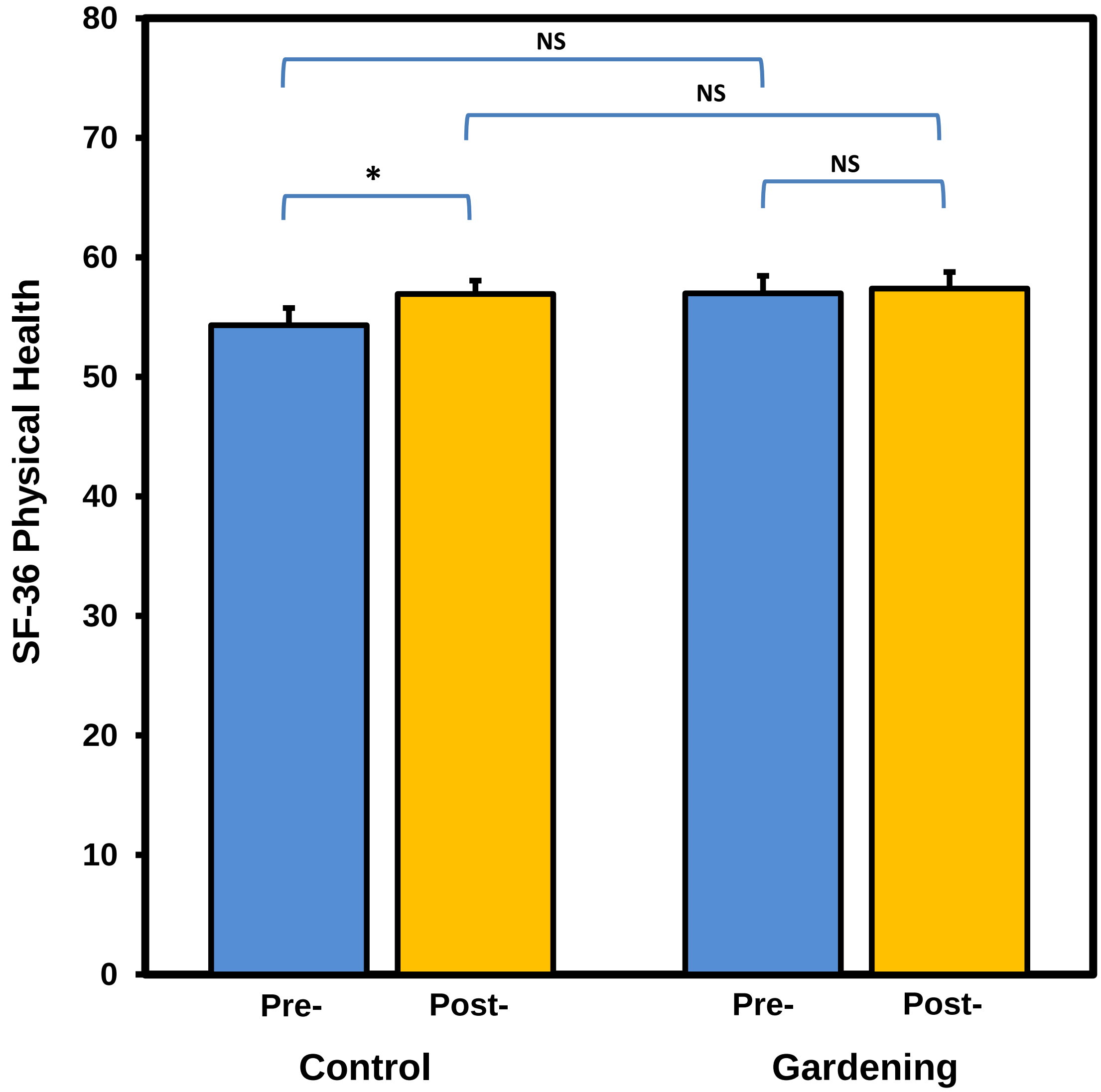

Figure 4-1. SF-36 physical health results. Self-report SF-36 Physical Health scores for the control (n=11) and the gardening (n=12) groups, pre- and postintervention. Means and standard errors are shown. A 2-sample t-test was used to compare means across groups and a paired t-test used to compare means within groups. * = $p < 0.05$, NS = Not significant, Pre = Preintervention, Post = Postintervention.

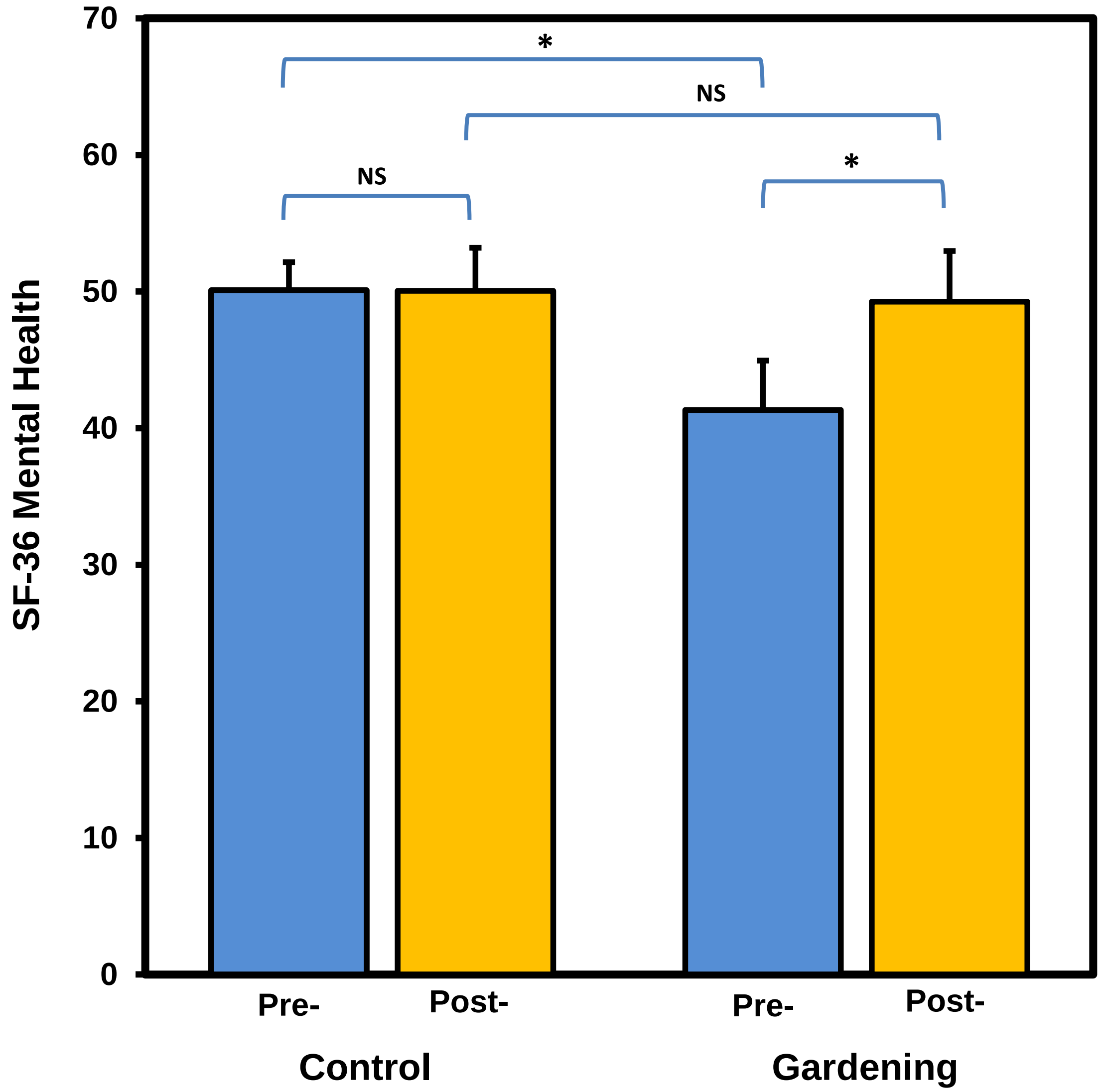

Figure 4-2. SF-36 mental health results. Self-report SF-36 Mental Health scores for the control (n=11) and the gardening (n=12) groups, pre- and postintervention. Means and standard errors are shown. A 2-sample t-test was used to compare means across groups and a paired t-test used to compare means within groups. * = $p < 0.05$, NS = Not significant, Pre = Preintervention, Post = Postintervention.

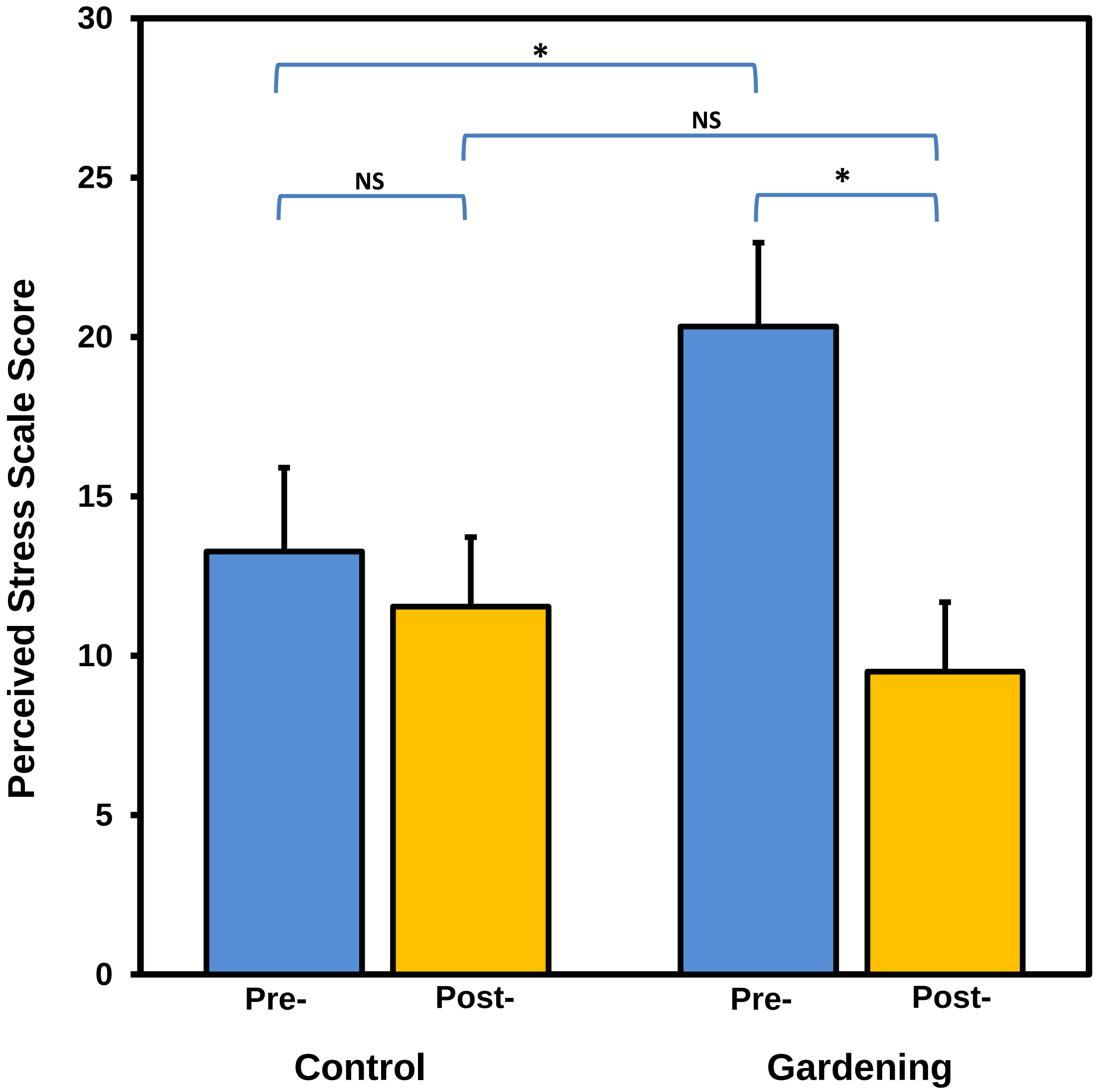

Figure 4-3. PSS results. Self-report Perceived Stress Scale scores for the control (n=11) and the gardening (n=12) groups, pre- and postintervention. Means and standard errors are shown. A 2-sample t-test was used to compare means across groups and a paired t-test used to compare means within groups. * = $p < 0.05$, NS = Not significant, Pre = Preintervention, Post = Postintervention.

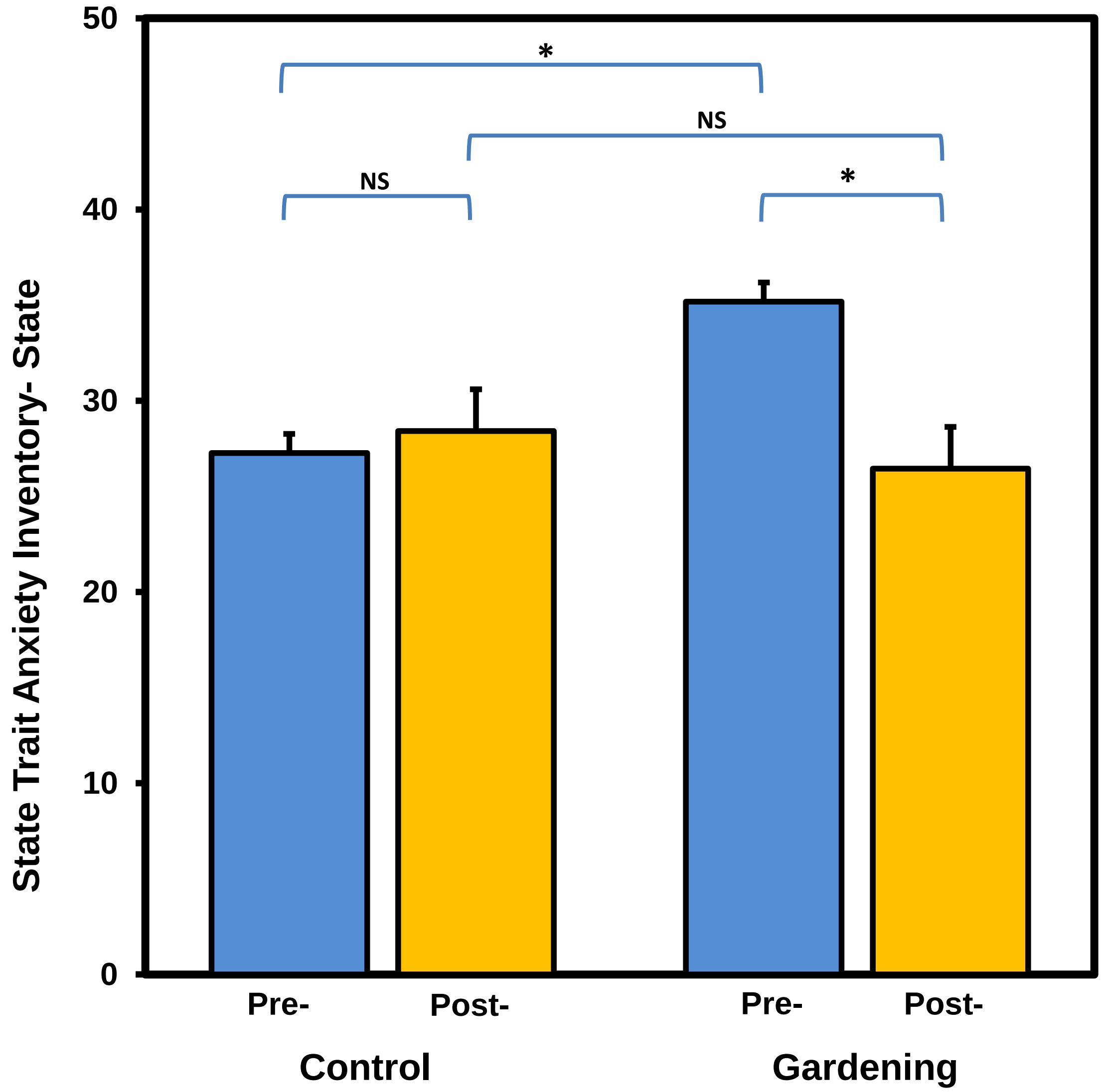

Figure 4-4. STAI-State results. Self-report State Trait Anxiety Inventory-State scores for the control (n=11) and the gardening (n=12) groups, pre- and postintervention. Means and standard errors are shown. A 2-sample t-test was used to compare means across groups and a paired t-test used to compare means within groups. * = $p < 0.05$, NS = Not significant, Pre = Preintervention, Post = Postintervention.

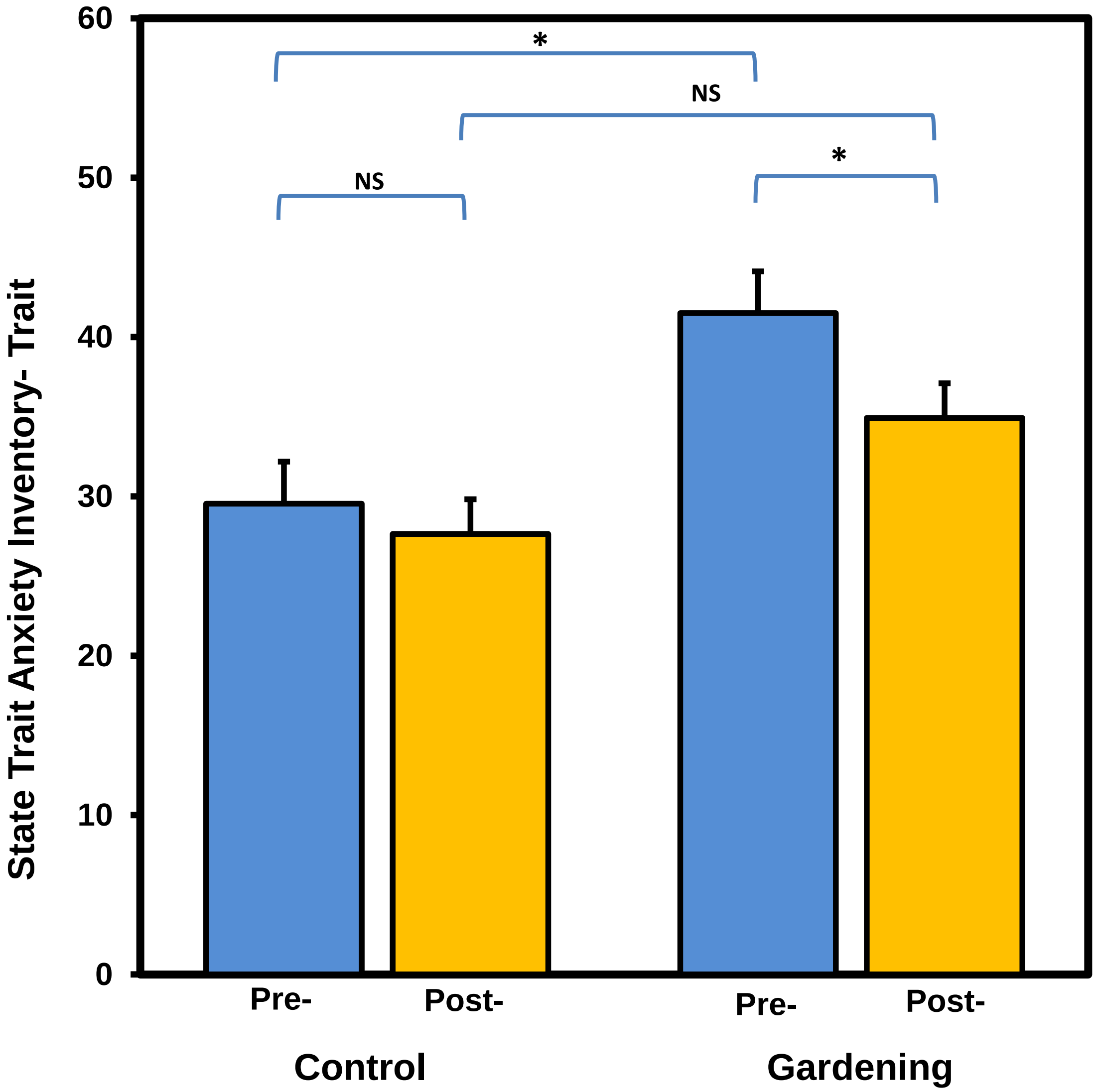

Figure 4-5. STAI-Trait results. Self-report State Trait Anxiety Inventory-Trait scores for the control (n=11) and the gardening (n=12) groups, pre- and postintervention. Means and standard errors are shown. A 2-sample t-test was used to compare means across groups and a paired t-test used to compare means within groups. * = p < 0.05, NS = Not significant, Pre = Preintervention, Post = Postintervention.

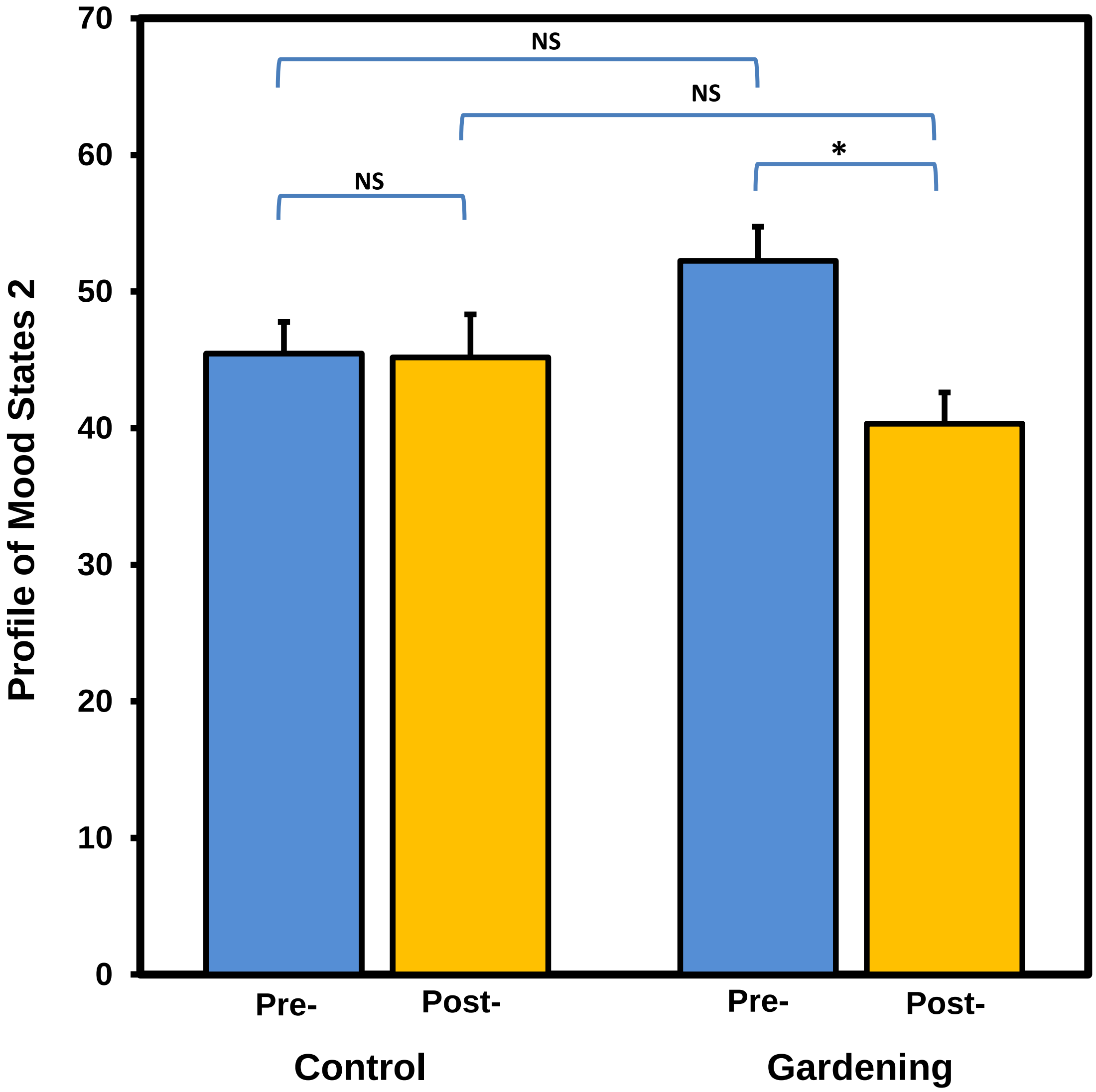

Figure 4-6. POMS2 results. Self-report Profile of Mood States 2 scores for the control (n=11) and the gardening (n=12) groups, pre- and postintervention. Means and standard errors are shown. A 2-sample t-test was used to compare means across groups and a paired t-test used to compare means within groups. * = p < 0.05, NS = Not significant, Pre = Preintervention, Post = Postintervention

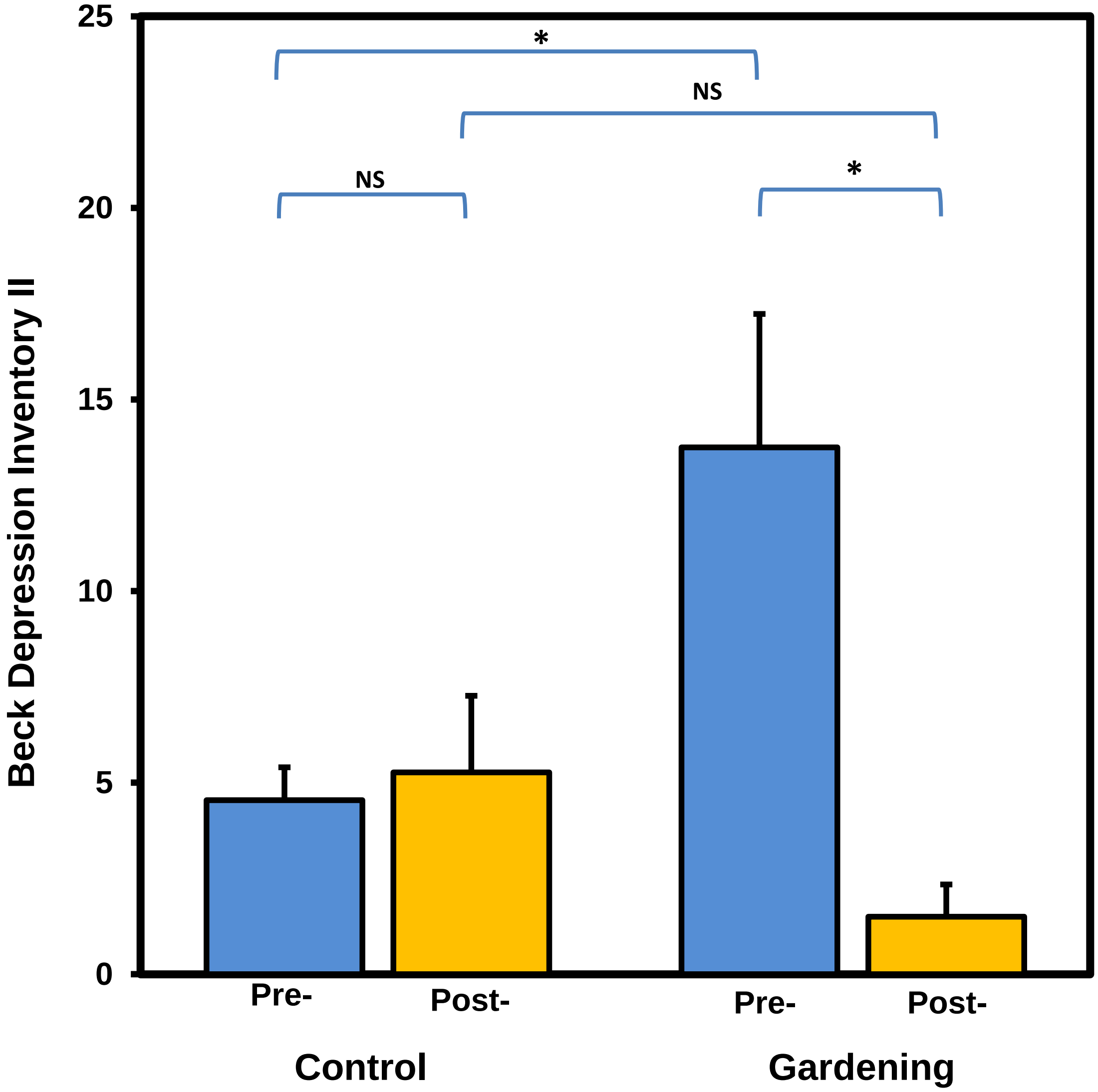

Figure 4-7. BDI II results. Self-report Beck Depression Inventory II scores for the control (n=11) and the gardening (n=12) groups, pre- and postintervention. Means and standard errors are shown. A 2-sample t-test was used to compare means across groups and a paired t-test used to compare means within groups. * = $p < 0.05$, NS = Not significant, Pre = Preintervention, Post = Postintervention.

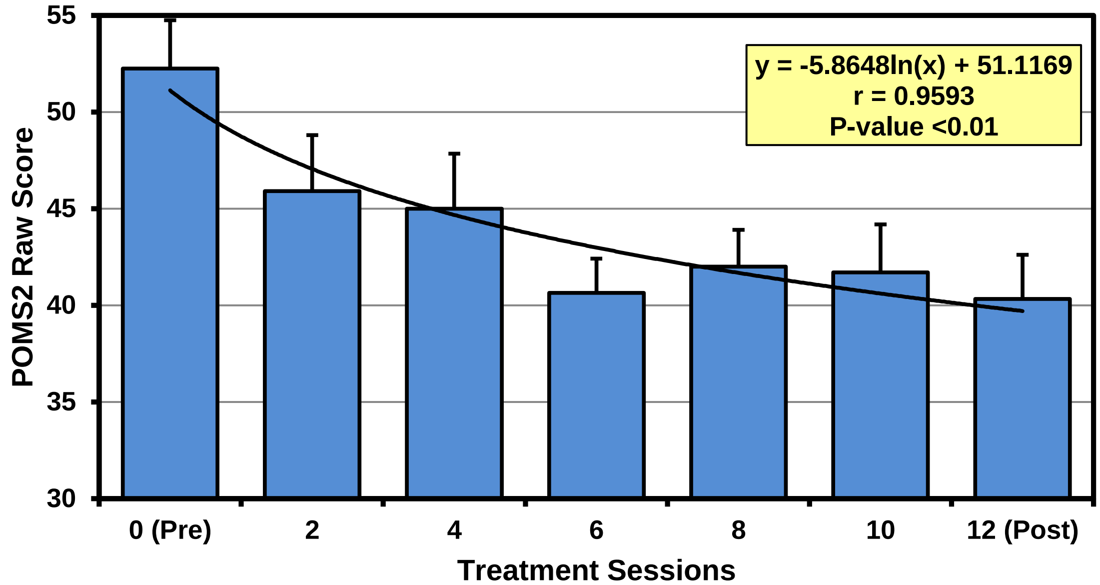

Figure 4-8. Weekly POMS scores. Weekly POMS mean scores for TMD for the treatment group. Standard error represented by error bars.

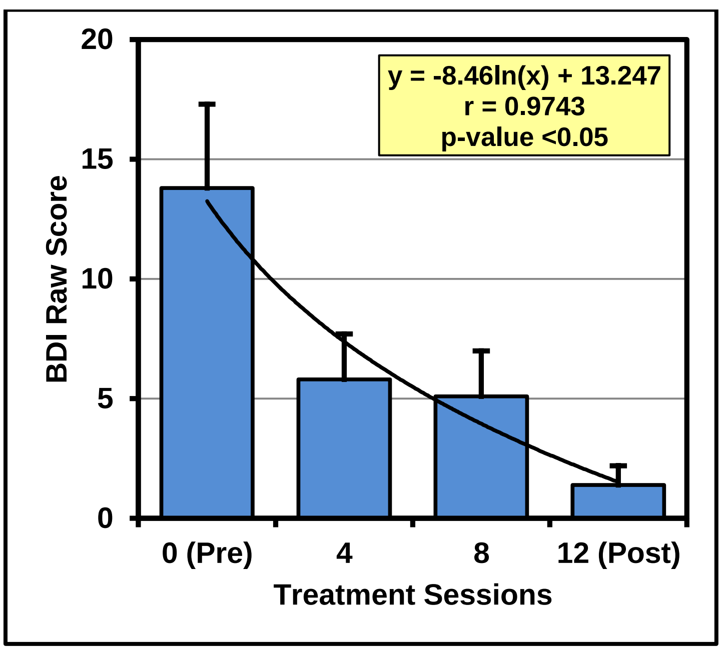

Figure 4-9. Bi-monthly BDI scores. Bi-monthly BDI mean scores for the treatment group. Standard error represented by error bars.

Table 4-4. Preintervention areas of activation contrasting treatment and control

			MNI Coordinates			
Paradigm	Brain Region	Cluster size	x	y	z	Intensity
Plants Only						
	Inferior Occipital Gyrus	11	-27	-90	-15	4.33
	Midbrain	10	0	-27	-15	4.90
	Lingual Gyrus	10	-21	-90	-6	4.19
	Lingual Gyrus	22	18	-90	-3	4.43
	Insula	25	39	-3	-3	5.76
	Cuneus	34	-9	-78	12	4.60
	Cuneus	11	24	-75	15	4.13
	Inferior Parietal Lobule	36	-42	-45	48	4.69
Women Only						
	Cerebellum Anterior Lobe	13	-6	-48	-27	4.69
	Lentiform Nucleus	14	15	0	0	4.79
	Right Cerebrum	12	24	-15	24	4.94
Women and Plants						
	Fusiform Gyrus	12	-48	-48	-15	4.01
	Lingual Gyrus	21	18	-90	-3	4.71
	Cuneus	30	-12	-75	6	5.26
	Right Cerebrum	10	24	-18	21	4.02

A threshold for significance was determined using an uncorrected p-value $\leq$ 0.005 and a voxel cluster size of $\geq$ 10. MNI coordinates indicate location of peak intensity. Positive intensity values indicate greater activation for the treatment group. Negative intensity values indicate greater activation in the control group.

Table 4-5. Postintervention areas of activation contrasting treatment and control

Paradigm	Brain Region	Cluster size	MNI Coordinates x	y	z	Intensity
Plants Only						
	Parietal Lobe	15	-21	-54	24	-4.45
	Cingulate Gyrus	17	-6	-27	30	5.17
	Inferior Parietal Lobe	12	30	-45	57	4.20
Women Only						
	Right Cerebellum	17	21	-51	-36	-4.36
	Temporal Lobe	12	42	-45	-9	3.87
	Inferior Frontal Gyrus	15	-48	18	-3	4.34
	Occipital Lobe	13	-36	-63	0	4.03
	Superior Frontal Gyrus	15	-24	48	21	4.02
Women and Plants						
	Cuneus	10	-12	-78	9	3.95
	Inferior Frontal Gyrus	22	48	30	15	-5.39

A threshold for significance was determined using an uncorrected p-value $\leq$ 0.005 and a voxel cluster size of $\geq$ 10. MNI coordinates indicate location of peak intensity. Positive intensity values indicate greater activation for the treatment group. Negative intensity values indicate greater activation in the control group.

Table 4-6. Treatment group contrasting preintervention and postintervention

			MNI Coordinates			
Paradigm	Brain Region	Cluster size	x	y	z	Intensity
Plants Only						
	Middle Temporal Gyrus	10	54	-21	-9	-4.94
	Superior Temporal Gyrus	16	48	6	-3	-5.15
	Parietal Lobe	13	36	-66	30	5.60
Women Only						
	Declive	23	-30	-72	-18	-5.73
	Parahippocampal Gyrus	11	24	-6	-18	-4.38
	Parahippocampal Gyrus	11	36	-33	-12	-6.21
	Parahippocampal Gyrus	27	21	-30	-9	-6.03
	Cuneus	11	18	-78	12	-4.39
	Middle Frontal Gyrus	17	30	45	18	7.25
	Precuneus	29	-18	-72	27	-5.14
Women and Plants						
	Fusiform Gyrus	12	-45	-54	-24	-4.49
	Frontal Lobe	10	-6	3	-18	-6.05
	Temporal Lobe	10	-36	-51	-3	5.24
	Inferior Frontal Gyrus	42	57	18	6	-7.22
	Posterior Cingulate Cortex	14	3	-51	6	-6.81
	Medial Frontal Gyrus	46	6	54	9	-5.52
	Insula	34	33	-30	24	5.87

A threshold for significance was determined using an uncorrected p-value $\leq$ 0.005 and a voxel cluster size of $\geq$ 10. MNI coordinates indicate location of peak intensity. Positive intensity values indicate increased activation at the postintervention scan. Negative intensity values indicate decreased activation at the postintervention scan.

Table 4-7. Control group contrasting preintervention to postintervention

Paradigm	Brain Region	Cluster size	MNI Coordinates x	y	z	Intensity
Plants Only						
	Superior Frontal Gyrus	16	-33	45	-15	6.62
	Inferior Frontal Gyrus	10	-42	30	3	6.73
	Superior Temporal Gyrus	19	57	-39	6	5.19
	Superior Frontal Gyrus	10	12	54	18	6.56
	Parietal Lobe	17	-18	-60	24	5.08
	Middle Frontal Gyrus	22	36	18	30	5.41
	Inferior Parietal Lobule	22	45	-48	48	5.83
	Superior Frontal Gyrus	12	15	-12	63	4.87
	Medial Frontal Gyrus	11	-9	-6	63	4.31
	Precentral Gyrus	14	-9	-24	63	5.49
Women Only						
	Superior Frontal Gyrus	10	24	63	-6	4.64
Women and Plants						
	Medulla	10	6	-45	-48	-4.80
	Posterior Lobe	12	-9	-57	-45	-5.78
	Pyramis of Vermis	12	0	-69	-27	-4.52
	Anterior Cingulate	20	3	15	24	-5.01
	Cingulate Gyrus	12	15	-21	42	-5.13

A threshold for significance was determined using an uncorrected p-value $\leq$ 0.005 and a voxel cluster size of $\geq$ 10. MNI coordinates indicate location of peak intensity. Positive intensity values indicate increased activation at the postintervention scan. Negative intensity values indicate decreased activation at the postintervention scan.

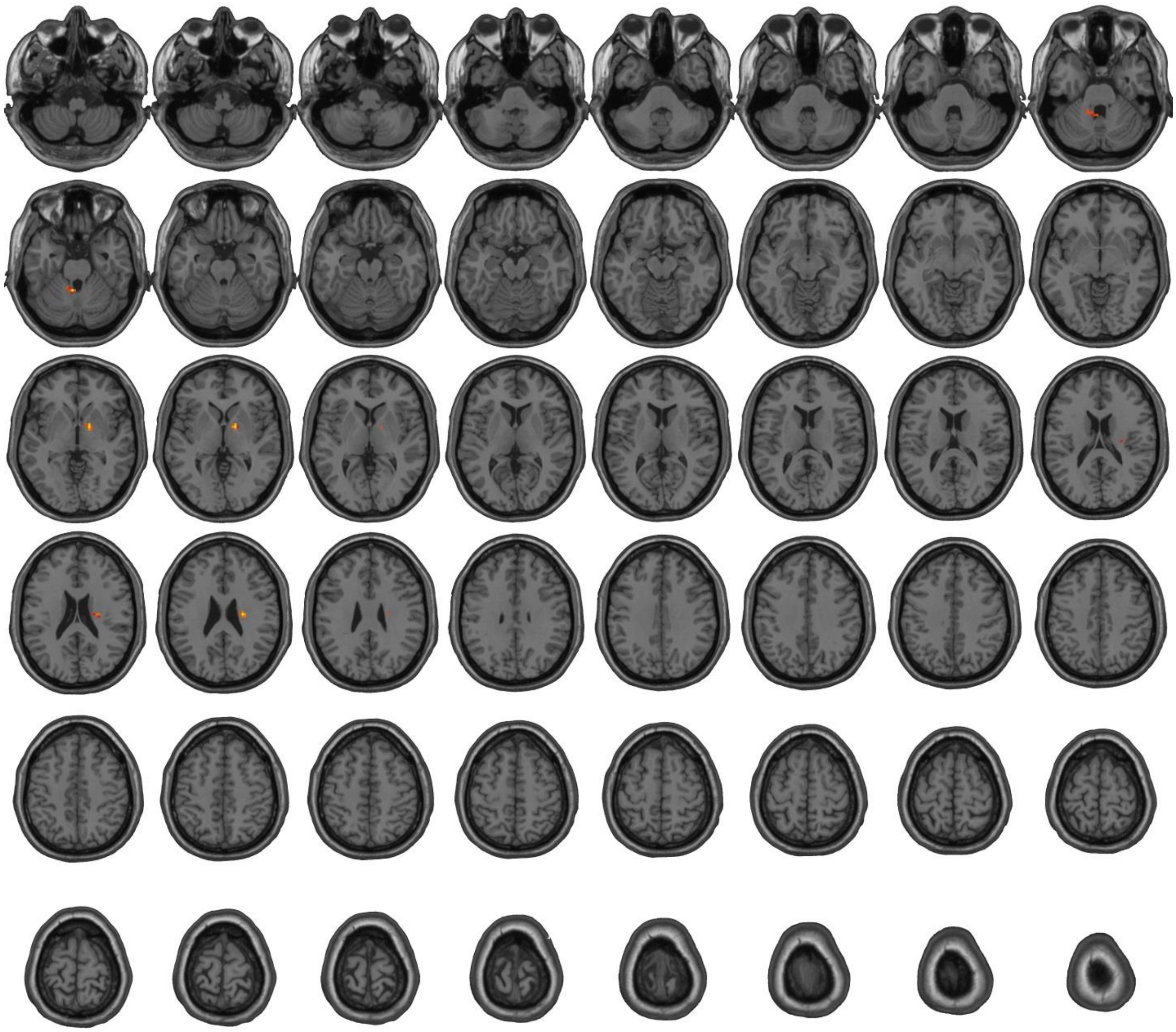

Figure 4-10. Women only activation map for preintervention. Activation map for the preintervention scan contrasting treatment and control groups. Participants were passively viewing 40 images in each scan of women only. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the treatment compared to the control scans. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

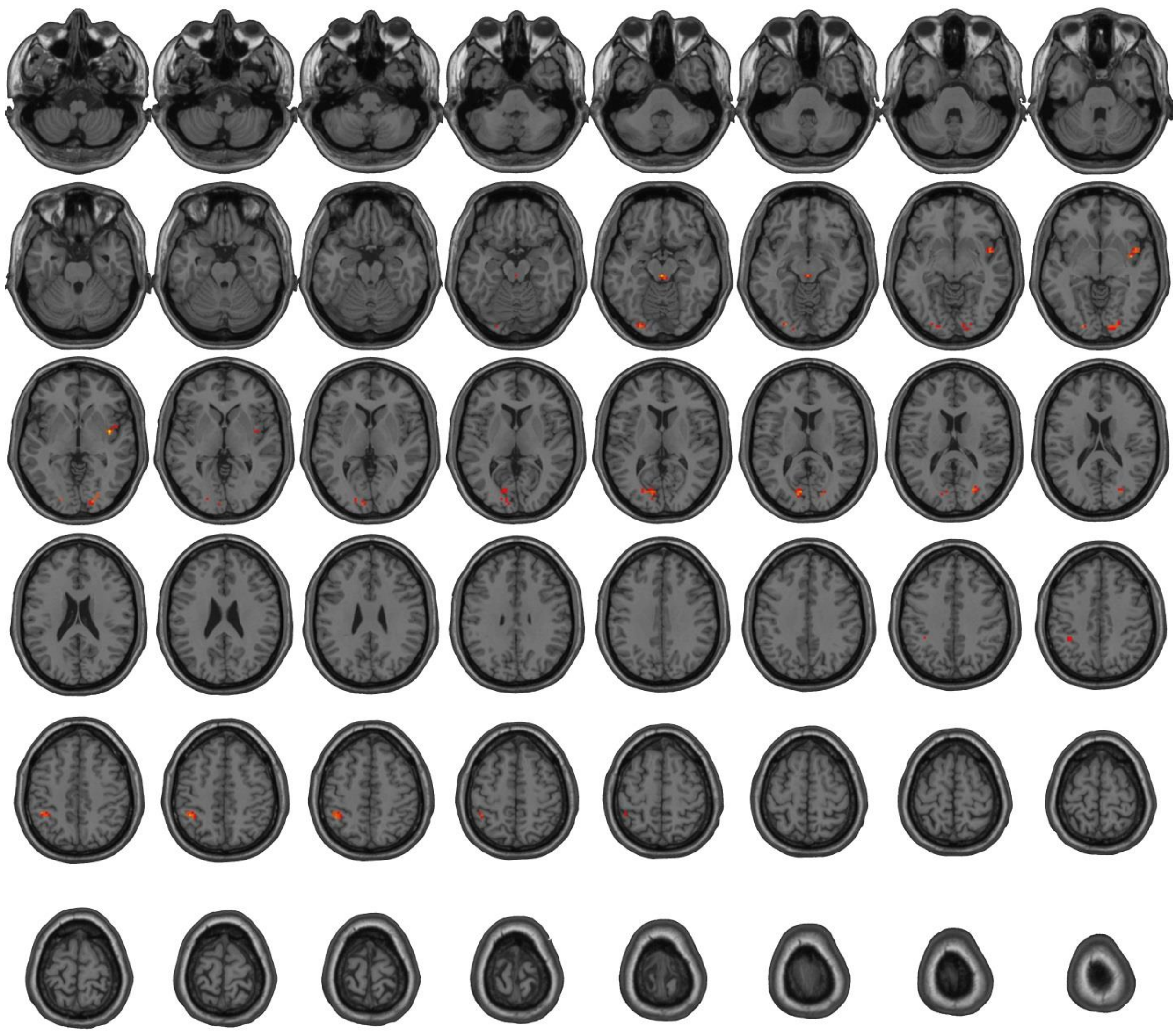

Figure 4-11. Plants only activation map for preintervention. Activation map for the preintervention scan contrasting treatment and control groups. Participants were passively viewing 40 images in each scan of plants only. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the treatment compared to the control scans. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

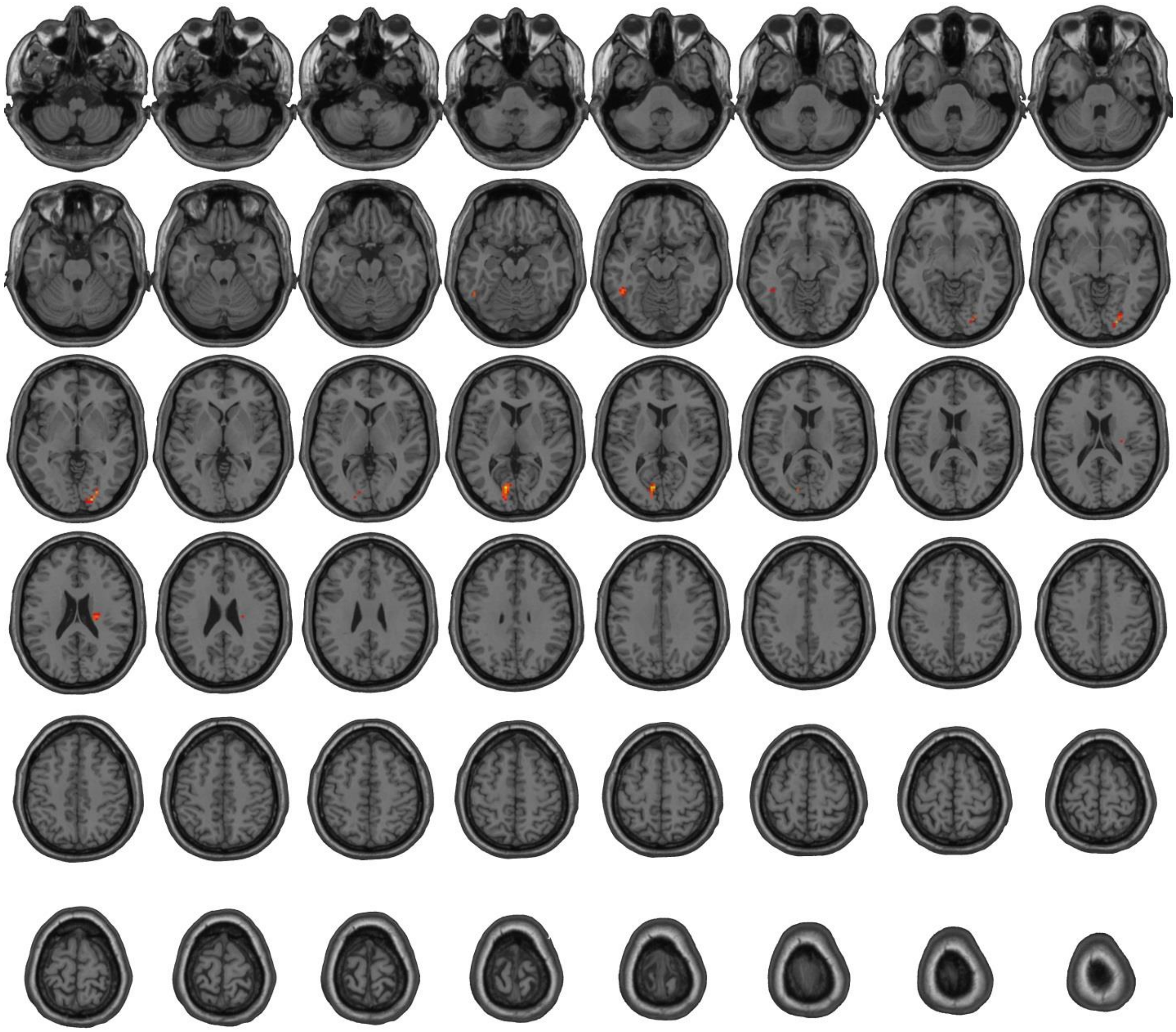

Figure 4-12. Women and plants activation map for preintervention. Activation map for the preintervention scan contrasting treatment and control groups. Participants were passively viewing 40 images in each scan of women interacting with plants. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the treatment compared to the control scans. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

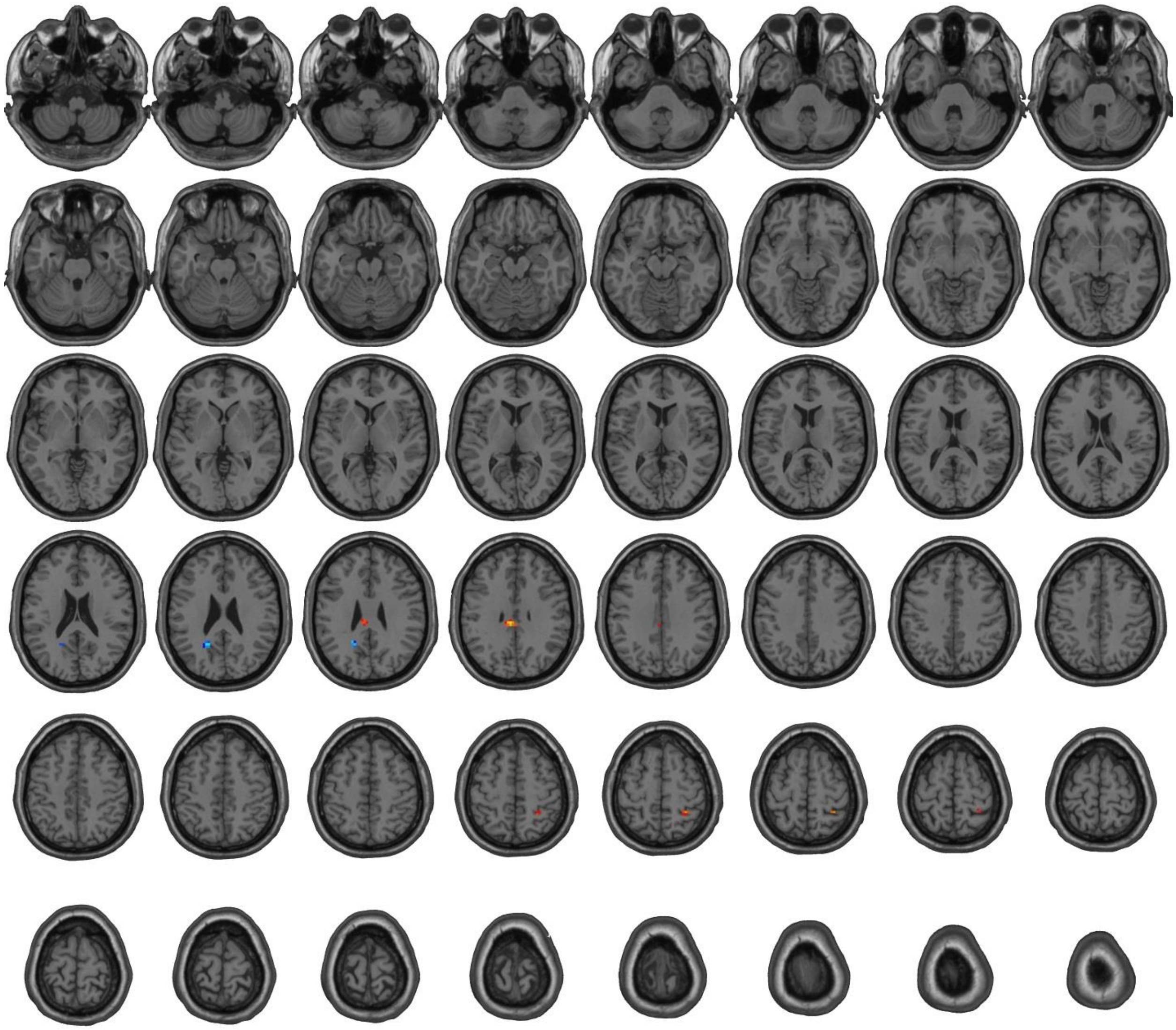

Figure 4-13. Plants only activation map for postintervention. Activation map for the postintervention scan contrasting treatment and control groups. Participants were passively viewing 40 images in each scan of plants only. Cool colors indicate areas with decreased activation while warm colors demonstrate increased activation in the treatment compared to the control scans. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

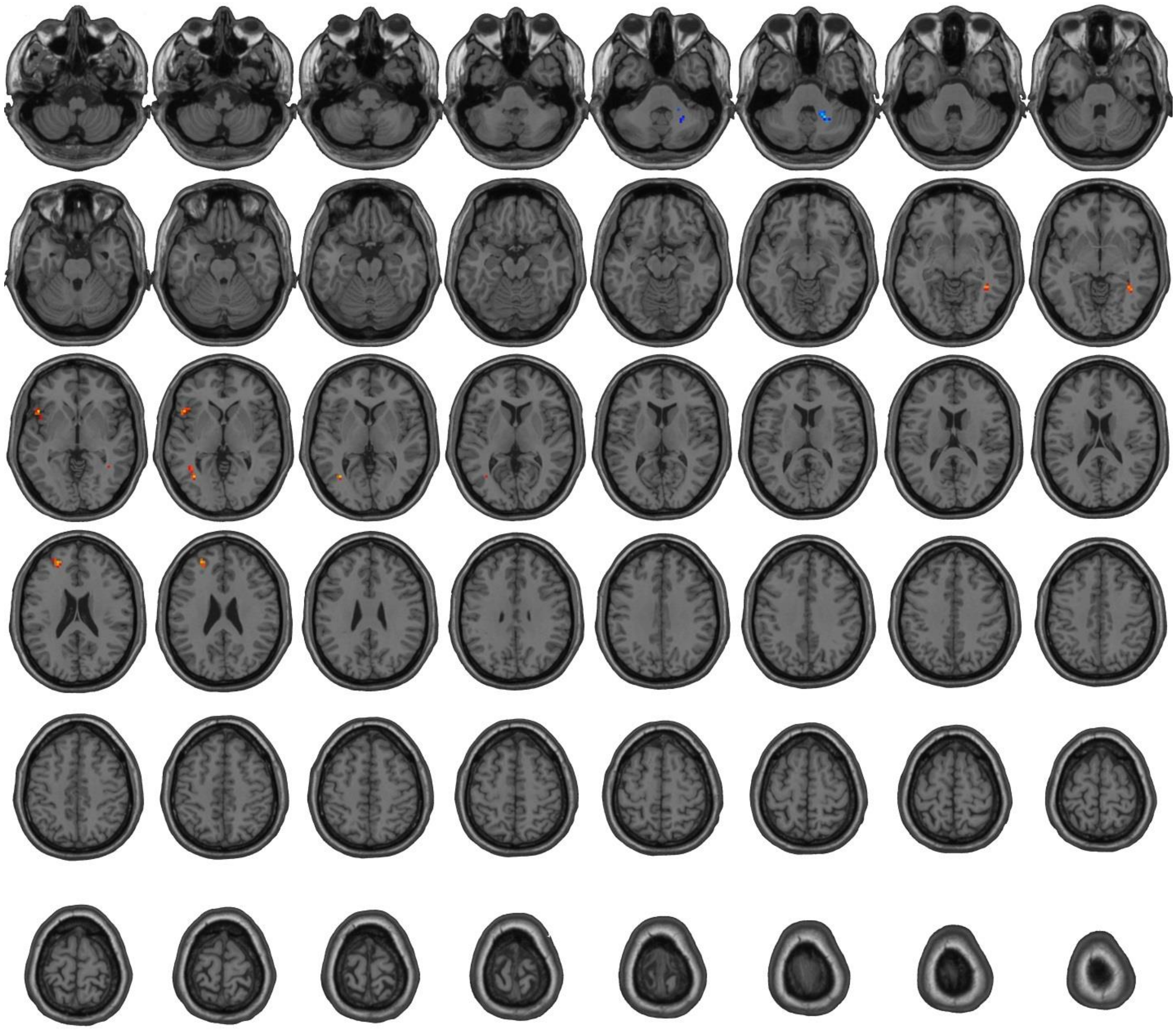

Figure 4-14. Women only activation map for postintervention. Activation map for the postintervention scan contrasting treatment and control groups. Participants were passively viewing 40 images in each scan of women only. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the treatment group compared to the control group. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

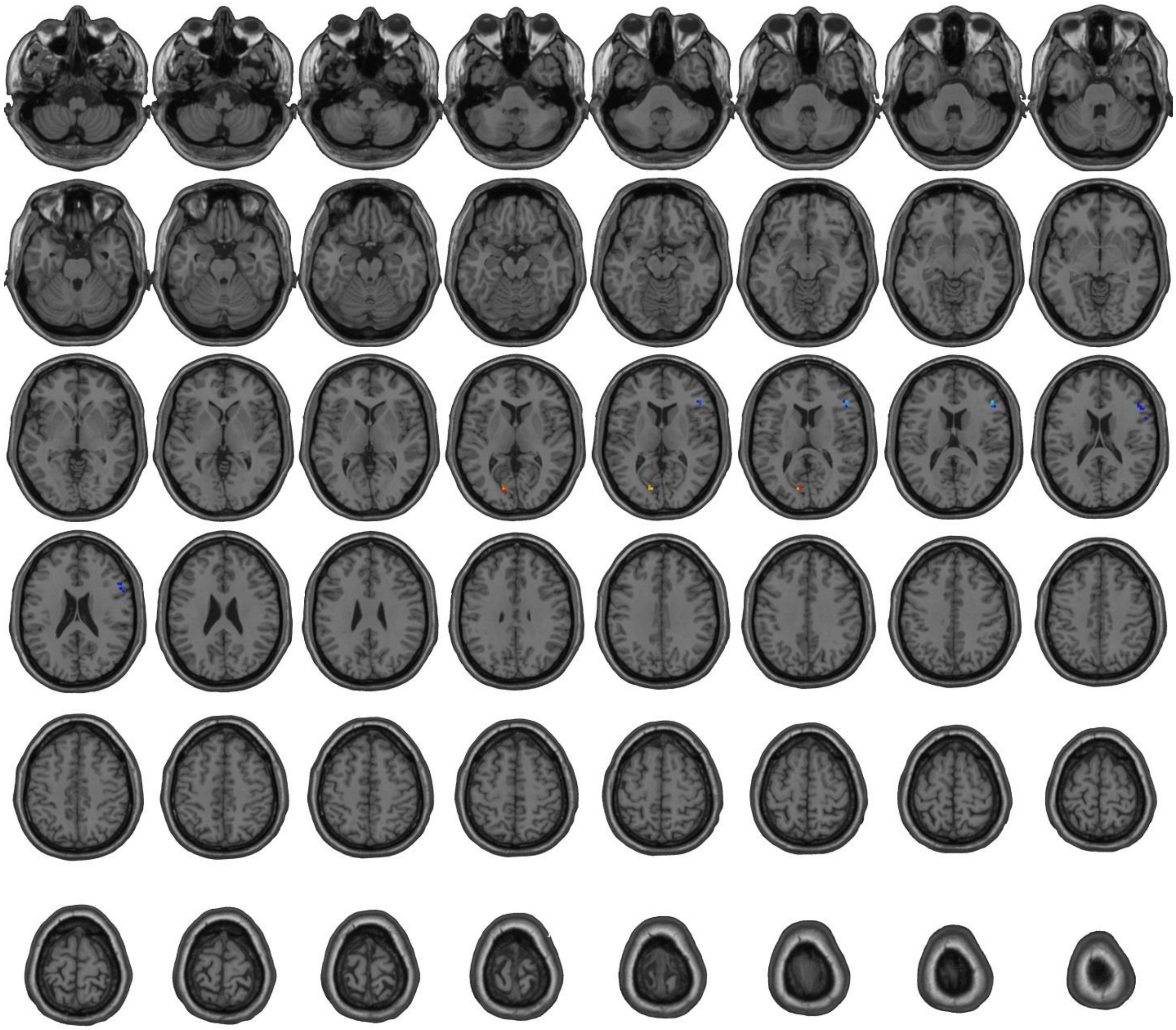

Figure 4-15. Women and plants activation map for postintervention. Activation map for the postintervention scan contrasting treatment and control groups. Participants were passively viewing 40 images in each scan of women interacting with plants. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the treatment group compared to the control group. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

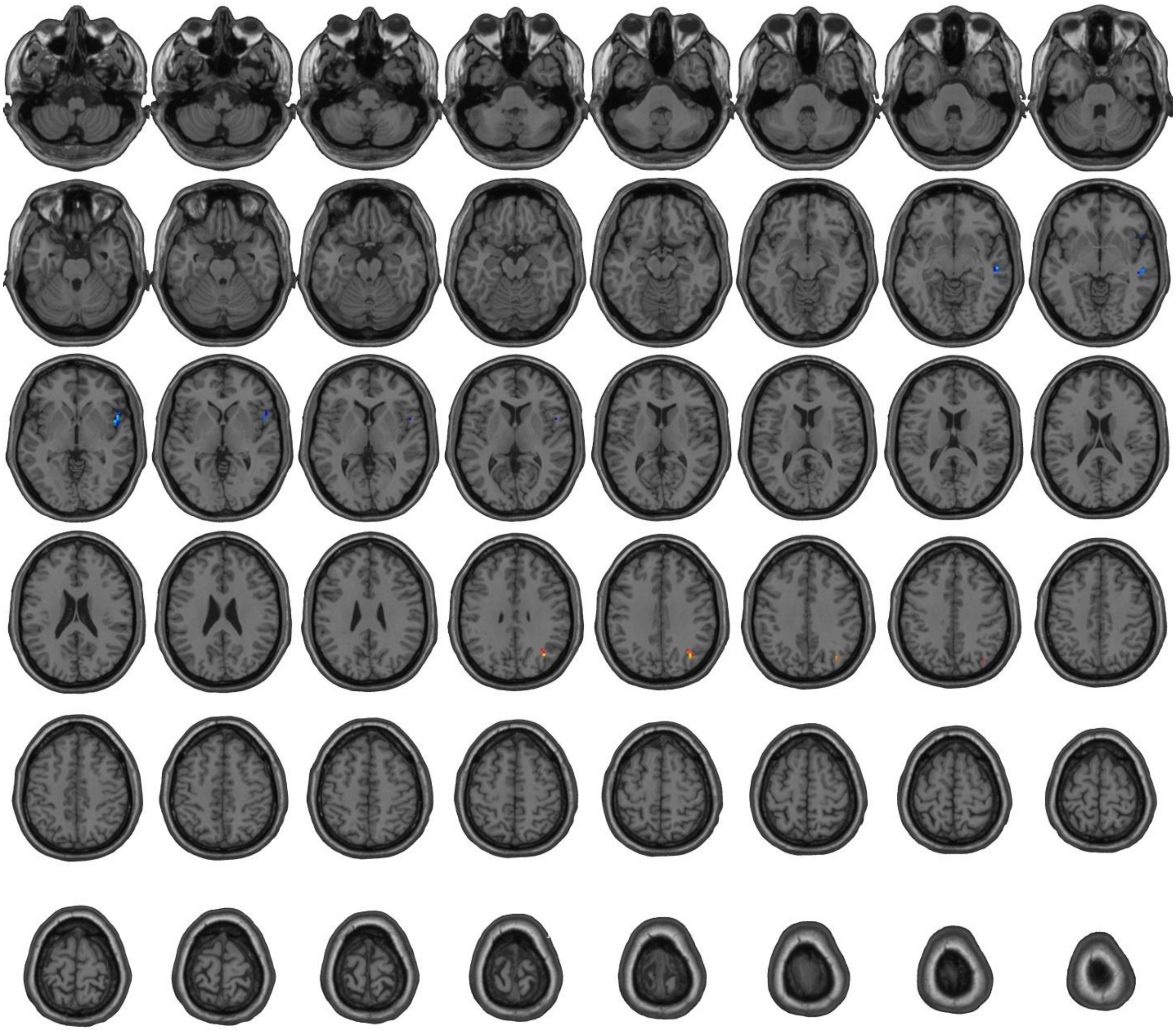

Figure 4-16. Plants only activation map for treatment group. Activation map for the treatment group contrasting preintervention and postintervention scans. Participants were passively viewing 40 images in each scan of plants only. Cool colors indicate areas with decreased while warm colors indicate increased activation in the treatment group compared to the control group. P < 0.005, voxel cluster size = > 10

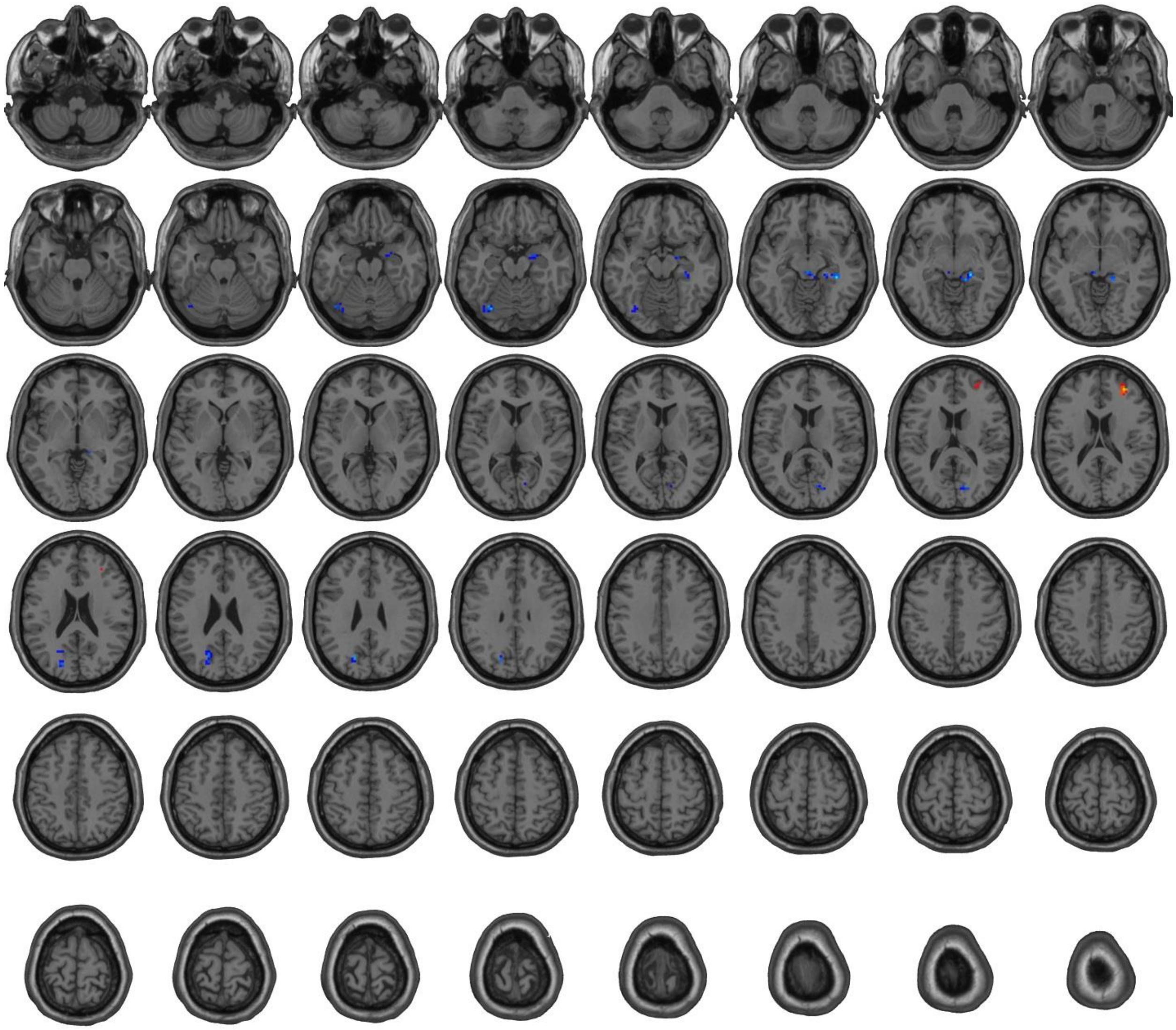

Figure 4-17. Women only activation map for treatment group. Activation map for the treatment group contrasting preintervention and postintervention scans. Participants were passively viewing 40 images in each scan of women only. Cool colors indicate areas with decreased while warm colors indicate increased activation in the postintervention scan compared to the preintervention scan. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

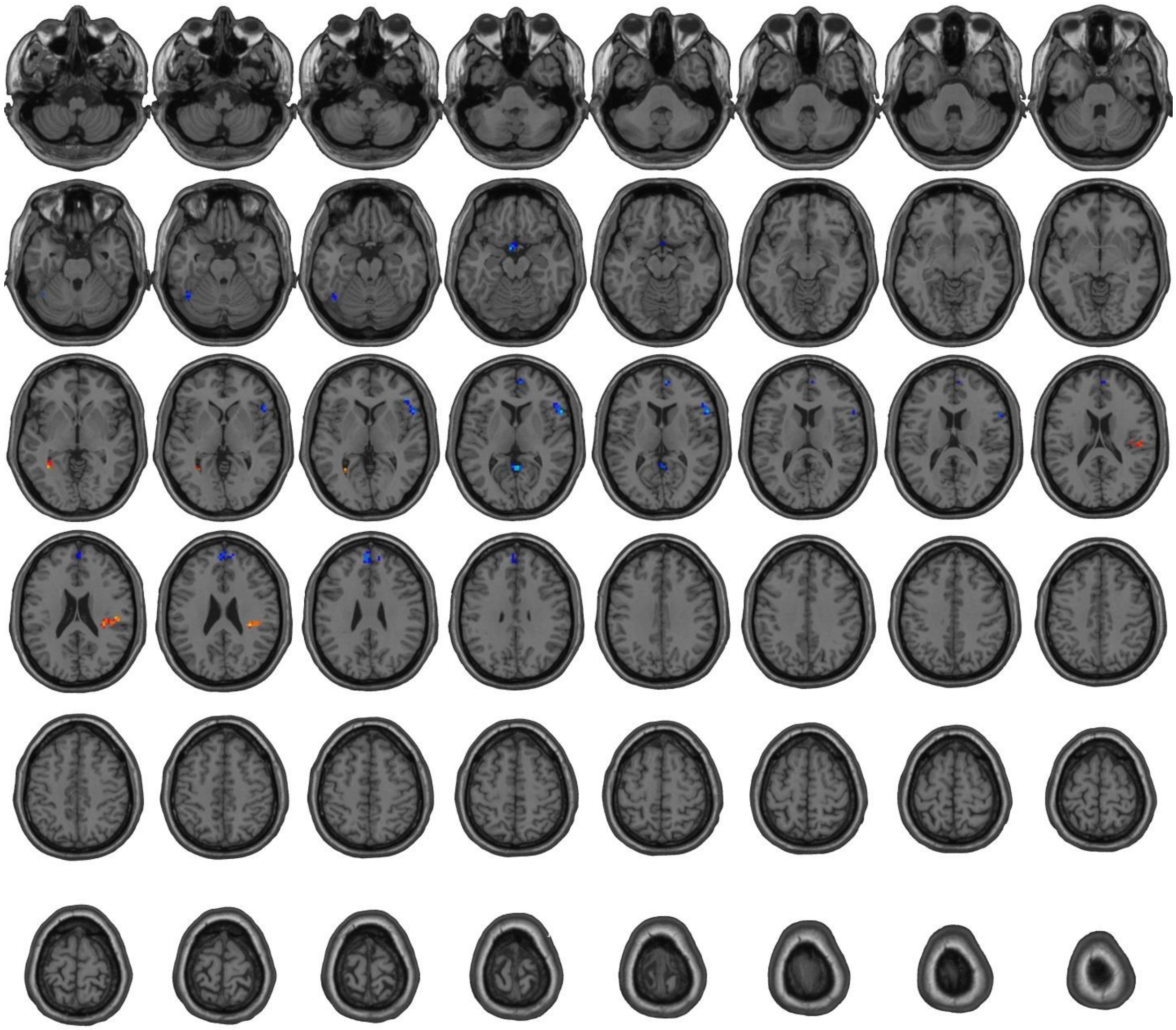

Figure 4-18. Women and plants activation map for treatment group. Activation map for the treatment group contrasting preintervention and postintervention scans. Participants were passively viewing 40 images in each scan of women interacting with plants. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the postintervention scan compared to the preintervention scan. $P < 0.005$, voxel cluster size = > 10

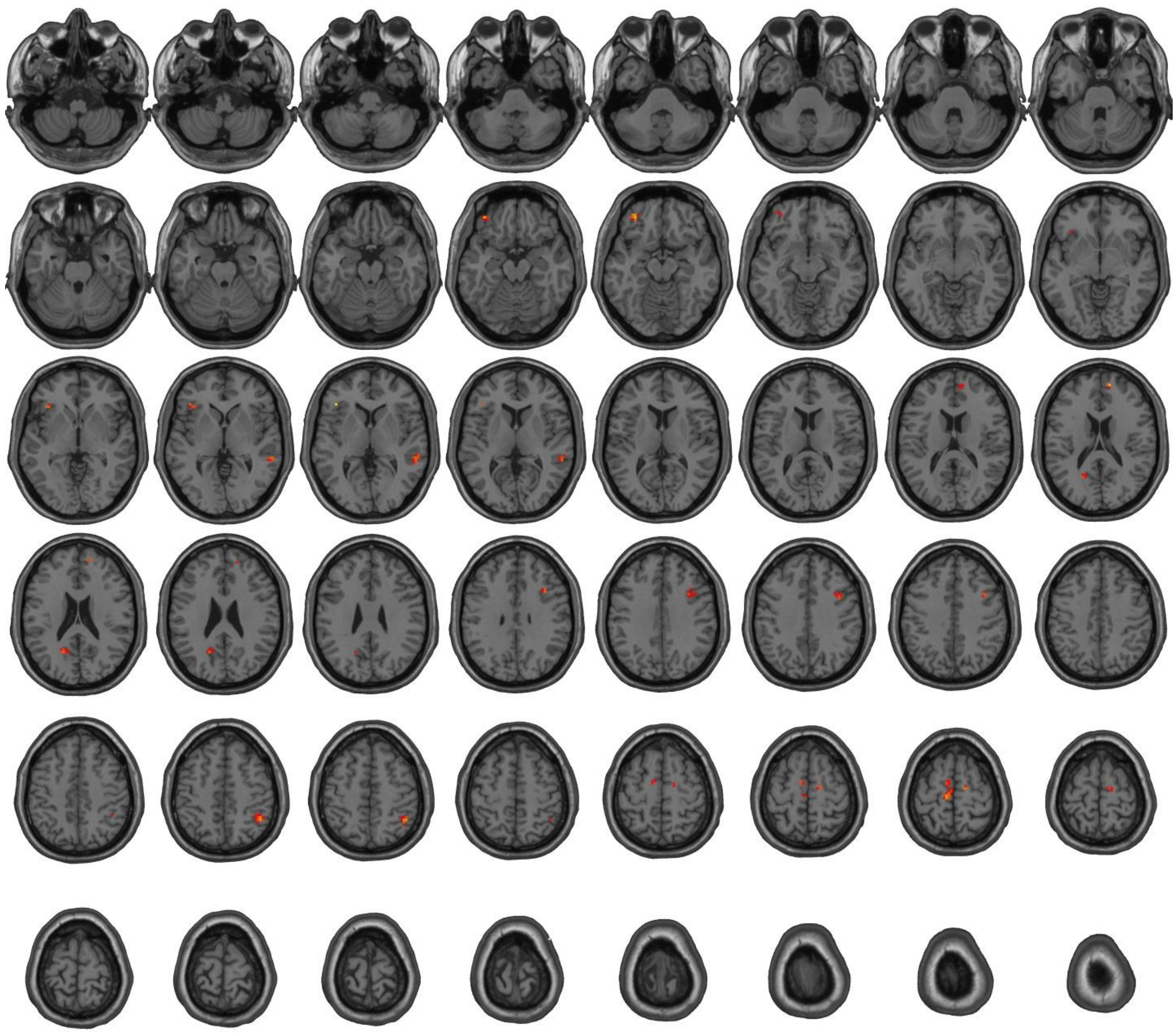

Figure 4-19. Plants only activation map for control group. Activation map for the control group contrasting preintervention and postintervention scans. Participants were passively viewing 40 images in each scan of plants only. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the postintervention scan compared to the preintervention scan. $P \leq 0.005$, voxel cluster size = ≥ 10

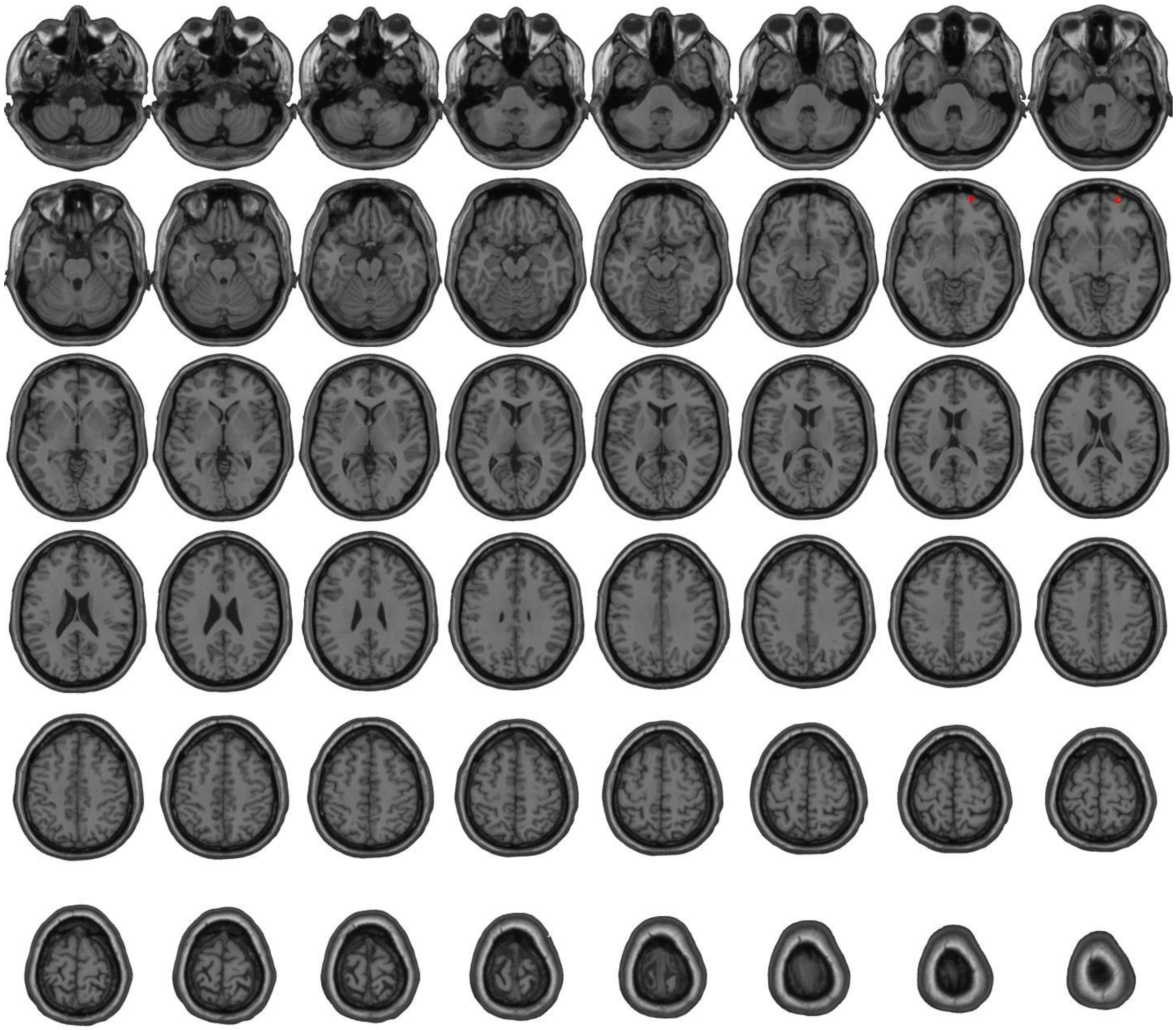

Figure 4-20. Women only activation map for control group. Activation map for the control group contrasting preintervention and postintervention scans. Participants were passively viewing 40 images in each scan of women only. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the postintervention scan compared to the preintervention scan. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

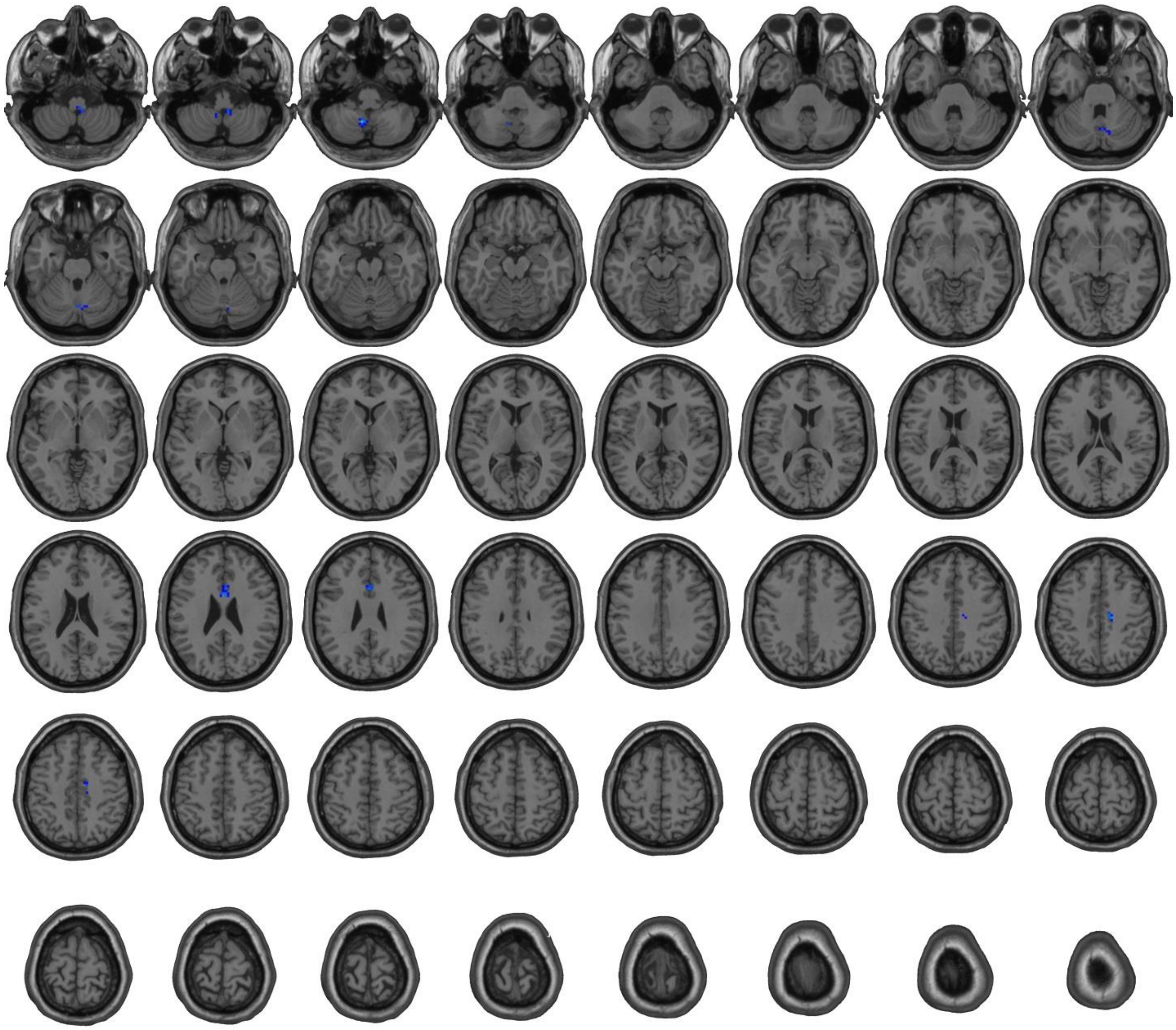

Figure 4-21. Women and plants activation map for control group. Activation map for the control group contrasting preintervention and postintervention scans. Participants were passively viewing 40 images in each scan of women interacting with plants. Cool colors indicate areas with decreased activation while warm colors indicate increased activation in the postintervention scan compared to the preintervention scan. P $\leq$ 0.005, voxel cluster size = $\geq$ 10

CHAPTER 5
DISCUSSION AND CONCLUSIONS

This final chapter includes a discussion of the reported results, the implications of the research, limitations that exist in the experimental design and methodology, and most importantly, the future necessary research. Objectives of this research project listed below guide this discussion chapter and were used to focus exploration of the relevant literature:

- Use psychometric assessments to evaluate the therapeutic impacts of the group-based gardening intervention on study participants' self-report general health, perceived stress, depression symptomatology, anxiety, and mood states profile of a wellness population consisting of only women.
- Use functional MRI to determine the effects of a group-based gardening program intervention on the patterns of brain activation of the study participants.
- Search for linkages between the patterns of brain activation and quantified therapeutic benefits.

Assessment of the first objective of this research study was accomplished by a volunteer screening process yielding a well-defined study population, and through using the results of the five self-reported questionnaires which revealed changes in quality of life and health. An important aspect of this project that strengthened the results from the psychometric assessments was the carefully chosen and screened sample population. The screening process created a population that, although small, was reduced in its variability between subjects and controlled for the effects of noise from dissimilarities between participants. This allowed statistical separation of the means that would normally only be achieved with a much larger study population.

The results from the psychometric assessments demonstrated clear trends toward improved self-reported emotional and mental health for the women who participated in the six-week gardening intervention with clear benefits towards their quality of life. Even though no change was evident in the treatment group's report of physical health as measured by the SF-36 health survey, several aspects of mental health were notably improved in a clinically meaningful way. Parallel improvements in mental health for the treatment group were observed with decreases in scores for perceived stress, depressive symptomatology, total mood disturbance, and anxiety recorded by the four psychometric assessment instruments employed in this study. Perceived stress scores were reduced to nearly half that of the baseline levels in the treatment group, but was unchanged in the control group. Similarly, total mood disturbance and State anxiety scores were decreased by about one-fourth from baseline measurements for the treatment group, again showing no change in the control group. The most compelling change in self-reported scores was the almost 90% decrease in the depressive symptomatology of the treatment group by the end of the gardening intervention. The results also demonstrated a reduction in scores for the POMS and BDI that declined in a continuous or stepwise fashion respectively as treatment dosage increased. Especially when viewing the change in the BDI score from the first sampling point to the second sampling point for the treatment group, the intervention appears to have an almost immediate effect on the participants. These time-course results will guide further inquiries into what "dosage" of plant interactions may be needed to produce clinically meaningful results.

The congruence of the five measures to demonstrate significant improvement in all of these mental health-related areas provides unusually robust evidence to support the self-perceived benefits of the gardening intervention provided in this study.

Upon closer inspection, one could argue that the results demonstrated in the treatment group by thepsychometric assessments simply reflect a regression toward the mean. While this is a point to be considered, regression to the mean should not be the first conclusion and the results deemed un-meaningful. As is evidenced in the scores for the PSS, STAI-State, POMS, and BDI, many postintervention scores for the treatment group dropped to below the scores recorded for the control group. Indeed, the movement of the treatment group scores to levels similar to and below that of the control group could reasonably signal gardening intervention treatment mediated improvements within the group towards healthy states of anxiety, stress, depressive and mood state.

The present results are comparable to previously conducted studies in the field of people-plant interactions and should not be considered unique or unanticipated (Gonzalez et al., 2011; Park and Matteson, 2009; Wichrowski et al., 2005). However, the degree and range of significant therapeutic benefits recorded with this small sample size study provide further supporting evidence for the self-reported benefits of interacting with plants that have been previously reported in the literature.

One aspect of the current results that is evident from the psychometric assessment data is the poor mental health and increased perceived stress, depressive symptomatology, and anxiety of the treatment group compared to that of the control group at the preintervention baseline measurement. Excluding the score for total mood disturbance measured by the POMS, the treatment group scored notably lower on the mental health measure (SF-36), and uniformly higher on all other measures when compared to the control group. This demonstrates an obvious difference between the two groups at the preintervention sampling point, and therefore the groups cannot be viewed as equivalent. The difference between these two groups likely stems from the group assignment process used in this study. Interested participants were not randomly assigned to their group, but instead allowed to select whether to participate in the treatment or control group in light and consideration of the large difference in commitment required for 16 visits versus four visits respectively (see methodology section for further justification). This self-selection method appears to have resulted in the difference between these two groups, as Chi-squared tests of the distribution of participant psychometric scores at the preintervention baseline demonstrated a clearly nonrandom outcome for BDI, χ^2 (N = 23) = 5.239; p = 0.022, PSS, χ^2 (N = 23) = 4.196; p = 0.041, and STAI-Trait, χ^2 (N = 23) = 12.68; p = 0.00037. One theory for the non-random distribution across the two groups is that the women who chose to be in the treatment group selected the gardening intervention because they felt compelled that some benefit may come from interacting with plants and engaging in gardening activities. In this way, they may have been acting subconsciously or intuitively to self-medicate through the gardening intervention in order to alleviate their elevated levels of stress, anxiety, and depressive symptomatology. While there was no empirical data gathered to support this theory, this idea may not be such a reach given that in our society there is voluminous anecdotal evidence widely reported in the popular media from gardeners that gardening reduces stress, tension, and anxiety and improves how gardeners feel.

Notes were recorded at the end of each session that captured among other observations, unsolicited comments that the participants made during the gardening sessions. The recorded comments are anecdotal, but add a useful dimension of information that can connect expressed feelings with the documented therapeutic benefits. In fact, many of the statements made by the participants during the sessions are reflected in the changes demonstrated by the self-reported questionnaires. Participants made comments such as “I was feeling stressed after coming from work but now I don’t feel stressed anymore.” Participants also stated their desire from the gardening session to continue on after the end of the six weeks. Other participants stated how they enjoyed taking care of their plants at home and how they would go spend time outside around them in order to feel their calming effects. Comments such as these during the intervention period reflect the changes that were demonstrated by the psychometric assessments.

The results gathered from the fMRI procedure of this study revealed novel results that have not been reported in any previous studies on gardening. While the fMRI results present an avalanche of information to be analyzed and used to determine unique effects of interactions with plants, this discussion will focus on the changes seen when the participants viewed images of women interacting with plants while being scanned. This stimulus was chosen as the best representation of the intervention administered to the women in the gardening group. Therefore, changes in the activation patterns revealed as a result of viewing these images may be the most informative for this study. However, it should also be pointed out that the significant changes detected in the patterns of activation for the treatment group were detected at a time point while they were not actively gardening. Therefore, this suggests that the effects of the gardening intervention have impacts that last past the actual time of the gardening activity. While interactions with plants may have immediate real-time neurological effects, this study's method of measuring patterns of activation as much as a week following the last active intervention suggests a persistence of longer-term changes in the patterns of brain function. These results could be argued to have a wider range of application as the results do not simply reflect measured changes during the actual gardening activities, but are detected while participants are not actively engaged in the intervention.

A contrast that should be noted before focusing on the women interacting with plants stimulus is the contrast of when viewing images of plants only and women only by all subjects at the preintervention baseline scan (see Figure 5-1). Contrasting the activation patterns when viewing plants only compared to women only reveal unique areas that are activated for each stimulus. These patterns confirm that the stimuli images used were inherently different, and were processed in different ways in the brains of the women in the study. The stimuli chosen were not so similar that they produced the same activation patterns that would deem the fMRI paradigm essentially ineffective. This important observation validates the images chosen to represent the various stimulus types in the fMRI paradigm.

Upon initial inspection of the fMRI results, clear differences are demonstrated in the activation patterns of the treatment and control groups when analyzed at both pre- and postintervention scans. Changes in activation patterns over time can also be seen in both the control and treatment groups separately. Preintervention differences between the treatment and control groups demonstrate elevated activation patterns for the treatment group when they viewed every type of stimulus (women only, plants only, and women interacting with plants). The areas showing these increased activation patterns for the treatment group include mostly visual and recognition areas of the brain (occipital lobe, lingual gyrus, cuneus). The observed differences in the control and treatment groups at preintervention are not unexpected given the self-reported measures for the psychological profiles of the respective groups also showed significant differences between the two groups at baseline measurements. When taken together, the fMRI results and the psychometric assessments together confirm that the control and treatment groups were different from the very beginning of the experiment.

Postintervention comparisons between the treatment and control group when viewing each type of stimulus also show significant differences. The stimulus considered of greatest interest because it best represents the gardening intervention is that of women interacting with plants. The treatment group demonstrates a deactivation in the inferior frontal gyrus, and an increase in activation in the cuneus when viewing this stimulus type. The coordinates reported in the inferior frontal gyrus can be more exactly defined as the ventrolateral prefrontal cortex (vlPFC). The vlPFC is an area of the brain often associated with executive functioning such as attention, memory, inhibition, and decision making (Tanji and Hoshi, 2008). Decreased activation in this area of the brain could indicate changes in recruitment of the vlPFC when viewing images of women interacting with plants.

When comparing the pre- and postintervention scans of the treatment group, changes in activation patterns are evident. Areas of change that are the greatest in voxel cluster size are deactivations in the inferior frontal gyrus and the medial frontal gyrus. The peak intensity coordinate for the deactivation in the inferior frontal gyrus in this pre/post contrast for the treatment group is nearly identical to the inferior frontal gyrus coordinates reported in the postintervention contrast between control and treatment groups. This decrease in activation in the inferior frontal gyrus in both contrasts gives further indication of the change in recruitment of the vlPFC in the treatment group. Not only did the treatment group show decreased activation in the vlPFC over time, but this change is also significant when compared to the control group at postintervention. Other areas with decreased activation in the treatment group when comparing pre- and post-scans are the fusiform gyrus, frontal lobe, posterior cingulate cortex, and medial frontal gyrus. The fusiform gyrus is typically involved in the recognition of human faces (Kanwisher et al., 1997), while the frontal lobe and medial frontal gyrus are involved in many functions including emotional regulation, executive functioning, metacognitive functions and reward processing (Stuss, 2011). The posterior cingulate cortex is associated with the default mode network which is active during wakeful rest, but less active during task-focused states (Leech and Sharp, 2014). Increased activation for the treatment group in the pre/post contrast is reported for the areas of the posterior insula and the temporal lobe. All of the reported changes are unique to the treatment group and are not found in the control group when comparing pre- and postintervention scans while viewing women interacting with plants. Alternately, the areas which demonstrate changes in activation in the pre/post contrast in the control group include the medulla, the posterior lobe, the pyramis of vermis, the anterior cingulate, and the cingulate gyrus. These areas are not congruent with the areas with reported change in the treatment group.

It is important to give special attention to the fact that the changes in activation discussed in the previous paragraph are found solely in the treatment group and are not present in the control group. The data gathered from the fMRI seem to suggest unique patterns and changes in patterns for the treatment group when compared to the control group. If no treatment effect could be measured on those women who participated in the gardening intervention, the treatment group would not show unique patterns of change in activation. However, this is not the case. The results indicate strong tendencies for the treatment group to decrease in activation patterns in locations of the brain that are not similarly reported in the control group.

While these distinct patterns do accomplish the second objective of this project to determine the effects of the gardening intervention on patterns of brain activation, an exploration of the literature is necessary to begin to understand the reason for these distinctive outcomes. The third objective of this study seeks to find a link between the therapeutic benefits of the gardening intervention as revealed by the psychometric assessments and fMRI results of altered patterns of brain activation. Comparison of this study to those found in the literature proved to be difficult as this type of study has no obvious precedent and seems to have not been performed before. The majority of fMRI studies are able to rely on previously conducted studies to guide paradigm design and regions of interest to be analyzed in the brain. However, because this type of study is unprecedented, it was deemed best to approach analysis on a whole-brain level and not limit inquires to one area of the brain. Another factor limiting the comparison of this study to others found in the literature is this study’s use of a passive viewing paradigm. Many current studies that utilize fMRI have a task that participants will execute while in the scanner such as test to indicate cognitive functioning or emotional processing. Because participants in this study were not asked to engage with presented material in any other way than by simply viewing, the results from the fMRI analysis are specific to this task and should not be considered a priori to be comparable to a task requiring active participation. However, the literature may yet give insight into what functions certain areas of the brain are involved in, and provide guidance to analyze the unique areas of activation found in this study.

When considering the changes in self-reported psychometric assessments of the treatment group, studies analyzing the influence of stress, depression symptoms, anxiety, and mood appear to be the best place to start when looking for similar results in the literature. A study published by Koric and her colleagues (2012) described a positive correlation between reported anxiety (using the STAI) and activation of the ventrolateral prefrontal cortex. Therefore the deactivation in vlPFC reported in this study may be tied to the changes reported in anxiety levels of the treatment group. A resting state study that evaluated the impacts of stress demonstrated increased functional activity in the medial prefrontal cortex and posterior cingulate cortex (very near the reported coordinates for the medial frontal gyrus and posterior cingulate cortex in this study) for a group with higher Perceived Stress Scores (Soares et al., 2013). Decreases in perceived stress of this present study may also have influenced the activation levels in the medial frontal gyrus and posterior cingulate cortex of the treatment group. Participants with elevated depression symptoms demonstrated weaker vlPFC activation during cognitive tasks, indicating the effect of depression on this area of the brain and its use during a task (Beevers et al., 2010). While the treatment group in this gardening study did show a decrease in activation in this area, it was not during a cognitive task and may therefore account for the difference in results. The gardening study showed opposing results for the treatment group which had reduced depression symptomatology and reduced activation in the vlPFC. Both positive and negative mood has been associated with areas of the brain reported in this study such as the vlPFC and the medial prefrontal cortex (Habel et al., 2005; Pelletier et al., 2003). While these studies have been conducted with active tasks and not passive viewing, results from these studies still indicate recruitment of these areas when experiencing stress, anxiety, or changes in mood. The association of these areas of the brain with quality of life parameters (such as stress, mood, depression symptoms, and anxiety) may indicate a link between the fMRI data and psychometric assessments scores as a result of the gardening intervention.

Another approach to exploring the data to provide insight into the observed results is to find studies that report similar patterns of increased or decreased activation, even if the intervention or task is seemingly dissimilar to that utilized in this study. One area where similar patterns can be found is in the field of mindfulness and meditation research. Studies that analyzed participants who meditate have demonstrated similar deactivation patterns as those reported in the treatment group of this study. Posterior cingulate cortex (pCC) deactivation is correlated with the meditation state in experienced meditators. These meditators also self-report feelings such as “undistracted awareness”, “effortless doing”, and “contentment” while in the meditative state that correlates with decreased pCC activity (Garrison et al., 2013). While the participants in our gardening study were not performing a task similar to meditation, it can be speculated that gardening can bring about similar experiences reported by the meditators in Garrison's study including "contentment" and "effortless doing". Some anecdotal and observational data suggest similar themes for those who regularly garden (Kaplan, 1973; Unruh et al., 2000). Confirmation of Garrison's results is also demonstrated in Brewers' study in 2011 where deactivations are present in the medial prefrontal cortex and pCC of meditators of all types. Gard and his colleagues (2001) have shown a decreased activation in the lateral prefrontal cortex and increased activation in the insula when meditators are experiencing pain. These results were found uniquely when the participants were in the act of meditating and not when at a non-meditating control state. All of the above patterns are similar in location and direction of change (increased or decreased activation) to those of the treatment group in this study when viewing images of women interacting with plants at postintervention.

One theory that is commonly cited as the justification for why people have an innate affinity for interactions with nature is Kaplan and Kaplan's attention restoration theory. Kaplan and Kaplan have conducted multiple research studies that suggest the ability of nature to provide a restorative experience that allows for directed attention to be returned and restored after being depleted by a demanding task (Kaplan, 1995). This theory can be compared to the results of this current study which show a change in activation levels of areas of the brain typically involved in executive functioning. The vlPFC is an area of the brain attributed with many cognitive processes that include attention, decision making, and inhibition. In general, the frontal lobe is involved in executive functioning depending on location and type of task. While a connection cannot be explicitly proven from this given study, the relationship between changes in activation in the vlPFC, the frontal lobe, and effects of nature/plants on cognitive function (such as attention) clearly warrant further exploration.

As mentioned in the introduction section of this thesis as a relevant study analyzing the effects of plant interaction on brain activity, Bratman and his colleagues (2015) offer a resource that may point to some appropriate areas to look for overlapping patterns. Bratman and his colleagues determined changes in cerebral blood flow (CBF) as a result of a walk through nature versus a walk down a busy urban road. It should be noted the study conducted by Bratman employed the use of arterial spin labeling to determine CBF and did not utilize functional MRI as this study did. The subgenal prefrontal cortex was the region of interest in Bratman's study. This area showed no significant change in any contrast in this study. However, out of the non-hypothesized regions that showed changes in CBF in Bratman's experiment, one area clearly overlaps with one in this study. The posterior cingulate cortex shows decreased CBF in the Bratman paper as well as a deactivation in activity in this study. Bratman also reports a change in an area termed medial frontal gyrus but the coordinates for this area are not reported to be close to this study's reported coordinates for medial frontal gyrus.

Limitations

As with all studies, this experiment had limitations that may have impacted the results of the study. As previously mentioned, the group assignment process for this study was a self-selection process by participants and not randomized. Randomizing participants to the control and treatment would strengthen a future study. The small sample size may also be a limitation although the number in this study is typical of other pilot studies found the fMRI literature. Unfortunately, this study had no previous published studies to help guide paradigm design or identify region of interest to analyze in fMRI results. This limitation caused certain decisions to be made on expertise and best judgment as opposed to results found in previous research. The control group did not participate in an alternate “equivalent” activity during the intervention period. Including an appropriate equivalent activity (such as reading inside or listening to music) may help to alleviate some of the effects of the “break in daily life” aspect that the gardening intervention may have accomplished. Also, the intervention had many components that all may have contributed to the recorded effects of the intervention such as the social component, physical activity, and the educational aspect that cannot be teased apart from the direct effects of the interaction with plants. This therefore limits the ability to attribute all change directly to an interaction with plants. Because the gardening intervention spanned six-weeks, it was difficult to control any outside influence to the participants that may have occurred during this same time that may have affected results, such as changes in personal relationships or workplace stress. One clear limitation is the use of women only. The choice of this demographic was necessary to minimize variability in the fMRI results, however this aspect of the experimental design does limit the application of these results to a population of women only belonging to a wellness group. These limitations should be considered when evaluating the results and findings, yet the information presented in this study is important to the development of this research field and provides new and meaningful insights regarding a group-based gardening treatment intervention and the resultant genuine therapeutic benefits for mental health and overall wellbeing. This study takes the first step in an effort to link the therapeutic benefits of gardening to changes in brain activation patterns and the mapping of functional regions of interest that can begin to provide a mechanistic explaination why gardening and people-plant interactions are therapeutic.

Future Studies

Recommendations can be made for future studies using the results of this study as a guide. The first recommendation is for a study that replicates this study using an increased population size and a randomized assignment to groups. Other studies might include a control group that participates in an alternative activity such as reading or listening to music in a group setting. Narrowing the intervention into stricter components that include no social aspect or limit physical exertion is also necessary. Studies including interventions with varying gardening session duration time and frequency of occurrence should also be investigated in order to better determine “dosage” effects. In addition to altering aspects of the gardening intervention, the fMRI portion of the study needs to also be further expanded and tested. Adjustment of fMRI parameters may need to be made such as determining regions of interest or changing the number and length of scans. Alternate paradigms could be used to determine different effects of the intervention. Such paradigms could include asking participants to perform a cognitive or emotional task while in the scanner. Creating stimuli that are more controlled in their complexity and visual composition would also improve reliability of the results. Better methods may also be found to replicate the experience of the plant-interaction while the participant is being scanned. This would better determine the patterns of activation that are unique to interacting with plants.

Concluding Remarks

This study has soundly supported the previously demonstrated beneficial effects of plant-interactions on self-reported quality of life that is found in the literature.

Improved mental health as well as reduced perceived stress, depressive symptomatology, anxiety, and mood disturbance in the treatment group have indicated positive changes that are both significant and meaningful. The unique areas and changes in activation for the treatment group at the scan following the gardening intervention seem to suggest the novel effects of interaction with plants, especially for areas involved in executive functioning such as the ventrolateral prefrontal cortex. This study offers activation patterns that have never been demonstrated before and can be used to guide future studies that seek to determine the impact that interactions with plants have on neurological processes and function.

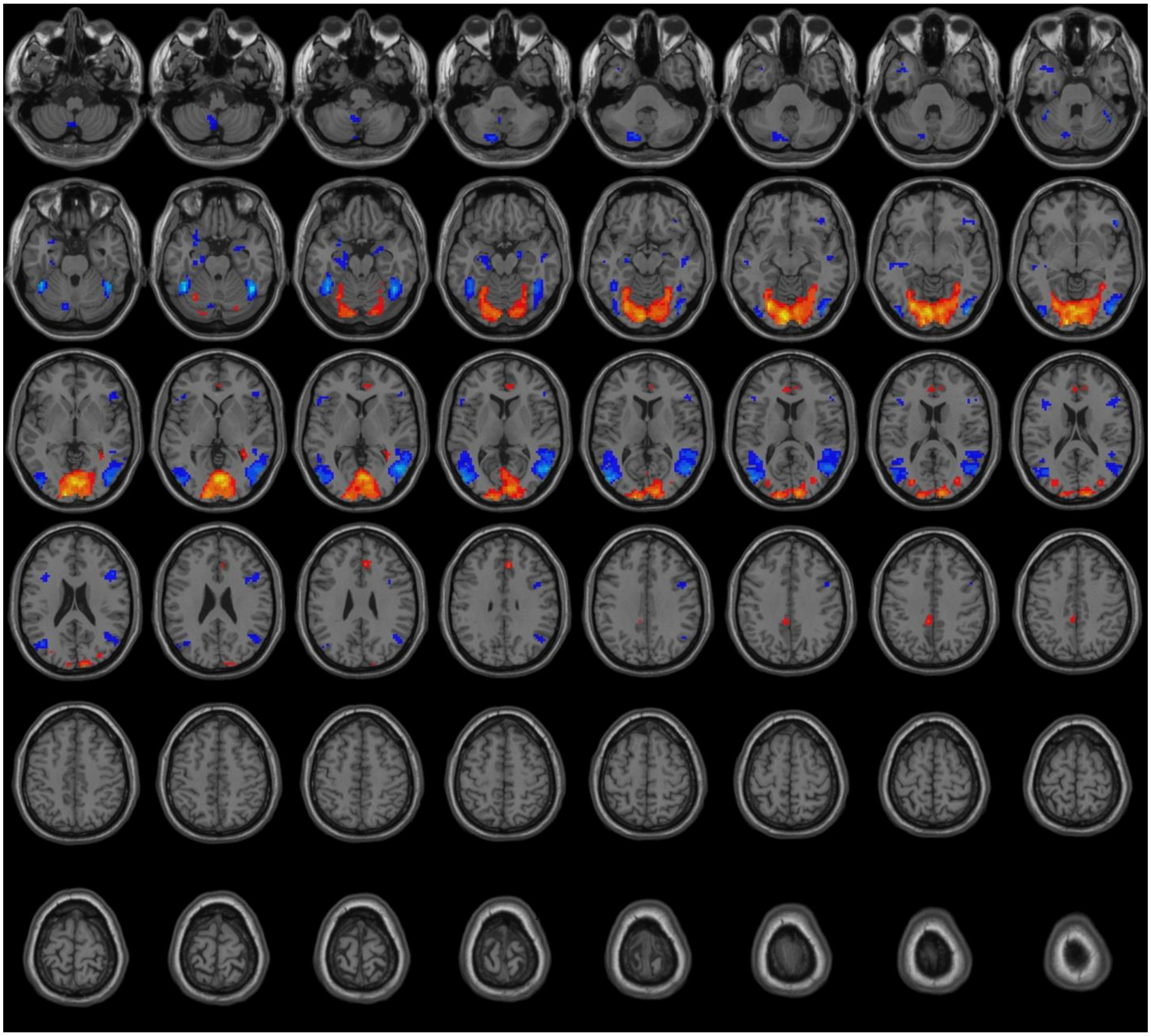

Figure 5-1. Plants only vs. women only activation map. Contrast of activation areas when viewing plants only vs. viewing women only in all subjects at the preintervention scan. Areas with warm color indicate increased activation when viewing plants only. Areas with cool colors indicate increased activation while viewing women only. $p \leq 0.005$ uncorrected, voxel cluster size= 10

APPENDIX A
FUNCTIONAL MRI PREPROCESSING AND ANALYSIS

Preprocessing was carried out by using Data Processing Assistant for Resting-State fMRI (DPARSF) (Yan and Zang, 2010, http://rfmri.org/DPARSF) which is based on Statistical Parametric Mapping (SPM8) (http://www.fil.ion.ucl.ac.uk/spm) and the toolbox for Data Processing & Analysis of Brain Imaging (DPABI, http://rfmri.org/DPABI). Data analysis was done using SPM12. All subjects were processed using the same operations.

Slice-timing correction to reference slice 21 was performed using SPM12's Fourier phase shift interpolation. Head motion was corrected using the maximum mutual information metric and linear interpolation. Voxel to voxel affine transformation matrix was used for intersubject registration along with 4^{th} degree B-spline interpolation. Anatomical T1 images comprised of white matter, grey matter, and CSF were co-registered to functional images using the DARTEL toolbox. Brain image template space is SPM12's MNI gray matter template 2 x 2 x 2 mm. Anatomical locations were determined using the SPM anatomy toolbox and confirmed by Talairach client. 4 mm FWHM Gaussian smoothing was applied to reduce differences in intersubject localization. Spatial normalization was performed using the DARTEL toolbox with parameters of (-90, -126, -72; 90, 90, 108) and a voxel size of 3 x 3 x 3 mm.

The multiple regression model of the General Linear Model (GLM) was utilized for statistical analysis of data. The estimation method used was ordinary least squares (OLS). Statistical modeling was based off the block design paradigm. Hemodynamic response function (HRF) was determined using SPM's canonical HRF. The only regressor corrected for was motion. Drift-modeling was incorporated using a Gaussian weighted running line smoother, cutoff 128 seconds. The autocorrelation model type was an AR(1) at a global level over the whole brain. Group modeling was done using a random effects model that compared preintervention and postintervention scans between the two groups using a 2-sample t-test and the preintervention and postintervention scans within the two groups using a paired t-test. An uncorrected $p \leq 0.005$ and cluster size of 10 voxels were used to determine the threshold for statistical significance. No regions of interest were used in the processing of this data set.

APPENDIX B
GARDENING STUDY RECRUITMENT FLYER

Study ID:IRB201400425 Date Approved: 12/3/2014 Expiration Date: 8/8/2015

UF IRB-01 Approved

Gardening Research Study for Women Ages 26-49

The Environmental Horticulture Department at the University of Florida is seeking **healthy women** between the ages 26-49 with little to **no gardening experience**. Volunteers will undergo two safe, noninvasive brain scans and participate in *"hands on"* gardening sessions in a greenhouse over an 8-week period. Sessions will occur biweekly and each last one hour. Participants may **receive plants**, educational materials, and **VISA gift cards** as compensation. For more information, please contact Christy at (352) 273-4576.

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BIOGRAPHICAL SKETCH

Christine Johns Penman was born in Cape Coral, Florida. Christine grew up the youngest of three children, mostly playing outside in the hot and sunny south Florida weather. Christine’s interest in plants started with a small garden on the patio planted with her father. Her love for growing things became even stronger after volunteering at Educational Concerns for Hunger Organization (ECHO) while in high school. This “international” farm is where she spent many hours learning hands on farming and meeting the interesting people who have a love for the art and science of growing things. Christine graduated from Evangelical Christian High School in 2008.

After graduation from high school, she attended the University of Florida where she received a bachelor’s degree in the horticultural sciences with an emphasis in organic crop production. With a minor focusing on international development and humanitarian assistance, Christine hoped to live internationally and work with subsistence farmers. However, plans changed when Ms. Erin Alvarez introduced her to the field of horticultural therapy.

In August of 2013, Christine entered the master’s program in Environmental Horticulture Department at the University of Florida under the guidance of Dr. Charles Guy. She has since been working towards her goal of becoming a registered horticultural therapist. Christine plans on working as a practitioner in the horticultural therapy, and working with plants for as long as she lives.