Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

Greening the Human Environment: The Untold Benefits

Virginia I. Lohr
Department of Horticulture and Landscape Architecture
Washington State University
Pullman, WA 99164-6414, USA

Keywords: gardens, health, human issues in horticulture, landscape, people-plant interaction, plants, response to nature, well-being

Abstract

A myriad of benefits of plants that have been documented by research are presented in this paper, along with a discussion of possible mechanisms. Plants, which are essential for our survival, provide food, fiber, building material, fuel, and pharmaceuticals. Plants also produce intangible benefits for people, such as improving our health. These benefits occur with scenes of nature, individual plants indoors, gardens outdoors, parks, and forests. The understanding of the role of trees, in particular, in promoting both human and ecological health is increasing. Plants make our surroundings more pleasant, and they help us feel calmer. They contribute to cleaner, healthier air, thus improving our well-being and comfort. Plants have been associated with reduced stress, increased pain tolerance, and improved mental functioning in people. Human responses to plants appear to be both learned and innate. Some studies suggest genetic components to the responses. Some primates are known to detect subtle differences in leaf color, selecting to eat those leaves with the highest nutritive value; people also respond more positively to plants of some colors than to others. Most people in the world now live in urban areas. These areas are typically devoid of plants, resulting in concerns over children being raised in such unnatural areas. These impacts will also be examined.

INTRODUCTION

Plants are essential for the survival of life on earth as we know it. Plants provide us with food, fiber, fuel, shelter, and pharmaceuticals. We use plants to decorate our homes and workplaces and to mark special occasions, such as holidays. For thousands of years, in cultures across the globe, plants and gardening have been considered physically, mentally, and socially good for people, yet until recently, there has been no research to verify such claims. In the past thirty years, numerous scientific studies have begun to document the relationships between people and plants, showing that people exhibit aesthetic, emotional, and physiological responses to plants and nature (for summaries, see: Relf and Lohr, 2003; Lohr, in press). The benefits from trees, gardens, and nature include: better air quality (Wood et al., 2002; Oyabu et al., 2003), lower stress (Ulrich et al., 1991; Park et al., 2010), lessened pain (Ulrich, 1984; Lohr and Pearson-Mims, 2000), reduced mental fatigue (Cimprich, 1993; Herzog, et al., 1997), improved children's cognitive capacities (Wells, 2000; Faber Taylor and Kuo, 2009), and reduced violence (Taylor et al., 1998; Kuo and Sullivan, 2001). Such research is contributing to an increased use of plants to solve health, environmental, and community problems (see, for example, Tyrväinen et al., 2005; Nowak, 2010). Improved understanding of the theoretical basis behind these beneficial effects would lead to more effective use of plants to deal with these issues. This paper examines some of the studies on the beneficial effects of plants and then examines some of the reasons why humans may respond positively to plants.

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

BENEFITS OF PLANTS FOR PEOPLE

Stress Reduction

One of the earliest documented human responses to plants was stress reduction. In one early study, students subjected to mild stress (taking an exam) were shown scenes of nature or of urban areas without plants (Ulrich, 1979). Those who saw nature reported an improved emotional well-being that is associated with stress reduction, while those who saw urban scenes expressed an increase in sadness. In further studies with people viewing nature compared to urban scenes, physiological changes related to recovery from stress, including lower blood pressure and reduced muscle tension, were documented (Ulrich et al., 1991; Parsons et al., 1998). These studies asked people to focus on images of natural or urban areas after exposing them to stressful pretreatments, such as viewing a video on workplace accidents. These studies used slides or videotapes of outdoor nature, including water and birds, in some cases, so the specific role of plants in these studies was not isolated.

A subsequent study showed that stress-reducing responses occur when people are in a room with interior plants added, showing that plants alone could evoke the response (Lohr et al., 1996). In this study, participants were randomly assigned to perform a stressful task in a room with no plants or with plants within their peripheral view. While performing the task, systolic blood pressure rose in both groups, but the increase was not as great in people performing the task with plants. After the task, systolic blood pressure dropped in both groups, but it remained above pre-task levels in people tested without plants, while for those tested with plants, it dropped to levels well below pre-task levels. This documented that containerized interior plants, like images of nature, could produce a calming response. It also showed that it was not necessary for people to focus on the plants for this calming response to occur.

Many studies using live plants and nature have extended the early research on stress reduction. A survey in Sweden, for example, showed that people who frequently visited urban green spaces reported fewer stress-related illnesses than other people (Grahn and Stigsdotter, 2003). A study of young men walking in a forest and in urban areas showed that blood pressure and pulse rate were lower when they walked in the forest than in the urban area (Park et al., 2010). This study found that salivary cortisol, a hormone associated with stress, was also lower when viewing or walking in forests than when doing so in urban areas. Another study, on men and women who spent 3 days in the forest, examined immune responses and showed that they increased while in the forest (Li, 2010). The increased immune function was still detectable 30 days after leaving the forest. Tsunetsugu and others (2010) have tried to isolate components that could contribute to this response. They have shown that blood pressure will begin to decrease within 20 seconds of smelling volatiles associated with certain trees.

Recovery from Illness

Other studies have examined the effects of plants on people with various illnesses. A landmark study examined a decade of patient records from a hospital having some rooms with a view of trees and other rooms with a view of a brick wall (Ulrich, 1984). It showed that people recovered more quickly from major gall bladder surgery if they had been assigned to a room with the tree view rather than the wall view. Patients with tree views also used fewer doses of strong pain medications than did patients with wall views.

Depression in women undergoing surgery for breast cancer has also been studied. Women in a treatment group were asked to perform a restorative activity for

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

20 minutes three times a week (Cimprich, 1993). Most chose walking in a garden. These women recovered much more quickly from the depression that typically follows breast cancer diagnosis, showing signs of recovery from mental fatigue within three months, while depression in those in the control group continued to worsen. A follow-up study asking women to spend 120 minutes a week in a natural, restorative environment confirmed the effectiveness of nature to improve the mental functioning of women undergoing treatment for breast cancer (Cimprich and Ronis, 2003).

A later study examined patients in a cardiopulmonary rehabilitation unit (Wichrowski et al., 2005). Patients participated in a horticultural therapy class in a greenhouse and a garden, and they participated in an interactive lecture on patient education for their medical condition. Their heart rate was measured before and after these sessions. There was no change when patients were in the lecture, but there was a drop of five beats per minutes in the horticultural therapy session. The authors considered this drop particularly noteworthy, since these patients were taking medications to blunt heart rate responses.

Pain Tolerance

The study of patients recovering from surgery (discussed above) showed that patients with a view of trees used fewer doses of strong medication for acute pain than did those with a view of a wall, indicating that views of nature were associated with pain reduction (Ulrich, 1984). Pain tolerance has also been shown to increase in the presence of plants in people without acute pain (Lohr and Pearson-Mims, 2000). In this study, discomfort was induced by placing a subject's hand in ice water. There were three treatments: control, colorful non-plant objects, and interior plants. The room with plants was rated more positively than the control room: for example, it was described as more cheerful and inviting than the control. The room with plants was not always rated more positively than the room with colorful objects; for example, both were similarly interesting, colorful, and ornate. Thus, both were similar in their potential to provide visual distractions. Results showed that plants were more effective at reducing discomfort than the control or the colorful objects. This positive benefit of plants, thus, was determined not to be due to helping keep one's mind off of the discomfort, because colorful objects were not as effective in increasing pain tolerance.

Other studies have replicated and extended research on the effects of plants and nature on pain and discomfort. One documented a reduced use of pain-relieving medications after appendectomies and thyroidectomies in patients in hospital rooms with plants (Park and Mattson, 2009). Another found that patients reported markedly better pain control during an invasive medical procedure (flexible bronchoscopy) when murals of nature scene were placed by their bedsides and they listened to nature sounds before, during, and after the procedure (Diette et al., 2003).

Mental Fatigue and Productivity

Mental fatigue, the inability to concentrate, direct attention, or make decisions, has also been shown to be reduced by plants (Cimprich, 1993; Cimprich and Ronis, 2003). One study asked participants to rate the restorative quality of various scenes (Herzog et al., 1997). Nature settings were rated as the most restorative and as significantly more restorative than sports settings or urban areas. In another study, college students performed various tasks in their dormitory rooms while researchers recorded the amount of nature visible from their window (Tennessen and Cimprich 1995). Students living in rooms looking out over nature, such as trees and grass, were less mentally fatigued and more productive than those with views of a built environment, such as sidewalks and parking lots.

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

Cognitive capacity in children has been documented to be improved in nature. One study showed an improvement in children's ability to concentrate when they moved from housing with few or no green spaces to homes with greener surroundings (Wells, 2000). Attention Deficit Disorder symptoms have been shown to be reduced when children spend time in settings with increasing amounts of nature present (Taylor et al., 2001). Another study showed that the reduction of symptoms of Attention Deficit Hyperactivity Disorder in non-medicated children with the disorder who walked in nature for 15 minutes was similar to the reduction obtained through medications normally prescribed for the disorder (Faber Taylor and Kuo, 2009).

Productivity has also been shown to be higher when plants are present. In one study, productivity was measured by tracking reaction time on a computer task that involved visual concentration, mental processing, and manual dexterity (Lohr et al., 1996). People responded more quickly (12% faster) when plants were in the room than when the plants were absent, and there was no increase in error rate associated with the faster response. They also reported feeling more attentive than did people in the room without plants. Other researchers have documented increased productivity on additional tasks (Shibata and Suzuki, 2002; Bringslimark et al., 2007).

Healthy Communities

Plants and nature enhance communities in ways ranging from cleaner air and water to better social functioning and reduced obesity. This is especially important given our increasing urbanization and sedentary lifestyles. Early studies showed that physical environments (landscaping and nearby land use) could contribute as much as social and cultural factors (population density and income) to the psychological and social health of a community (Brogan and Douglas, 1980). Subsequent research has increased our understanding of specific social impacts of plants on communities. For example, older people living in housing units with common outdoor spaces with trees experienced more positive interactions with their neighbors than did those living in units with paving (Kweon et al., 1998). In young adults, spending time in green outdoor spaces has been related to improved perceptions of the quality of life (McFarland et al., 2008). Green landscapes have been associated with more parental supervision and discipline and with less parental aggression (Taylor et al., 1998). Green landscapes also fostered activities that support healthy development in children. **A**bsences from school were lower among students with plants in their classrooms than among students in rooms without plants (Han, 2009); this study also documented fewer disciplinary problems in the classrooms with plants.

Trees and greenery have been linked to reductions in community violence. One study found that residents in high-rise public housing with trees exhibited less verbal aggression, less physical aggression, and less violence than those in housing without trees (Kuo et al., 1998). Green outdoor spaces have also been linked to reduced vandalism, litter, graffiti, and crime (Kuo and Sullivan, 2001). Drivers' stress response based on physiological indicators, such as heart rate and skin conductance, can be affected by the roadside: viewing strip-mall style roadside environments impeded recovery from stressful situations, while roadside nature scenes enhanced recovery and the ability to cope with introduced stressors (Parsons et al., 1998).

Positive and negatives impacts of the urban environment and its design on community health have received attention from various sources (Frumkin, 2001; Barton and Pretty 2010). Improved health has been documented in areas with increased greenery. One study showed that children living in communities with more green nearby had better body mass index scores than children in areas with low amounts of green (Bell et al., 2008). Another showed that the mortality rates that are

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

associated with income deprivation in urban areas are less among people living in urban areas with more exposure to green (Mitchell and Popham, 2008). Weight-bearing activities have been recommended to women as a way to have high mineral bone density to lower the risk of osteoporosis; bone density in women who did yard work was shown to be as high as bone density in women who did weight training, and it was higher than in women who did jogging, aerobics, or calisthenics (Turner et al., 2002). Other researchers have looked for synergistic effects between exercise and time in nature by having people jog in the presence or absence of pleasant or unpleasant scenes with or without nature (Pretty et al., 2005). They found that blood pressure was reduced and self-esteem was improved for all groups after jogging, but the changes in both were greatest when the jogging was done in the presence of pleasant scenes with nature. More recent research has found that activity in green areas improves mood and self-esteem within just 5 minutes (Barton and Pretty 2010).

WHY WE RESPOND

Two major theories on *how* people respond to plants have been widely discussed. One has focused on attention restoration theory (Kaplan and Kaplan, 1989; Kaplan, 1995). This theory focuses on the ability of plants to relieve mental fatigue. The other has focused on the evolutionary association with nature and the resulting reduction in stress when we are in more natural surroundings (Ulrich, 1993). The question of *why* people respond to nature relates to these theories.

Behavioral Ecology

Humans have evolved in conjunction with nature. It is reasonable to assume that we have developed cues to factors in nature that would be important to know for survival. There is probably a reason why we like to look at clouds, stars, flowers, lakes, and mountains. They hold important information about our surroundings. There is no question that people have physiological responses to at least one aspect of nature: day length (Bronson, 2004). Why wouldn't people also respond to other aspects of nature, such as plants or the weather? Such primitive responses would be associated with mental processing that could be critical for maintaining life in early human existence (Sato, 2005).

There is evidence that our responses to nature have both innate and learned components. An early study by Balling and Falk (1982) hinted at this. They asked American adults and children how much they liked scenes of different biomes. Young children and adults expressed a strong preference for the savanna. Adults also expressed preferences for the biome where they grew up, such as deciduous forest. The authors suggested that the children were expressing an innate preference (for the savanna), while adults were expressing both innate (for the savanna) and learned preferences (the familiar). A subsequent study with subjects who were living in the rainforests of Nigeria and who were unfamiliar with savannas found that they also expressed strong preferences for the savanna biome (Falk and Balling, 2010). This confirmed the cross-cultural nature of the preference for savannas.

If humans have innate responses to savanna scenes, it is likely because the scenes contain important survival information. Some speculate that the savannas, which contained spreading trees and open grasslands, were associated with good habitat for early humans (Orians, 1986). Finding good habitat can require large amounts of energy, so quick recognition of high quality habitats would be valuable. Orians and Heerwagen (1992) suggested that highly productive habitats for early humans were characterized by trees with broad canopies and relatively short trunks. Such easy-to-climb trees would provide people with both prospect (a view out to

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

detect prey) and refuge (quick escape from predators) (Appleton, 1975). *Acacia tortilis*, a tree with this form, grew in the East African savanna in habitats that were good for human habitation (Appleton, 1975; Orians, 1986). In areas that would be too dry to be favorable for humans, trees would be shrubby and dense, while in very wet areas, trees would be tall and narrow, thus the spreading form would be a cue to suitable habitat (Orians 1986). Other researchers also theorize that our responses to savanna-type environments are a result of our evolutionary origins and suitability of these habitats for human survival (Coss and Charles, 2004; Falk and Balling, 2010).

Environmental Cues

Humans do not respond in the same manner to all plants and all forms of nature. For example, humans respond positively to water (Talbot and Kaplan, 1984; Tahvanainen et al., 1996) and negatively to spiders (Vernon and Berenbaum, 2002). There is evidence that people respond more positively to trees than to other plant types in the landscape (Talbot and Kaplan, 1984; Dwyer et al., 1991; Tahvanainen et al., 1996). Researchers have begun to isolate particular components of nature that evoke positive human responses.

1. Tree form. In a number of studies, trees with spreading forms have emerged as landscape components associated with scenes that people like (Orians and Heerwagen, 1992; Sommer, 1997; Lohr and Pearson-Mims, 2006). A preference for these wide trees has been demonstrated in people in Africa, Asia, Europe, and North America (Orians, 1986; Sommer, 1997; Falk and Balling, 2010). A preference for wide spreading trees is consistent with the theory that our responses to savanna-type environments with such trees are a result of our evolutionary origins. Orians (1986) hypothesized that if this is true, the preference should also be expressed in landscapes designed for aesthetics, such as parks and gardens. He found this was true. He also showed that people manipulate trees by genetic selection and pruning to give them savanna forms. In Japan, for example, trees that do not naturally exhibit the savanna growth form are often heavily pruned to create that form (Fig. 1).

If a preference for spreading trees is evolutionarily based, then there should be other responses to them in addition to preference. There should be positive feelings that would draw us toward locations with such trees. Lohr and Pearson-Mims (2006) documented that people do exhibit positive emotional responses to such trees. In this study, people viewed images of urban scenes with non-natural objects or with trees that were columnar, rounded, or spreading added to the images. They confirmed that scenes with the spreading tree were the most preferred. People felt happier and less sad when they looked at any of the scenes with trees compared to the non-tree scenes, but the responses were strongest to the scenes with the spreading trees.

2. Color. Color is another environmental variable that is associated with the differences in the suitability of landscapes for human survival. Bright greens would be associated with healthy plants with good nutrient qualities, while yellow plants could indicate environmental stresses and reduced food potential. Thus, it would be reasonable to hypothesize that some responses to plant color may be pre-programmed, as responses to tree form appear to be, because they both provide useful survival information (Orians and Heerwagen, 1992). Responses to colors that indicate nutritional value have been documented in primates (Lucas et al., 1998). Macaques, which have eyes similar to ours, selected green leaves with the hue that correlated to leaves with high nutrient content. The hypothesis on human responses to color was supported by the results of studies on responses to tree canopies of various hues and

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

intensities. One showed that people prefer looking at green trees to looking at trees of other colors (Kaufman and Lohr, 2004). It also showed that people make distinctions between different greens and prefer trees with hues and intensities that would be associated with healthy trees. A second study used physiological measures to show that trees with a medium green canopy were more calming than other canopy colors, including a less-bright green, orange, and yellow (Kaufman and Lohr, 2008).

3. Fractals. Fractals are geometric forms containing patterns that repeat as the form is magnified. Images of fractals vary from patterns that almost cover the entire image with detailed structure (a fractal dimension value of nearly 2) to ones where the image is sparse and nearly blank (a fractal dimension value close to 1) (Taylor, 2006). Many patterns in nature, such as tree branches and clouds, are fractal and fall within the lower to middle of the fractal dimension range (Wise and Taylor, 2002). Aesthetically pleasing scenes in nature, including savanna scenes, also fall within this range. Human vision has been found to be particularly efficient at processing fractal patterns in the 1.3 to 1.5 dimensional range. Some speculate that this ease of gathering large amounts of information may be related to our sense of aesthetics (Redies, 2007). People also exhibit lower levels of stress when looking at images with fractal patterns within the 1.3 to 1.5 range, whether natural or not (Taylor, 2006). Some researchers speculate that the universal appeal of Japanese Zen rock gardens, such as the one at Ryoan-ji Temple in Kyoto, may be due to the unconscious perception of a tree-like shapes or fractal-like "skeletons" inherent in their design (Van Tonder et al., 2002).

Studies on the relationships between nature and human behavioral ecology and on the effects of particular landscape components on people are increasing our understanding of both how and why plants affect people. The studies discussed above are just a few of those that have been published on this research.

Children in Cities

The world is becoming more and more urbanized, which means fewer and fewer children are being raised in natural areas. The book *Last Child in the Woods* (Louv, 2005) has popularized a growing concern about children's loss of exposure to nature. Adult preferences and attitudes towards plants, which are presumed to be largely learned, are strongly influenced by childhood interactions with nature (Lohr and Pearson-Mims, 2004). Research is showing that reduced childhood interaction with nature does correlate with less appreciation for trees and nature in adults (Lohr et al., 2004). If these childhood interactions with plants are lost or reduced, what will the consequences be?

Research based on phone interviews with 2,004 adults from the largest cities in the U.S. has shown how important it is for children to interact with trees, plants, and nature (Lohr and Pearson-Mims, 2005). Adults were asked how often they had spent time in various childhood activities in nature, such as "picking flowers, fruits, or vegetables from a garden," and about the surroundings where they were raised. Increased frequency of childhood activities in nature had a strong influence on adult attitudes. For example, 69% of adults who often took care of plants as a child felt that trees had personal meaning, while only 44% of those who never did so felt this way about trees. Passive interaction with nature also had a strong influence: of those from a childhood home "next to a garden or flower beds," 65% strongly agreed that trees are calming, while only 56% of those from a home *not* next to a garden or flower beds strongly agreed. Living "next to large buildings" or "busy streets" as a child did not affect adult attitudes toward the calming nature of trees, but did affect feelings about their intrinsic value, with fewer of these respondents saying that trees had personal

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

meaning than those whose homes were *not* next to large buildings or busy streets. These responses have been documented in people from a wide range of demographic and ethnic backgrounds.

These results showed that being raised near urban elements rather than near nature could negatively affect adult attitudes towards nature and trees. They support concerns about children being raised in isolation from nature. The results also showed that any childhood interaction with plants and nature, whether active or passive, had strong influences on adult values. Arranging hikes for children in parks or forests, incorporating gardens into elementary schools, and adding plants to our building facades and roofs are all examples of ways we can ameliorate the effects associated with being raised in stark urban areas.

Conclusions

Many studies have documented a wide range of positive effects of plants on people. They have been published by researchers in horticulture, landscape architecture, environmental psychology, medicine, and many other fields. Only a small fraction of those studies have been discussed in this paper. Those that have been discussed clearly shown that plants contribute positively to our mental health, improve our physical health, and make our communities healthier.

Researchers are beginning to understand why many of these responses to plants occur. Some responses appear to be deeply rooted in our genetic make-up, contributing to our ability to interpret our surroundings quickly and survive in natural environments. Others appear to be learned, contributing to our culture and our ability to adapt to new surroundings. If, through these studies, we gain a better understanding of our response to specific aspects of plants and nature, then we might better predict our response to plantings before they are put in place and maximize their benefits.

Plants have been associated with such positive effects as reducing stress, speeding recovery from illness, reducing violence, and improving mental processing. Research has documented beneficial effects on people exposed to gardens, forests, interior plants, and even pictures of single plants. Benefits come from both active and passive interactions with nature. Research on the effects of plants on people has shown, in essence, that plants are essential for people to be at their best. Plants are needed in our lives, all around us, everyday. They have a civilizing effect; they humanize our surroundings.

Literature Cited

Appleton, J.H. 1975. The Experience of Landscape. John Wiley, New York.

Balling, J.D. and Falk, J.H. 1982. Development of visual preference for natural environments. Environ. Behavior 14:5-28.

Barton, J. and Pretty, J. 2010. What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. Environ. Sci. Technol. 44:3947-3955.

Bell, J.F., Wilson, J.S., and Liu, G.C. 2008. Neighborhood greenness and 2-year changes in body mass index of children and youth. Am. J. Prev. Med. 35:547-553.

Bringslimark, T., Hartig, T., and Patil, G.G. 2007. Psychological benefits of indoor plants in workplaces: Putting experimental results into context. HortSci. 42:581-587.

Brogan, D.R. and Douglas, J.L. 1980. Physical environment correlates of psychosocial health among urban residents. Amer. J. Commun. Psychol. 8:507–522.

Bronson, F.H. 2004. Are humans seasonally photoperiodic? J. Biol. Rhythms 19:180-192.

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

Cimprich, B. 1993. Development of an intervention to restore attention in cancer patients. Cancer Nurs. 16:83-92.

Cimprich, B. and Ronis, D.L. 2003. An environmental intervention to restore attention in women with newly diagnosed breast cancer. Cancer Nurs. 26:284-292.

Coss, R.G. and Charles, E.P. 2004. The role of evolutionary hypotheses in psychological research: Instincts, affordances, and relic sex differences. Ecol. Psychol. 16:199-236.

Diette, G.B., Lechtzin, N., Haponik, E., Devrotes, A., and Rubin, H.R. 2003. Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: A complementary approach to routine analgesia. Chest 123:941-948.

Dwyer, J.F., Schroeder, H.W., and Gobster, P.H. 1991. The significance of urban trees and forests. J. Arbor. 17:276-284.

Faber Taylor, A. and Kuo, F.E. 2009. Children with attention deficits concentrate better after walk in the park. J. Atten. Disorders 12:402-409.

Falk, J.H. and Balling, J.D. 2010. Evolutionary influence on human landscape preference. Environ. Behavior 42:479-493.

Frumkin, H. 2001. Beyond toxicity: human health and the natural environment. Amer. J. of Prev. Med. 20:234-240.

Grahn, P. and Stigsdotter, U.A. 2003. Landscape planning and stress. Urban Forestry Urban Greening 2:1-18.

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

Herzog, T.R., Black, A.M., Fountaine, K.A., and Knotts, D.J. 1997. Reflection and attentional recovery as distinctive benefits of restorative environments. J. Environ. Psychol. 17:165-170.

Kaplan, R. and Kaplan, S. 1989. The Experience of Nature: A Psychological Perspective. Cambridge Univ., New York.

Kaplan, S. 1995. The restorative benefits of nature: Toward an integrative framework. J. Environ. Psychol. 15:169-182.

Kaufman, A.J. and Lohr, V.I. 2004. Does plant color affect emotional and physiological responses to landscapes? Acta Hort. 639:229-233.

Kaufman, A.J. and Lohr, V.I. 2008. Does it matter what color tree you plant? Acta Hort. 790:179-184.

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

Kuo, F.E., Sullivan, W.C., Coley, R.L., and Brunson, L. 1998. Fertile ground for community: Inner-city neighborhood common spaces. Amer. J. Comm. Psychol. 26:823-851.

Kweon, B.S., Sullivan, W.C., and Wiley, A. 1998. Green common spaces and the social integration of inner-city older adults. Environ. Behavior 30:832-858.

Li, Q. 2010. Effect of forest bathing trips on human immune function. Environ. Health Prev. Med. 15:9-17.

Lohr, V.I. In press. What are the benefits of plants indoors and why do we respond positively to them? Acta Hort. (2nd Int. Conf. Landscape Urban Hort.).

Lohr, V.I. and Pearson-Mims, C.H. 2000. Physical discomfort may be reduced in the presence of interior plants. HortTechnol. 10:53–58.

Lohr, V.I. and Pearson-Mims, C.H. 2004. The relative influence of childhood activities and demographics on adult appreciation for the role of trees in human well-being. Acta Hort. 639:253-259.

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

Lohr, V.I. and Pearson-Mims, C.H. 2005. Children's active and passive interactions with plants and gardening influence their attitudes and actions towards plants and the environment as adults. HortTechnol. 15:472-476.

Lohr, V.I. and Pearson-Mims, C.H. 2006. Responses to scenes with spreading, rounded and conical tree forms. Environ. Behavior 38:667-688.

Lohr, V.I., Pearson-Mims, C.H. and Goodwin, G.K. 1996. Interior plants may improve worker productivity and reduce stress in a windowless environment. J. Environ. Hort. 14:97-100.

Lohr, V.I., Pearson-Mims, C.H., Tarnai, J., and Dillman, D.A. 2004. How urban residents rate and rank the benefits and problems associated with trees in cities. J. Arbor. 30:28-35.

Louv, R. 2005. Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. Algonquin Books, Chapel Hill, NC.

Lucas, P.W., Darvell, B.W., Lee, P.K.D., Yuen, T.D.B. and Choog, M.F. 1998. Colour cues for leaf food selection by long-tailed macaques (*Macaca fascicularis*) with a new suggestion for the evolution of trichromatic colour vision. Folia Primatol. 69:139-152.

McFarland, A.L., Waliczek, T.M., and Zajicek, J.M. 2008. Campus green spaces and perceptions of quality of life. HortTechnol. 18:232-238.

Mitchell, R. and Popham, F. 2008. Effect of exposure to natural environment on health inequalities: an observational population study. Lancet 372:1655-1660.

Nowak, D.J. 2010. Urban biodiversity and climate change. p. 101-117. In: N. Müller, P. Werner, and J.G. Kelcey (eds.), Urban Biodiversity and Design. Wiley-Blackwell, Chichester, UK.

Orians, G.H. 1986. An ecological and evolutionary approach to landscape aesthetics. p. 3-22. In: E.C. Penning-Rowsell and D. Lowenthal (eds.), Landscape Meanings and Values. Allen and Unwin, London.

Orians, G.H. and Heerwagen, J.H. 1992. Evolved responses to landscapes. p. 555-579. In: J.H. Barkow, L. Cosmides and J. Tooby (eds.), The Adapted Mind: Evolutionary Psychology and the Generation of Culture. Oxford Univ., New York.

Oyabu, T., Sawada, A., Onodera, T., Takenaka, K., and Wolverton, B. 2003. Characteristics of potted plants for removing offensive odors. Sensors Actuators B 89:131-136.

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

Park, S.H. and Mattson, R.H. 2009. Therapeutic influence of plants in hospital rooms on surgical recovery. HortSci. 44:102-105.

Parsons, R., Tassinary, L.G., Ulrich, R.S., Hebl, M.R. and Grossman-Alexander, M. 1998. The view from the road: Implications for stress recovery and immunization. J. Environ. Psychol. 18:113-140.

Pretty, J., Peacock, J., Sellens, M., and Griffin, M. 2005. The mental and physical health outcomes of green exercise. Int. J. Environ. Heath Res. 15:319-337.

Redies, C. 2007. A universal model of esthetic perception based on the sensory coding of natural stimuli. Spatial Vision 21:97-117.

Relf, P.D. and Lohr, V.I. 2003. Human issues in horticulture. HortSci. 38:984-993.

Sato, M. 2005. The development of conceptual framework in physiological anthropology. J. Physiol. Anthropol. Appl. Human Sci. 24:289-295.

Shibata, S. and Suzuki, N. 2002. Effects of the foliage plant on task performance and mood. J. Environ. Psychol. 22:265–272.

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

Sommer, R. 1997. Further cross-national studies of tree form preferences. Ecological Psychol. 9:153-160.

Tahvanainen, L., Tyrväinen, L., and Nousianinen, I. 1996. Effects of afforestation on the scenic value of rural landscape. Scandinavian J. Forest Res. 11:397-405.

Talbot, J.F. and Kaplan, R. 1984. Needs and fears: The response to trees and nature in the inner city. J. Arbor. 10:222-228.

Taylor, A.F., Kuo, F.E. and Sullivan, W.C. 2001. Coping with ADD: The surprising connection to green play settings. Environ. Behavior 33:54-77.

Taylor, A.F., Wiley, A., Kuo, F.E., and Sullivan, W.C. 1998. Growing up in the inner city: Green spaces as places to grow. Environ. Behavior 30:3-27.

Taylor, R.P. 2006. Reduction of physiological stress using fractal art and architecture. Leonardo 39:245-251.

Tennessen, C.M. and Cimprich, B. 1995. Views to nature: Effects on attention. J. Environ. Psychol. 15:77-85.

Tsunetsugu, Y., Park, B.J., and Miyazaki, Y. 2010. Trends in research related to "Shinrin-yoku" (taking in the forest atmosphere or forest bathing) in Japan. Environ. Health Prev. Med. 15:27-37.

Turner, L.W., Bass, M.A., Ting, L. and Brown, B. 2002. Influence of yard work and weight training on bone mineral density among older U. S. women. J. Women Aging 14:139-148.

Tyrväinen, L., Pauleit, S., Seeland, K. and de Vries, S. 2005. Benefits and uses of urban forests and trees. p. 81-114. In: C.C. Konijnendijk, K. Nilsson, T.B. Randrup, and J. Schipperjin (eds.). Urban Forests and Trees. Springer, Berlin.

Ulrich, R.S. 1979. Visual landscapes and psychological well-being. Landscape Res. 4:17-23.

Ulrich, R.S. 1984. View through a window may influence recovery from surgery. Science 224:420–421.

Ulrich, R.S. 1993. Biophilia, biophobia, and natural landscapes. p. 73-137. In: S.R. Kellert and E.O. Wilson (eds.). The Biophilia Hypothesis. Island/Shearwater, Washington, DC.

Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A., and Zelson, M. 1991. Stress recovery during exposure to natural and urban environments. J. Environ. Psychol. 11:201-230.

Van Tonder, G.J., Lyons, M.J. and Ejima, Y. 2002. Visual structure of a Japanese Zen garden. Nature 419:359-360.

Vernon, L.L. and Berenbaum, H. 2002. Disgust and fear in response to spiders. Cognition Emotion 16:809-830.

Wells, N.M. 2000. At home with nature: Effects of "greenness" on children's cognitive functioning. Environ. Behavior 32:775-795.

Wichrowski, M., Whiteson, J., Haas, F., Mola, A. and Rey, M.J. 2005. Effects of horticultural therapy on mood and heart rate in patients participating in an inpatient cardiopulmonary rehabilitation program. J. Cardiopulmonary Rehabilitation 25:20-275.

Wise, J.A. and Taylor, R.P. 2002. Fractal design strategies for enhancement of knowledge work environments. Proc. 46th Meeting Human Factors and Ergonomics Soc., Santa Monica, CA. p. 854-859.

Wood, R.A., Orwell, R.L., Tarran, J., Torpy, F. and Burchett, M. 2002. Potted-plant/growth media interactions and capacities for removal of volatiles from indoor air. J. Hort. Sci. Biotechnol. 77:120-129.

Final publication availabe from: www.actahort.org:
Lohr, V.I. 2011. Greening the human environment: The untold benefits. Acta Horticulturae 916:159-170.

Figure 1. Heavily pruned trees (left) in the Shinjuku Gyoen National Garden in Tokyo, Japan, with a shape similar to those found in savanna compared to the same trees without heavy pruning (right) in the Yakima Area Arboretum in Yakima, Washington, USA (photographs by Virginia Lohr).