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Relationship between Psychological Stress and Houseplants

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Relationship between Psychological Stress and House Plants

Hippocrates (460-370 BC), the father of modern medicine, believed in vis medicatrix naturae, a Latin rendering of a Greek phrase that references an ancient medical principle of the ability of nature to heal (Neuburger, 1944). This idea purportedly held by Hippocrates can be found in the intrinsic quintessence of humans to the extrinsic environment in which we live, and Hippocrates emphasized the idea of homeostasis between the two. This sentiment was expressed around 2,500 years ago, and it reveals the importance and impact of the natural environment outside us to our inner functioning. Early in the 20th century, Sir John Arthur Thomas gave another interpretation of the word nature within the context of *vis medicatrix*, "defining it instead as the natural, non-built external environment. He maintained that the healing power of nature is also that associated with mindful contact with the animate and inanimate natural portions of the outdoor environment" (Thomas, 1914). While this sentiment suggests the idea of individuals immersed in parks, mountains, and other "green" environments, it reveals the importance and impact of the natural environment. However, the focus of the phrase, *vis medicatrix naturae* should really be on the first part of the statement, that is, the healing aspect. This begs the question: what is being healed in humans and what is the role of nature in this healing? Thomas specifically suggested that the nature-based environment had a significant impact on the mental health of humans. The inference being made by both Hippocrates and Thomas is that there is a symbiotic relationship between nature and the well-being of people. Put simply, nature is healing the stress humans experience by the events and hassles experienced in daily living. Nature impacts and mediates stress levels in humans.

There is a substantial body of literature examining the relationship between exposure to nature and physiological and/or psychological responses. Ulrich (1991) examined psycho-physiological changes affected by nature scenes in comparison to urban scenes. Findings from his initial studies suggested that undergraduate students who viewed photographic scenes of

nature demonstrated a faster improvement in positive mental outlook and a decline in reported fear and arousal as compared to those students who viewed an urban scene. This research was also corroborated with objective markers of stress physiology including electromyography (EMG), skin conductance (SC) and pulse transit time (PTT). The physiological markers (EMG, SC, PTT) showed a consistent pattern of rapid and more complete recovery from stress/arousal upon exposure of vegetation-rich nature scenes. Additional research by Park et al., (2013) revealed enhanced parasympathetic nervous activity and decreased cortisol (i.e., stress hormone) concentration after spending time in a forest environment. Tsunetsugu et al., (2013) found that spending time in the forest led to a decrease in blood pressure and pulse rate. Lower levels of cortisol have also been reported in adults after performing the same mental activities in a garden setting compared to an indoor classroom (Lee et al., 2015).

The initial studies examining the relationship between nature and human responsiveness led to similar research investigating the effect of houseplants on psychological and physiological functioning. According to Manaker (1996; as cited by Han & Ruan, 2019), there is evidence of the use of interior plants at least 2000 years ago. In fact, there was a significant increase in the use of indoor plants in the latter half of the 20th century. Whether it be initially for aesthetics, air quality, or social status, an increasingly substantial body of evidence suggest people-indoor plant interactions are also psychologically and physiologically beneficial. It is also possible that the increased use of houseplants is an effort to gain some of the benefits seen in the natural environment. Since the average American spends 90% of their time indoors, (United States Environmental Protection Agency, 2018), it is important to identify and understand the processes and limitations involved in the people-indoor plant interaction. More people than ever are spending more money on houseplants, and in the past 3 years the sales of houseplants has

increased around 50% to around 1.7 billion U.S. dollars (National Gardening Survey, 2019; as cited by Garden Centers of America, 2019). This growth in the sales and interest in indoor plants may be related to the increases in stress and time spend indoors in the United States and around the world (American Psychological Association, 2020; Asgari et al., 2016). In fact, the World Health Organization has declared stress to be "the Health Epidemic of the 21st Century" (Fink, 2017). A valid research question to ask is: are people bringing nature inside to provide psychological and physiological stress reduction and an increase in well-being?

The purpose of this literature review is to provide an in-depth review of the existing data on the impact of indoor plants on well-being, defined as being both psychological and physiological, in individuals. Specifically, this paper seeks to provide a thorough summary of the empirical studies that have explored this relationship between stress and indoor plants in various settings and with differing populations.

Stress

Stress is a subjective, evolutionary response with many factors that vary from person to person. What is stressful to one person can be enjoyable to another due to differing cultural, developmental, and genetic factors (Gurung, 2019). The body is composed of an interconnected network of physiological systems made to achieve and preserve a relatively stable internal state known as homeostasis. Sometimes this equilibrium will be in a state of disharmony arising from intrinsic, extrinsic, real, or perceived forces, known as stressors, which the body needs to counter to reestablish homeostasis that has been threatened by these forces (Tsigos et al., 2020). The disharmony reflects the body's inability to allocate sufficient resources to restore the balance, meaning that the body is in a stressed state. When the brain perceives stress, it activates coordinated neurophysiological responses in the brain and the periphery to initiate behavioral and physiological responses that facilitates allostasis and adaptation in response to those stressors (Suri & Vaidya, 2015; Tsigos et al., 2020).

This response can either be adaptive or maladaptive and presents on a continuum. The positive side, the adaptive stress response, encourages resilience and positive coping mechanisms to prevent future adverse impacts from stress stimuli. The negative side, the maladaptive stress response, is associated with adverse sensitivity to stress-associated pathology and dysfunctional stress coping mechanisms (Suri & Vaidya, 2015). An ineffective stress response can lead to diseases, poor physiological functioning, behavior changes and adverse personality development due to the disruption of the body's homeostasis. Since stress can have all these negative effects and doesn't feel pleasant to the person experiencing it, stress can be regarded harmful, but not all stress is bad, as mentioned by Suri & Vaidya (2015). Meanwhile, eustress is positive stress that

can be a motivating force that helps in the development of resilience (The American Institute of Stress).

In addition to positive and negative classifications, stress can also be acute, chronic, or traumatic. Acute stress is stress that is triggered and resolved within a short period of time, while chronic stress is stress that is persistent and leads to daily frustration or anxiety (Britannica). Traumatic stress occurs due to a traumatic event. This stress can resolve on its own but can cause acute stress disorder (American Psychological Association). If it persists for over a month, some people may develop post-traumatic stress disorder (Bryant, 2016, as cited in U.S. Department of Veterans Affairs). Therefore, due to the multiple manifestations associated with stress, this term can be defined in many ways. In this section, we will cover four prevalent stress theories to be able to better understand the term stress.

Theories of Stress

Walter Cannon's Fight-or-Flight theory (1914)

In 1914 Walter Cannon published his study on the disruption that stressors had on homeostasis. In his study, he detailed how stress affects the autonomic nervous system (ANS). The autonomic nervous system (ANS) is composed of two parts: the parasympathetic nervous system (PNS) and the sympathetic nervous system (SNS). In the parasympathetic division, Walter noticed that the pupils constricted, salvation was simulated, respiration decreased, the bronchial passages were constricted, heart rate decreased, digestion was simulated, and the bladder contracted. In the sympathetic division the opposite occurred: the pupils dilated, salvation was inhibited, respiration increased, the bronchial passages dilated, heart rate increased, digestion was inhibited, and the bladder relaxed. He also saw an increase in the

secretion of adrenal hormones, increased secretion of sweat gland, and the hair follicles raised forming goosebumps.

It is suggested that these physiological responses occur as a consequence of increased rate of respiration when the SNS is activated, which causes more oxygen to fill the lungs. This increase in oxygen helps circulation in the body raising heart rate and blood pressure to get the oxygenated blood into the muscles. The metabolic rate also increases to help break down energy to prepare the body for its next course of action, which is where the name fight or flight was derived from. The SNS activates these mechanisms while also inhibiting hunger and sex drives to deal with the stressor more effectively. Once the stressor is gone, the PNS causes a downregulation in those same systems of respiration, circulation, and metabolism and resumes the normal functioning of hunger and sex drives.

Cannon was the first to detail out these processes, and he presented a theory which states sympathetic-adrenal-medullary (SAM) activation when a threat is presented. The SNS activates adrenal glands which secrete catecholamines. These catecholamines are made in the inner part of the adrenal glands known as the medulla, and there are two hormones that are in the catecholamines group that play a large part in the stress response, epinephrine (adrenaline) and norepinephrine. Cannon argued that a fight-or-flight response occurs when a stressor causes SAM activation.

There are eight effects of fight-or-flight according to Guyton (1977; as cited by Gurung, 2019), which include “blood pressure, blood flow to large muscles, total energy consumption, blood glucose concentration, energy release in the muscles, muscular strength, mental activity, and the rate of blood coagulation all increase”. These effects are due to chemical secretions. First the hypothalamus is activated which controls the SNS through corticotropin-releasing factors

(CRF). CRF activates two parts of the brain, the anterior pituitary gland which secretes adrenocorticotropic hormone (ACTH) and the locus coeruleus in the brainstem, more specifically the pons, which is associated with an increase in norepinephrine. Epinephrine then leads to the rise in heart rate and blood pressure. When there are constant stressors present, the body increases its production of epinephrine which causes higher levels of ACTH. Research has shown that there are higher levels of epinephrine with fear and higher levels of norepinephrine with anger (Ax, 1953; Ward et al., 1983; as cited by Gurung, 2019). SAM is an interconnected system and current research in this field examines the inclusion of freeze, the inability to fight or flee in the presence of a stressor, in the fight-or-flight response.

Taylor et al.'s Tend-and-Befriend Theory (2000)

Cannon's fight-or-flight theory was the prevalent theory for many years, but as researchers looked closer at the stress response, they found more manifestations than simple freeze in the fight or flight response. Shelly Taylor argued that females incorporate tend-and-befriend in their response to stressors. This response difference between males and females deal with the differences in evolutionary roles that women fulfilled. Throughout history, females were responsible for looking after infants and children while males fought. If a female fought, she could die and leave her young vulnerable, and if she fled then she would have to either leave her young or take them with her which would reduce her speed and ability to flee. Because of the differences in roles, females were more likely to tend, looking after others, and befriend. This is because females who were more prone to this trait procreated more, died less due to avoiding fighting, and learned the role socially for survival.

This theory is backed up by numerous studies and incorporates the attachment and caregiving systems in the brain. These systems have ties to increases in heart rate, blood pressure, and cortisol like Cannon's theory but instead of fighting or fleeing it causes nurturing and social behavior. Looking at neuroendocrine markers, women initially have the same hormone and SNS response to stress, but those stress responses don't manifest as the same behavior. In the fight response, testosterone drives male aggression, but females have a higher level of oxytocin which counteracts cortisol and catecholamines. The presence of oxytocin inhibits the flight response primarily by increasing feelings of relaxation and decreasing fearfulness.

Not only does it counteract the fight and flight response, but females reveal decreased oxytocin levels when they are less social (Jamner et al., 1998; as cited by Gurung, 2019). When oxytocin levels are increased, there's an increase in empathy which helps in befriending (Hecht et al., 2012; as cited by Gurung, 2019), and through multiple animal studies and recently human studies, it's been shown that this hormone is heavily involved with maternal bonding.

In animals, specifically mammals, tending has been seen when young are removed and then returned to the mother. The young and mother both have a stress response to the removal, and when returned the mother displays tending behaviors through actions such as grooming and nursing (Meaney, 2001; Dwyer, 2008; as cited by Gurung, 2019; Anacker & Beery, 2013). Touch has been found to be soothing for the mother and the child, and in humans, mothers who breastfed were found to have less stress (Uvnas-Moberg, 1996; Uvnas-Moberg et al., 2015). Pregnant women who had more oxytocin formed better bonds with their children, and an increase in oxytocin as a child resulted in stronger tending and befriending later in life (Feldman et. al., 2007; Taylor, 2012). There were also studies done where they compared males and

females after a stressful day. Males tended to fight with their family and seek solitude while women sought out family (Repetti & Wang, 2017). These numerous studies have shown that Shelly Taylor's divide between men having a fight-or-flight response and women having more of a tend-and-befriend approach has validity and should be considered when discussing stress responses.

Selye's General Adaptation Syndrome (1956)

Selye's development of the general adaptation syndrome began when he was given ovarian extracts as an assistant professor. He took those ovarian extracts and injected them into rats and found that the rats developed ulcers. These results warranted further investigation, so he replicated the study with a control group who received placebo injections. Selye found that both the experimental and control groups developed ulcers. Due to his lack of knowledge and experience in handling animals, he unintentionally stressed out both rat groups while weighing, injecting, and observing them. Selye observed that along with developing ulcers, the animals also had shrunken adrenal glands and their lymph nodes were deformed. After realizing that stress was the likely factor leading to deformity, he exposed rats to a variety of stressors such as extreme temperatures, sounds, and rain. They all developed similar problems and Selye theorized that the stress system in rats would react in the same way to different stressors, and the stress response system was general and nonspecific.

Selye detailed out the stress response system as occurring from the hypothalamic-pituitary-adrenal axis (HPA axis). The HPA axis is similar to SAM activation and is oftentimes combined. It follows the same route of the hypothalamus activating the pituitary gland which in turn activates the adrenal gland. The main difference between the two is that in the HPA axis, the cortex, which is the outer part of the adrenal gland, is what gets activated, not the medulla. This

outer part secretes a hormone class known as corticosteroids and the main hormone in this class is cortisol. Cortisol is what triggers the production of energy through gluconeogenesis. Gluconeogenesis produces glucose through stored glycogen, and this helps break down protein, mobilize fat, and stabilize lysosomes.

This is generally how all organisms respond to stress according to Selye and he named this the general adaptation syndrome. The body goes into alarm at the presence of a stressor, the HPA axis is activated, and the body deals with the stressor during what is known as the resistance stage. The body resolves most acute and short-term stressors during this stage, but if a stressor persists then the body will go into a state of exhaustion. Therefore, chronic stress can cause so much damage psychologically and physically. Current research that stems from this theory examines the effects of genetic variations and early stress on brain functioning.

Lazarus's Cognitive Appraisal Model (1966)

When Richard Lazarus was studying stress, he only had physiological stress models to reference. He deemed this an insufficient way to define stress, just as we saw with Taylor (2000) and Selye (1956), so he made his own model, which focused on the psychological aspect of stress. In the psychological model of stress, stress is defined as a disproportion in a person's demands and available resources to handle the demands. This lets the stress responses vary between individuals. The way that someone perceives an event and their thinking patterns are called appraisals. There are different factors that influence our appraisal such as duration (acute or chronic), valence (negative or positive), control, predictability, definition (ambiguous or precise), and centrality (proximity to cause). A person can have many different stressors at once with work, school, and home life. These are just events until a person interprets them as stressful.

Making appraisals are the main cognitive event, and there are two major types of appraisals. The first is primary appraisal, which is figuring out if the event is positive, neutral, or negative. If the event is negative, then we further evaluate if it is a harm-loss, threat, or challenge appraisal. Primary appraisals are influenced by how much of a bet we have in the event's outcome (Lazarus, 1991) and skill level in the task (Liu & Li, 2018; as cited by Gurung, 2019).

When there is a potential for loss or an actual loss of something that has a great personal significance, people make a harm-loss appraisal. This can be anything from an illness diagnosis to a breakup. When a person perceives there to be a demanding threat that puts them in danger and they could get hurt, a threat appraisal is made. This can be social such as a reputation being ruined or physical like strenuous exercise. Challenge appraisals are when an event is viewed as a challenge with potential to benefit and grow from it.

After the primary appraisal, people evaluate if there are sufficient resources to cope with the event. This evaluation is called secondary appraisal, and if there are insufficient resources then the event is perceived as threatening, harmful and a stressor. This causes high stress for the individual. If the event is perceived as a challenge and there are sufficient resources, then it stays as an event and causes little to no stress. This model allows for flexibility in whether or not a person experiences stress that is lacking in the above-mentioned theories.

Definition of Stress

Early researchers defined stress from a physiological perspective. Walter Cannon (1929) and Hans Selye (1956) based their definitions of stress off the activation of physiological systems such as the sympathetic-adrenal-medullary (SAM) activation and the Hypothalamic-pituitary-adrenal (HPA) axis. Psychological elements weren't added to this definition until later

researchers, such as Lazarus (1966), started researching how the perception of a stressor, which is the cause a stress response, can affect whether a person has a physiological response to an event. Even then, Taylor (2000) found that it was an insufficient explanation of stress and added the differences between males and females. To address the many factors that relate to stress, a broad definition of stress will be used. For this literature review, stress is defined as a stressor associated with an imbalance of physiological and/or psychological homeostasis.

Human-Nature Interaction

As mentioned in the introduction, nature has an extensive influence on humans mentally, emotionally, and psychologically. The purpose of this section is to cover the three main theories that relate to the reasoning behind the positive benefits that people gain from interaction with nature.

Theories

Kaplan & Kaplan's Attention Restoration Theory (1989)

The basic premise of Kaplan & Kaplan's Attention Restoration Theory (ART) (1989) is that natural environments contain elements that provide a relaxing space through which humans can reduce mental fatigue, which helps restore directed attention. Directed attention is under voluntary control and this refers to the human ability to pay attention to a particular task that requires effort (Kaplan, 1995; Ohly et al., 2016). However, this ability is limited and becomes exhausted with use, especially if overworked or overloaded with mental processes. Focusing requires the individual to exclude other thought stimuli from nearby environments, and voluntary control makes this possible by suppressing distractions that may be inherently more interesting. Having to actively suppress distractions causes directed attention fatigue to set in when there is no motivational draw to rest or restore the ability. Directed attention fatigue can lead to poor decision-making and self-control (Ohly et al., 2016). ART proposes that individuals experiencing

nature benefit from a relaxing and refreshing environment that facilitates and enhances their ability to reflect and recover from directed attention fatigue. This is done through fascination, extent, and compatibility. Nature has fascinating aspects that can be classified as 'soft' fascinations such as clouds, sunsets, trees, and these aspects help capture an involuntary attention sphere in humans, which provides a means through which rest and recovery can take place. The reason is that the inherent characteristics associated with these elements that draw human interest require minimal mental effort to process, thus causing no strain on the voluntary human attention paid to them (Jiang et al., 2020; Kaplan, 1995). The extent of nature helps people feel connected to the world around and allows for the realization of how small people are in comparison to nature.

Ulrich's Stress Reduction Theory (1991)

The second main theory of the field is Ulrich's Stress Reduction Theory (SRT) (1991). For this study, the participants viewed a stressful movie in black and white about work accidents for ten minutes. The participants then saw and listened to videos of six natural and urban settings for ten minutes. During this time, physiological measures such as electrocardiogram (EKG), pulse transit time (PTT) which has to do with systolic blood pressure, spontaneous skin conductance responding (SCR), and frontalis muscle tension (EMG) were taken. EKG and PTT are indicators of cardiovascular activity. The researchers also took self-ratings before the videos and after with the Zuckerman Inventory of Personal Reactions (ZIPERS) which looks at fear, positive affects, anger/aggression, attentiveness/interest, and sadness. They found that recovery from the stress inducing movie was quicker when they viewed natural settings compared to urban settings. The movie and nature "elicited high levels of involuntary or automatic attention,

which contradicts the notion that restorative influences of nature stem from involuntary attention or fascination" (Ulrich et al, 1991). The researchers argued that ART, which is a theory that states the reason nature restores humans is because of fascination, is false because both the stressful and nature film had high levels of involuntary attention.

The primary argument is that the natural environment presents an unthreatening setting that provides humans with the space to calm down, generate positive feelings, and reduce arousal. Ultimately, natural environments will promote stress recovery by reducing the adverse psychological and physiological signs of stress (Jiang et al., 2020). According to Ulrich et al. (1991), humans may not have the same capacity to recover from stress in artificial settings as natural ones because human evolution mostly occurs within the latter context. Essentially, the argument Ulrich drives with SRT is that the natural environment can improve individuals' positive affect and attention following a stressful event. It can operate as a remedy or solution in stress management as the natural environment possesses certain qualities that provide the individual with an incentive to adapt due to the positive affective appraisals derived from them (Ratcliffe et al., 2013). These qualities can either be aesthetic or semantic. Aesthetic elements may feature perceived complexity, patterns, texture, or environmental mystery, while semantic elements show themselves through such aspects as absent threats or resource availability. Whichever the case, human beings can make use of natural spaces to reduce stress because these inherent characteristics reduce blood pressure, lowers cortisol levels in the body, which results in lowered self-reported stress, and increases positive mood (Jiang et al., 2014; Ewert & Chang, 2018). The SRT and ART environmental psychology theories support the idea that nature facilitates restoration from mental fatigue, stress, and negative moods, thus improving individuals' health and well-being.

Wilson's Biophilia Hypothesis (1984)

The final idea of this field is the biophilia hypothesis, and this hypothesis was officially proposed by Wilson in 1984. The basic premise is based on evolutionary theory, and states that since humans used to live in nature, we are drawn to it and possess an innate tendency to seek it out. This tendency has a genetic basis according to Wilson, with nature providing resources that would have been beneficial to survival such as food and water. It can be seen in common idioms such as "beating around the bush" and cultures worldwide such as the sacredness of cows in Hinduism (Brittanica, 2011). Examples of this have also found through studies of biophobias, which is a fear of an element of nature such as arachnophobia. These biophobias come from a time when encounters with these elements could mean death and have carried over to modern times through genetics (Rogers, 2019). This hypothesis is often incorporated into interior design and can include scents, greenery, pictures/paintings, sounds and window views.

Literature Review

University Studies

The first part of this literature review consists of eight studies. They were mainly conducted in North American and Asian universities. The participants in these studies were currently enrolled students, except for one study that included the faculty and staff along with students and one study that did not specify where the participants were recruited from. The study that did not specify was included in this category because the participants were close to the average age of a university student, and it best fit with these studies. All of the studies included physiological and psychological measurements except for one which only included psychological measurements. Plant columns with indoor greenery listed did not specify plant type.

Chart

Reference	Participants	Country	Plants	Methods	Measures	Results
Chang & Chen, (2005)	38 students, 10 males and 28 females	Taiwan	Indoor greenery	6 different office environments with a mixture of window views and indoor plants. Participants viewed all 6 office slides and filled out questionnaires	EMG, EEG (alpha and beta bands), BVP, State-Anxiety Inventory	Window with nature and indoor plants had the greatest effect on EEG-b. Window views with nature had the greatest EEG-a effect and lowest BVP. Window view had a greater psychological effect compared to indoor plants. Participants were less stressed in the window view with nature and indoor plants, city view and indoor plants, and window view of nature

Choi et al., (2016)	103 students, 51 males and 52 females	South Korea	Epipremnum aureum	Participants closed their eyes, were shown one of the indexes, and this repeated until they had seen all 4 indexes to see which was the most preferred.	HRV, EEG (alpha bands), surveys measuring preference for index of greenness and subjective index of greenness.	Males had greater autonomic activity, females had a higher mean amplitude at the left occipital lobe, 50% index of greenness was the most preferred and subjects rated it to be around 15% higher in greenness index than it actual was
Dijkstra et al., (2008)	77 students, 35 males and 42 females	Netherlands	Indoor greenery	Single- factor between-subjects design. Participants were given a photo of a hospital room with either plants or a picture of a hospital room with no plant and were asked to imagine that they were hospitalized in that room.	10-item bipolar adjective scale, Stress Arousal Checklist	Plants reduce stress but this effect is mediated by perceived attractiveness.
Igarashi et al., (2015)	18 female students	Japan	Dracaena plants	Participants viewed a cardboard box, then a screen image of a plant or an actual plant and then repeated.	Spectroscopy measured Oxy-Hb, modified SDM	oxy-Hb was higher viewing an actual plant in the left and right prefrontal cortex, both TV group and real plant group felt more comfortable and relaxed and the real group felt more natural
Kim & Mattson, (2002)	150 students, 75 males and 75 females	USA, Kansas	red-flowering and green foliage varieties of Geraniums	Induced stress through a movie, then had 3 groups, red-flowering group, green foliage group, and no plant group to look at stress relief.	EEG (alpha and beta), EDA, finger skin temperature, ZIPERS	Red-flowering geraniums had a high effect on stress recovery on highly stressed females through their greater recovery in EEG beta activity and EDA responses as well as self-reported positive affects and greater attentiveness from ZIPERS. Males and mildly stressed females had no differences.
Lee et al., (2015)	24 males	Japan	Peperomia dahlstedtii	Crossover experimental design, had two tasks, a computer task and a transplanting task. Participants did one of the tasks on day 1and then the other on day 2	HRV, blood pressure, pulse rate, SDM	Participants in the transplanting task felt comfortable, soothed, and natural and the computer task they felt uncomfortable, awakened, and artificial. Transplanting task had lower log[LF/(LF+HF)] and lower diastolic blood pressure

Lohr et al., (1995)	96 students, 48 males and 48 females	USA, Washington	17 plants from 11 different species	Completed a computer task during one of two conditions, plants in their peripheral view or no plants	Computer program, ZIPERS, Blood pressure, pulse readings	Plant condition had a quicker reaction time, less stressed, and felt more attentive
McSweeney et al., (2019)	147 students, 118 females and 29 males	Canada	Indoor greenery	Completed filler tasks in a randomly assigned condition, experimental condition used a biophilic design or control.	HRV, NR-6, SLSI, SAM, Digit Span Test, EAS	Experimental group had greater changes in HR during and after the filler tasks, higher EAS ratings. HRV correlated with environmental preference and stress reduction
Park et al., (2016)	24 male students	South Korea	Epipremnum aureum	Crossover experimental design with repeated measures. Looked at a cardboard box, and then lifted it and there was a plant or no plant under it.	NIRS for oxy-Hb concentration (left and right prefrontal cortex), modified SDM, POMS	In the plant condition, oxy-Hb in the right prefrontal cortex decreased, felt more natural, comfortable, and relaxed, lower T-A, A-H, and F scores. Higher V scores.
Yin et al., (2020)	100 university faculty, staff, and students, 63 females and 37 males	USA, Massachusetts	Indoor greenery	Between subjects design using VR. Had a stressor then 1 of 4 offices, 3 had biophilic design elements and 1 was a control.	HRV, HR, SCL, SBP, DBP, STAI	Biophilic environment groups had faster RMSSD increase rates during recovery, decrease in SBP, DBP, STAI after recovery

Literature

Chang and Chen (2005) examined the effects of window views and indoor plants on psychophysiological response in a workplace environment. To do this, the researchers used a convenience sample of 38 students, 10 male and 28 females, and measured electromyography (EMG), electroencephalography (EEG), blood volume pulse (BVP) and State-Anxiety Inventory. With EEG, they specifically examined alpha wavelengths (EEG-a) which are inversely associated with arousal levels (EEG-a) and beta (EEG-b) wavelengths directly associated with arousal levels. They simulated an office environment with 6 conditions: window with a city view, window with a city view and indoor plants, window with a nature view, window with a

nature view and plants, office with no window view and no plants, and office without a window view with plants using Photo Impact 5.0.

When participants entered the study, they were seated on a couch 3 meters away from the screen. Participants were hooked up to the biofeedback instruments and were asked to describe the setting with adjectives. They then viewed the slides: a natural scenery slide for 24 seconds for the baseline, blank blue slide 5 s for the rest period, adjective exercise with the office slides without a time limit, viewing and thinking about the office slides for 15 s, filled out State-Trait Anxiety Inventory while viewing office slide no time limit, and they repeated this for all 6 office slides.

For analysis, the 6 office scenes were independent, and the rest were dependent. The results were as follows: EEG-b window with nature and indoor plants had the greatest effect and window view with either nature or city had the highest EEG-a effect. Window view with nature had the lowest BVP. Window view with nature and indoor plants, window with city view and indoor plants, and window view of nature had the highest State-Anxiety values, which means they were less anxious in those environments. Window view had more of a psychological effect than indoor plant presence. Participants were less nervous/anxious when watching a nature view with plants present. Most of the participants were anxious and tense with no window and no plants.

Choi et al., (2016) designed a study to find the optimal index of greenness by using psychophysiological responses and subject preference. The researchers recruited participants which consisted of 103 adults (51 males and 52 females). These participants looked at plants with an index of greenness (5%, 20%, 50%, and 80%) for 3 minutes in a lab setting. While they

viewed the plants, heart rate variability (HRV) and EEG (specifically EEG-a) were measured. Participants then filled out surveys on their preference for index of greenness and subjective index of greenness.

The way that they calculated the index of greenness was by using a photo that had the same general range of vision as a participant would and using the proportion of leaves of the plant, Epipremnum aureum, to the total photo area, and then converted it to percentages. Subjects came in, were explained the procedure, height and body composition were measured using a fat analyzer and anthropometer. Demographics were collected and then physiological devices were attached. Subjects closed their eyes for 3 minutes then they were randomly shown one of the indexes for 3 minutes. They then closed their eyes for 2 minutes and rested and after were shown a different index for another 3 minutes. After they had seen all the indexes, they answered the subjective survey. For the subjective survey, they were shown all 4 pictures and asked to choose their preferred photo, and then rated it on a scale of 7 pairs of opposite emotion words. Then the participants guessed the index of their photo.

One- and two-way analysis of variance were used. HRV values, which are used to measure mental stress indirectly, were normal with no significant difference except for males having a higher SDNN, VLF, low frequency band power (LF), and low frequency band power to high frequency band power ratio (LF/HF ratio), and low values show parasympathetic dominance. This is consistent with previous findings that males have greater autonomic activity compared to females. The root mean square of successive differences between normal heartbeats (RMSSD), which high RMSSD indicates increased PNS activity, was significantly different at the 50% index for males. EEG was also insignificant except for female participants had a significantly higher mean amplitude at the left occipital (O1) electrode compared to males.

Participants preferred the 50% index of greenness the most (45.8% of participants) and reported the subjective index of greenness for all the indexes to be around 15% higher than the actual level. At the 50% greenness index, the words fresh and comfortable were used the most to describe how the participants felt.

Dijkstra et al., (2008) examined the effects of indoor plants on stress through perceived attractiveness. To do this, they recruited 77 students (35 males and 42 females) with an incentive of a lottery with multiple cash prizes. They used a single-factor between-subjects design. The experimental group received a picture of a hospital room with indoor plants and the control group received a picture of a hospital room with no plants, but in the picture of a room, there was a photo of an urban setting. Both groups were asked to imagine themselves in a scenario where they were hospitalized with a legionella infection. The participants were asked to image having symptoms such as headaches and muscle pains from this infection. For measures, the researchers used a 10-item bipolar adjective scale, an 18-item Stress Arousal Checklist. After the participants received the photo and imagined themselves in the scenario, the measures were administered.

For statistical analysis, the researchers used independent sample t-tests and mediation analysis with multiple regressions. They found that participants with the photo of a hospital room with plants perceived less stress, and the presence of plants made a room more attractive. When attractiveness was factored into the analyses, the presence of plants and perceived stress became insignificant and the attractiveness was significant. This means that perceived attractiveness mediates the relationship between plants and stress.

Igarashi et al., (2015) discussed previous literature about natural scenes being able to evoke neurophysiological responses that can relieve stress and suppress anxiety, and they wanted to build on the literature and examine if an image of a plant had the same effects as a real plant. To do this, the researchers recruited 18 female college students. They used 3 dracaena plants, that were side by side on the floor or they viewed the same sized plants side by side on a TV screen. Participants viewed a cardboard box as the control for 30 s, the actual plants for 3 minutes, a cardboard box on the TV for 30 s, then the image of the plants on the tv for 3 minutes. They then reversed the actual and TV, so some participants received the TV treatment and then the real treatment and some the opposite order. Oxy-hemoglobin (oxy-Hb) in the prefrontal cortex was measured with spectroscopy. For analysis they used pre- and post-measurements. They also gave a subjective evaluation of the emotional impact of the tv and real using the modified semantic differential method (SDM).

The researchers used a two-way ANOVA, and found significance between real vs TV, viewing time, and a stimulus and time interaction of the left prefrontal cortex. They also found a substantial difference in oxy-Hb, it was much higher when viewing the actual plant compared to the TV plant in the left prefrontal cortex. This was similar to what happened in the right prefrontal cortex. There was also a substantial effect of visual stimulus and stimulus x time interaction in the right prefrontal cortex. Even though there were differences in oxy-Hb, subjects had similar subjective feelings with both the fake and real plants making them feel more comfortable and relaxed, but the real plants were rated more natural.

Kim and Mattson (2002) designed a study to examine the difference between foliage and flowering plants. They used geraniums which have minimal to no scent and can either have red

flowers or just green foliage. This study was set up in three groups, two experimental groups that were composed of a red-flowering group and a green foliage group and a control group that had no plants. What the researchers induced stress by having participants (75 males and 75 females) watch parts of the movie “My Life”. This movie was shown to cause emotional stress in men physiologically and psychologically through a previous study done by Robertson et al., (2001, as cited in Kim & Mattson, 2002).

While participants viewed the stress inducing movie, their psychophysiological indicators were measured through brainwave activities with EEG (specifically EEG-a). They also measured electrodermal activities (EDA) and finger skin temperature. EEG, EDA, and finger skin temperature were measured continuously and simultaneously. They also used a five-point Likert scale measuring fear, sadness, anger/aggression, positive affects, and attentiveness called the Zuckerman Inventory of Personal Reactions (ZIPERS).

They took this self-rated measurement at the baseline period and the recovery period. The experiment was approximately 25 minutes in which they had a 5-minute baseline, a 10-minute stressor, and a 5-minute recovery period. During the baseline they completed the demographic questionnaire then they listened to a tape describing the procedure. They then filled out ZIPERS and after completion they watched the parts of the movie for 10 minutes. Once the video clips were over, they pulled apart the curtains to one of the three conditions for 5 minutes and then the participants filled out ZIPERS again.

For the analysis, the researchers divided up the groups by mean scores and had three groups, non-stress induced subjects, mild-stress induced subjects, and high-stress induced subjects. Because the non-stressed subjects couldn’t have a stress recovery response, they only did analysis on the mild and high stress induced subjects.

In those groups, they found that there were no significant differences in alpha waves and skin temperature, as well as males across the two groups, and mild-stress induced females between the treatments. High-stress induced females on the other hand had substantial differences with the EEG beta activity and EDA responses. They found a quicker recovery with red flowering geraniums and a slower recovery with the green geraniums that approached the same level as the red flowering group. After the first minute the red flowering group had a 70% recovery which was twice as much as the other two groups. At minute 5 there were no major differences between the three groups. EDA was significantly different at the 5th minute in the high-stress females. There was a greater recovery in EDA, 65% recovery while nonflowering had 11% and no plants had 16%. With ZIPERS they had differences in positive affects and attentiveness. Red flowers showed an increase in positive affects, while nonflowering and no plants had a decrease. In all the groups there were decreases in attentiveness, but the red flowering group had the least decrease.

Lee et al., (2015) examined the effects of interaction with indoor plants on stress. To do this, they recruited 24 young for a three-day study. They used a crossover experimental design to look at the physiological and psychological response differences between two tasks. The participants were taught how to do both tasks so that they felt comfortable accomplishing them. Task one took place in a greenhouse room and participants transplanted and tended to peperomia dahlstedtiis. Task two was a computer task where participants worked on a document in a word processor. This task is one of the most typical computer activities, and this task requires continuous physical activity similar to the transplanting task. The researchers divided up the group into two groups of 12. They did one task on day 1 and the other task on day 2. During the

completion of the tasks, HRV was measured with an electrode attached to the participants' chest when they were in the waiting room prior to the tasks. Blood pressure and pulse rate was measured before and after the activity with a digital blood pressure monitoring device. High-frequency (HF) shows PNS system activity and Low-frequency (LF)/(LF + HF) shows SNS activity, which happens in a stressed state. They also used a self-rating assessment called the semantic differential model (SDM) before and after the tasks.

SDM showed that the participants had different feelings from the transplant and computer task. The transplant task felt comfortable, soothed, and natural while the computer task felt uncomfortable, awakened, and artificial. (LF)/(LF + HF) increased for the computer task and decreased for the transplanting task, and there was a significant difference in diastolic blood pressure with the participants in the transplanting having lower diastolic blood pressure.

Lohr, et al., (1995) examined how indoor plants effected worker productivity and stress in an environment that did not have window access. The researchers had done a preliminary study with 160 undergraduate students that formed the basis of this study. For the currently discussed study, they recruited 96 (48 male and 48 female) undergraduate participants. When the participants were asked if they liked plants, 81% said yes and the rest either had no preference or responded no. Sixty-three percent of the participants had plants in their homes/offices, and there were no significant differences in demographic characteristics other than having plants. Around 75% in the without plant treatment owned plants while 58% that did not own plants were in the plant treatment.

The researchers measured blood pressure, ZIPERS, and pulse during a computer program that was designed to examine productivity and induced stress. This program randomly displayed

one of three shapes. The shapes were different sizes and in differing locations on the computer screen and appeared at random time intervals. When the shape appeared, the participants had to press the corresponding computer key as quickly as possible. They measured this reaction time to examine mental functioning under stressed or fatigued conditions. The researchers also looked at reaction time by having 100 symbols presented in the same randomized sequence and they participants had to press the correct key. The recorded blood pressure indicated that it effectively induced stress in the participants.

There were two treatments, plants present, and plants absent. For the plants present, they had 17 plants with 11 different species placed in the participant's peripheral view. When participants entered the room, they took the ZIPERS questionnaire, blood pressure and pulse readings. Then the computer task with blood pressure and pulse measured halfway, then ZIPERS and blood pressure and pulse readings and a demographic survey.

Results of univariate and multivariate analysis of variance showed that there were no differences in ZIPER for the plant or no plant groups except in the question, "I feel attentive or concentrating", in which the plant group had an increase in score from before the task to after the task. Pulse was insignificant, but blood pressure was similar in both groups and rose during the task which shows that the task caused stress, and the rise was less in the plant group. Both groups had a drop in blood pressure after the task, and the decrease was greater in the plant room. This is a similar trend to the blood pressure, but blood pressure was not significant. Plant presence didn't affect the number of errors made on the computer task, but reaction time was 12% faster in the plant group which means there was increased productivity. Plant condition had a quicker reaction time, less stressed, and felt more attentive.

McSweeney et al., (2019) examined the effects of indoor nature on physiological stress markers. To do this, they used a convenience sample of 147 undergraduate students (118 females, 29 males). Those participants got randomly assigned to control or experimental condition. In the experimental condition, they used biophilic design and had a desk facing a window with a mixed urban landscape view, green-leafed plants, paintings/pictures of local/familiar landscapes, nature sounds, and an oil diffuser with organic pine oil. The control conditions had none of these. They were connected to three electrocardiographic leads to measure HRV.

The study lasted 50 minutes. The first 15 minutes the participants completed The Nature Relatedness Scale (NR-6), The Student-Life Stress Inventory (SLSI) and demographics. Then participants sat for 5 minutes, and then they completed filler tasks such as the Search and Memory test (SAM) for 10 minutes which measures attention performance and the Digit Span Test for 5 minutes which measures attention. The final 10 minutes participants completed the Environmental Assessment Scale (EAS).

After analysis, there were no differences in NR-6 score, SLSI score. There was significant relationship between SLSI scores for heart rate (HR), sex, and age for HF. The groups did not have any differences in HRV at the baseline, and ANCOVA showed a main effect of condition for Average NN intervals (AVNN) in the experimental condition. Both groups had an increase in HR during the filler tasks and then a decrease after, but the experimental group's changes were greater. HRV was significantly correlated between environmental preference and physiological stress reduction. Participants in the experimental condition rated their environment higher on EAS, and they rated it as more colorful and attractive while the control rated it as drabber and more unattractive.

Park et al., (2016) examined the effect of foliage plants by measuring prefrontal cortex activity and mood states. To do this, they recruited 24 male students with a $20 incentive. They used a crossover experimental design with repeated measures. Prior to testing, body weight and height were measured with a body fat analyzer and anthropometer.

There was a cardboard box on a desk, after a 30 second baseline/resting period, there was either a plant known as Epipremnum aureum in a container under the box or an empty container and they sat and viewed it for 3 minutes. oxy-Hb concentration in the left and right prefrontal cortex was measured continuously. After the 3 minutes, participants filled out a modified SDM and the Profile of Mood States (POMS) to look at subjective evaluations of emotional affects and this took around 1 minute. POMS is 30 questions with 6 subcategories tension-anxiety (T-A), depression-dejection (D), anger-hostility (A-H), fatigue (F), confusion (C), and vigor (V).

Oxy-Hb concentration in the right prefrontal cortex in the plant group significantly decreased but no there were no differences in the left prefrontal cortex. Modified SDM showed that the plant group felt significantly more natural, comfortable, and relaxed. POMS showed lower T-A, A-H, and F while V was higher in the plant group

Yin et al., (2020) examined the effects of a biophilic indoor environment on anxiety and stress recovery. To do this, they recruited 100 participants (63% female) that were given $15 for compensation. A between-subjects design was used. There was a virtual reality (VR) stressor, and then participants explored 1 of 4 virtual office environments. There was one non-biophilic based office and three offices with biophilic design elements. For the biophilic offices, one had indoor greenery, one had an outdoor view, and one had both. They used an electrocardiogram

(ECG) to measure HRV and HR. EDA was measured through skin conductance level (SCL), which is used to quantify SNS activity, and they also examined systolic (SBP) and diastolic (DBP) blood pressure (BP), which was measured at the baseline, the stress inducing task, and after the recovery period. Used a shortened form of the STAI. For HRV they calculated RMSSD. LF/HF ratio was also calculated.

For the study, participants had 15-minute preparation, 5-minute baseline, 7-minute stressor, 6-minute recovery in the randomly assigned room, 5-minutes to remove the VR headset, and a 5-minute survey. During the stressor, they viewed a virtual office that was untidy and had a lot of background noise from traffic and machinery, they also did two stress induction tasks (memory and arithmetic task) in the VR. After the stressors, their BP was measured and they completed the STAI, then they viewed the virtual office for the recovery period. Then they took BP and STAI again. Finally, all devices were removed, and they completed demographics and asked questions about general health conditions, caffeinated beverage drinking, good sleep quality the night before, and stress level. The experiment took around 45 minutes.

They excluded participants from data analysis if their physiological stress did not increase after the stressor. There were no differences in demographics, baseline physiological measurements, stress and anxiety levels after the stressor between the 4 groups, and LF/HF ratio, HR, and SCL between the environments. There were increases in physiological stress after the stressor. The researchers also found significant decreases in the biophilic environment group in SBP and DBP, as well as STAI scores after recovery in all 4 conditions. The biophilic environment groups had faster RMSSD increase rates during recovery compared to non-biophilic environments. Indoor green condition was significantly faster in RMSSD rates which would indicate better stress recovery.

Overview

The studies presented mostly consisted of students attending a higher-level educational institution. Some general ways to improve future literature in this category would be to test a broader age range and to have more studies include questions on the known effects of exercise, sleep quality, health conditions, and caffeine and alcohol consumption on participant's stress recovery. It would also be worthwhile to examine the differences between utilizing baseline measurements and examining the difference in these measurements during and after exposure compared to inducing stress and using a treatment. Replicating some of the studies would allow for a better representation of the general population, as there were two studies that utilized a convivence sample, one study that only examined females, and two studies that only examined males. Researchers should also strive to exclude possible biophilic stimuli in rooms such as windows unless it is part of their study.

Some of the interesting results that should impact future research are the effect of environmental preference (Park et. al., 2016). Eunhee & Mattson (2002) also had an interesting finding that males had no significant results in stress recovery using houseplants, but the stressor used was a movie about a son and a father that was found to induce stress in a previous study. This is especially interesting because males are known to have greater autonomic activity (Choi et. al., 2016). These studies also highlighted the differences in male and female responses. Another interesting result is the effect of perceived attractiveness as seen in Dijkstra et al., (2008) and this has monumental implications for the effects of indoor plants and stress relief. Some future directions for these studies would be to closer examine gender differences closer as well as a closer look on environmental preferences and perceived attractiveness.

Workplace Studies

The second part of this literature review consists of three studies. They were conducted in three different countries: Norway, United States of America, and Japan. The participants in these studies consisted of currently employed office workers. Two of these studies were correlational studies, and one was an experimental study. All three of the studies included psychological measurements and only the experimental study included a physiological measurement.

Chart

Reference	Participants	Country	Plants	Methods	Measures	Results
Bringslimark et al., (2007)	385 office workers, 243 were male and 142 females	Norway	Dracaena concinna, Dracaena fragrans, Epipremnum aureum, Ficus benjamina, Spathiphyllum wallisii, Beaucarnea recurvata, and Schefflera arboricola	Had employees fill out an email questionnaire	Questionnaire, that had questions about personal characteristics, gender and age, physical workplace factors, psychosocial workplace factors, indoor plants, perceived stress, sick leave, and productivity	Sick leave decreased and productivity increased in the presence plants. Plants nearby positively correlated with perceived stress. Gender was positively correlated with plants in view, plants nearby, and own plants.
Dravigne et al., (2008)	449 office workers, 260 males and 175 females	USA, Texas and Midwest	Asked if they had plants	Had employees fill out an email questionnaire	80 question survey that had EPA, Job Satisfaction Survey, overall life quality, demographics, and work environment questions	Indoor plants and window views had greater overall life quality, and job satisfaction. Males with plants rated job satisfaction higher.
Toyoda et al., (2020)	63 office workers, 33 males and 30 females	Japan	Tillandsia pseudobaileyi, Chamaecyparis obtusa, Pinus thunbergii, Trichocereus pachanoi, Chamaedorea elegans, Philodendron oxycardium, Codiaeum variegatum, Dracaena fragrans, Echeveria peacockii, and Echeveria ‘Splendor’	5 weeks, week 1 was a control, weeks 2-3 participants learned how to take care of plants, weeks 4-5 participants took care of the plants	STAI, self-rated pulse measurements	After the intervention period STAI scores decreased, and during the intervention period the ratio of participants with a decreased pulse rate increased.

Literature

Bringslimark et al., (2007) examined the psychological benefits that indoor plants may have. To do this, the researchers sent out an anonymous email questionnaire to 605 office workers in three different workplaces in Norway. This questionnaire was filled out by 385 people, and 63% of respondents were male. Each of the chosen workplaces had a plant firm that installed and maintained plants, and the employees were able to choose plants and decorations for their workstation. The plants that were available for choice were Dracaena concinna, Dracaena fragrans, Epipremnum aureum, Ficus benjamina, Spathiphyllum wallisii, Beaucarnea recurvata, and Schefflera arboricola. These plants varied in size and placement.

The questionnaire looked at several factors. The independent variables were personal characteristics, gender and age, physical workplace factors, psychosocial workplace factors, and indoor plants. For the physical workplace factors, they used an MM-questionnaire. This questionnaire asked if they had been disturbed by 12 different workplace factors which included noise, lighting, stale or dry air, smells, temperature, and static electricity. The psychosocial workplace factors were taken from the General Nordic Questionnaire for Psychological and Social Factors at Work. This questionnaire looked at job demands, control at work, support from superiors and coworkers. The indoor plants had 3 questions about plant presence, ownership of plants, plants in view, and plants nearby. For the dependent variables they asked questions about perceived stress (Perceived Stress Scale), asked about their sick leave, and questions about productivity. This questionnaire used a five-point Likert scale and had an incentive by being told they would be entered into a drawing for a gift card (around $160) to a Norwegian department store.

For analysis, they used multivariate analyses. Hierarchical regression analyses were used to determine the amount of influence indoor plants had. They found that all the plant variables correlate with gender, and females tended to have more plants around them. Perceived stress and plant placement are positively correlated, the more plants in 1m from the respondents' desk, the higher the level of perceived stress. They also found that sick leave decreased, and productivity increased in the presence plants.

Dravigne et al., (2008) examined the effect that indoor plants and window views had on the employee's job satisfaction and life quality. They did this by posting a survey for office workers in Texas and the Midwest. They offered an incentive in the form of a 5-dollar Lowes gift card. They were sorted into 4 groups, no plants/no windows to green spaces (50.6%), plants/no windows with green space view (18.2%), no plants/window with a green view (13%), and plants and window with green view (18.2%). They found that there were no statistically significant differences except with gender and if they equalized those levels then the subsample size would have been too small.

In the survey they used 80 questions the categories were: environmental preference (Environmental Preference Assessment), job satisfaction (The Job Satisfaction Survey), overall life quality (questions about overall life quality; used previous studies to come up with the questions), demographic and work environment questions (yes/no about the presence of plants and windows; also asked about gender, age, educational and occupational level, work schedule, commute time, number of coworkers, and salary range).

There were no differences in environmental preference scores, most preferred newer architecture which has more windows, is open, and airy. There were significant differences in job

satisfaction, plants and windows group as well as plants and no windows rated their satisfaction higher. Windows and no plants group was lower while no windows and no plants had poor job satisfaction. For the question, "When all things in your life are considered, how do you feel today?" no plants and no windows as well as no plants with windows had a lower content and very happy scores while no plants and no windows had the only people that felt miserable. For the question, "Overall, how would you rank your overall quality of life", no plants and no windows were the only group to have participants put that they're dissatisfied. Indoor plants and window views had greater overall life quality and job satisfaction and males with plants rated job satisfaction higher.

Toyoda et al., (2020) examined the effect small plants have on stress reduction in offices. A privately owned Japanese company funded the study and they recruited 63 participants (33 males and 30 females) who were desk workers from that company through email with no offered incentives. All the offices were similar and none of them had a window view. There were two phases, week 1 was control with no plants while weeks 2-5 were experimental. Weeks 2-5 were further divided. During week 2 and 3 participants learned about how to care for plants and weeks 4 and 5 participants got used to taking care of the plants. The researchers collected physiological and psychological stress data during these times. Stress measurement was taken at the end of the workday twice during the experimental week, once at the end of the control period and once at the end of the experimental period. Pulse rate was recorded twice a day throughout the study. Used STAI-Y2 which measures trait anxiety for the stress measurements. The participants were taught how to measure their own pulse rates and throughout the study they measured it when they (1) felt fatigue and (2) after intentionally looking at the desktop for 3 min in the control. In

the experimental period, instead of the desktop they looked at the plant. They also provided written feedback through an open-ended questionnaire.

During the control period there was nothing on the participants desktop, and then the participants were given 6 different plant choices to put on their desk. The choices were air plants (Tillandsia pseudobaileyi), bonsai (Chamaecyparis obtusa, Pinus thunbergii), cactus (Trichocereus pachanoi), foliage plant (Chamaedorea elegans, Philodendron oxycardium, Codiaeum variegatum), kokedama (Dracaena fragrans), and succulents (Echeveria peacockii, Echeveria 'Splendor'). Out of all of the participants 3 chose air plants, 7 chose bonsai, 5 chose cacti, 15 chose foliage plants, 22 chose kokedama, and 11 chose succulents. They were told to put it near their PC monitor and if the plant died it was immediately replaced.

The researchers found that STAI scores significantly decreased between pre- and post-intervention. "High" anxiety levels (which is a predefined score) decreased from 20 to 19 participants and "low" anxiety levels increased from 18 to 23 participants. Gender, age, and type of plant chosen didn't matter, it's more about if the participant likes the plant. Decrease in pulse rate means sympathetic sedation and increase means sympathetic excitement, and during the control period, 3 participants had a significant pulse decrease, 4 had an increase, and 56 had no changes. During the intervention period, 17 participants had a pulse decrease, 9 had an increase, and 37 had no changes. Significant pulse decrease was greater in the intervention compared to the control period.

The open-ended questionnaire was divided into 4 categories, psychological benefits, physical benefits, social benefits, and work environment-related benefits. There were the most comments in the psychological benefits category. From the participants that had increased STAI scores there were 12 positive comments out of 23. 33 comments were negative, and there were 5

categories of negative comments about the growth of plants, outbreak of small insects, emergence of mold, practical management of plant cultivation, and knowledge of plant cultivation management. There were 38 total positive comments out of 63 participants, and 33 negative comments with 17 negative comments on the plant dying or being unhealthy and 12 of those comments were given by participants who had a decrease in STAI scores. After the intervention period STAI scores decreased, and during the intervention period the ratio of participants with a decreased pulse rate increased.

Overview

The participants in these studies were composed of office workers from three different countries. Because of known cultural differences, a closer examination on how the countries that the studies were conducted in effect results would be necessary to be able to better generalize to the population. Out of the three studies, two utilized an email questionnaire and those two also offered an incentive. Bringslimark et al., (2007) found that having plants nearby actually increased stress, and that females tended to have more plants around them. Dravigne et al., (2008) found that participants with indoor plants and window views had the greatest life quality and job satisfaction, and males that owned plants had the highest job satisfaction. The results of these two correlational studies are inconsistent, which shows a need for more literature in this area. It would be worthwhile to expand on this literature by having more experiments instead of correlational studies through a survey as well as examine the effects that incentives have on the types of participants recruited.

Toyoda et al., (2020) were the only researchers to have completed an experiment in this field, and they found that STAI scores decreased as well as pulse rate after the intervention period, but the researchers had participants take their own pulse which could introduce bias. They also had participants complain about the growth of plants, outbreak of small insects, emergence of mold, practical management of plant cultivation, and knowledge of plant cultivation management, so better education on how to take care of plants would be a way to further improve this study. An interesting find from this experiment that warrants closer examination in future studies was that the type of plant did not necessarily matter, as long as the participant liked that plant. Overall, the results of the three studies are inconsistent and there needs to be more research in this field because there could be potential to decrease stress and increase productivity.

Youth and Adolescent Studies

The third part of this literature review consists of four studies. They were conducted in Asian schools, and the participants in these studies were currently enrolled students. These students ranged from elementary to high school levels. Two of the studies took place over several weeks, and two took place in less than one day. All four of the included studies implemented an experimental design.

Chart

Reference	Participants	Country	Plants	Methods	Measures	Results
Han, (2017)	35 middle school students, 18 males and 17 females	Taiwan	Malabar chestnuts, aglaonemas, centipede tongavine	5 segments of 4 weeks over a semester. 1st segment was baseline, the other 4 were 2 experimental variations. One was active interaction, and one was passive.	State Anxiety Inventory, Well-Being Measures, Restoration Scale, Restorative Components Scale, preference and perception of plants	Students who actively interacted with plants had greater self-reported stress restoration and both experimental groups had greater attention restoration
Ikei et al., (2014)	85 high school students, 41 males and 44 females	Japan	Dracaena deremensis	Randomized trial order, participants looked at a cardboard box, then either a plant or no plant, and then repeated with the other condition.	HRV, pulse rate, and modified SDM	HF was higher, [LF/(LF+HF)] and pulse rate was lower, and participants reported more positive feelings
Park et al., (2008)	42 female high school students	South Korea	Spathiphyllum wallisii, Nephrolepis exaltata, Pachira aquatica, Scindapsus aureus, Acorus gramineus, Araucaria exelsa, Kalanchoe blossfeldiana, Pilea cadierei, Rhododendron schippenbachii, and Guzmania sp.	15-week study. Two schools were studied. In the experimental group, plants were installed in and around their classrooms, the control had no plants.	Stress measurement questionnaire, cortisol, particulate matter in the air, questionnaire (questions about classroom environment, image profile of classroom, and medications taken), and health condition (number of days late for class, absences, early dismissals, and infirmary visits)	Rooms with plants had lower particulate matter in the air and were rated more positively. Students in the experimental group had less infirmary visits and the students in one of the schools had less stress.

Shao et al., (2020)	26 elementary school students, 15 males and 11 females	China	Plant cuttings	Within-subject design. The participants did both tasks in a random order. Task one was a horticultural activity where the participants propogating stem cuttings and task two was playing a gardening game on a smartphone.	HRV, skin conductivity, skin temperature, SDM, and STAI	During the horticultural activity HRV (high-frequency band) increased, anxiety was lower, and participants reported feeling more positive. LF/HR and skin conductivity decreased.

Literature

Han, (2017) examined the effect of passive and active interaction with indoor plants on junior high school students. To do this, a classroom of 7th grade students (35 students, 18 males and 17 females) students was recruited and randomly assigned to different scenarios involving installed plants or no plants. There were two experimental variations, an active interaction group where students were required to take care of the plants and a passive interaction group that did not take care of the plants. This lasted for a semester, which was divided into 5 segments of 4 weeks. At the end of each segment, they collected the students' subjective perceptions and objective performances as well as at the end of every segment period the students filled out a questionnaire. In the questionnaire there was personal background, the State Anxiety Inventory (measures the anxiety and uneasiness of the respondent), the Well-Being Measures (developed based on attention restoration theory to measure relaxation and mental fatigue), the Restoration Scale (based on ART and stress reduction theory and measures the influence of the environment on the participant's restoration from psychophysiological stress), the Restorative Components Scale, preference and perception of plants.

Segment 1 was the baseline, and after there were 45 plants installed in and around the classroom. Those 45 plants had no scent, a green color, and consisted of 18 Malabar chestnuts, 15 aglaonemas, and 12 centipede tongavine. 3.1% of the floor area of the classroom was

occupied by these plants. A two-factor MANOVA was used for state anxiety, well-being, restoration, restorative components, preference, plant knowledge, plant burden, sick leaves, and rewards.

These statistical analyses showed no significant differences in background or between the segments. Because of this, they averaged the segments for the groups and compared it to the baseline. They also divided up the students based on their proximity to the plants and found that the distance between the students and the plants had no effect. The researchers found that the students who actively interacted with the plants had a significantly greater self-reported stress restoration compared to the students who only passively interacted with the plants, and both groups had a significant increase in attention restoration.

Ikei et al., (2014) examined the effects of foliage plants on high school students. To do this, they recruited 85 high school students (41 males and 44 females). These students were exposed to 3 foliage plants called dracaena deremensis on top of a desk. There was a no-plant group as the control, and they randomized the trial order. All the students started off looking at a cardboard box for 1 minute. Then there was the visual stimulation (either nothing or the plant) underneath the cardboard box, and they looked at it for 3 minutes. Afterwards, they took a subjective test. The study was then repeated to counterbalance, and participants watched a box for 1 minute and received the other experimental condition for 3 minutes and then took another subjective test.

The researchers continuously measured heart rate variability and pulse rate. They also had participants also subjectively evaluated the emotional effects of the plant and no-plant group by using the modified SDM. After using statistical analyses, they found that high frequency

component, which measures parasympathetic nervous activity, was significantly higher while low frequency component, which measures sympathetic nervous activity, and pulse rate was significantly lower. Participants in the plant condition also reported feeling more comfortable, relaxed, and natural.

Park et al., (2008) examined the effects of plantscapes on the stress levels of high school students. To do this, 42 females, 16-17 year old, from two different schools (K and J) were assigned to a control or experimental group, respectively. The study was conducted over 15 weeks. Mental stress, saliva cortisol, and physical symptoms were assessed a week prior to the installation of plants, 6 weeks after plant installation, and at the end of the study. These dates coincided with midterm and final exams. The plants used were Spathiphyllum wallisii, Nephrolepis exaltata, Pachira aquatica, Scindapsus aureus, V schippenbachii, and Guzmania sp.. They looked at the particulate matter in the air, had a questionnaire which had demographics, satisfaction with classroom environment (5 stages), image profile of classroom (5 stages), medical records, medications. They had a stress measurement that had 58 questions about school life, personal relations, domestic problems, individual problems, and environmental problems (5 stages). The saliva cortisol was collected between 2 and 5 pm. Health condition was looked at by the number of days late, absences, leaving early, visits to the infirmary, and medications used.

The room with plants had a statistically lower value of fine particulate matter. Image profiles and environmental questionnaire showed that classrooms that had plants had higher positive descriptor ratings such as clean, soft, bright, comfortable, and fresh. For the question of ‘appropriate place for classes’ in school K 31% of students were very dissatisfied before the plants and it dropped to 0 very dissatisfied students after the plants were added. 31% of students

were dissatisfied and this dropped to 15%. Satisfied students increased from 7% to 23%. A similar trend was found in school J. No students were dissatisfied, and moderate students decreased from 92% to 33%, satisfaction increased from 8% to 42% and very satisfied from 0 to 25% which is a significant increase. For the question of 'relaxed place' school K there was no major change, but there was a change in school J.

Stress with the plant room in school K was lower than the control room, and this was especially seen in the study and school life section as well as the personal relations section. School J had no significant changes between groups or cortisol content of saliva. In school K, cortisol content of saliva increased mid-test and decreased post-test in both groups. Infirmary visits increased in the control groups and decreased in the experimental group in both schools. Stress levels were lower in the experimental plant room group in one of the two schools studied, and control rooms had no differences in stress over the course of the study. Infirmary visits for both schools were lower between the experimental group and control group.

Shao et al., (2020) examined the relationship between horticultural activity and stress recovery in children. To do this, 26 elementary school students (15 males and 11 females) were recruited. The study was conducted after the school day. They used a within-subject design, so both of the two tasks were completed by the participants in a random order. The first task was a horticultural activity. Before the study began, the researchers taught the participants how to prepare cuttings and plant them. For the task, stem cuttings were prepared to propagate plants, and were grown in pots with soils as the activity. The second task had participants play a gardening game on smartphones where they grew seeds and plants. When they did the task, the participants were connected to the ErgoLAB sensors to look at HRV, skin conductivity and skin

temperature. They explained the study for 2 minutes, connected the participants to the ErgoLAB for 3 minutes, had a 1-minute baseline period and then performed the task for 5 minutes. After the task, they used a SDM questionnaire and STAI, which took 5 minutes to fill out. They then were asked to relax again for 1 minute. They performed the second task for 5 minutes and then filled out SDM and STAI for 5 minutes. The study took 27 minutes per subject.

HRV showed that the high-frequency band, which is an indicator of parasympathetic nervous activity, significantly increased during the horticultural activity compared to the smartphone activity. LF/HR ration and skin conductivity decreased during the horticultural activity compared to the smartphone activity. There were no differences between skin temperature. SDM showed that participants felt more comfortable, relaxed, colorful, and cheerful after the horticulture activity compared to the smartphone and significantly preferred the horticultural activity. STAI showed that the anxiety was lower for the horticultural activity.

Overview

These studies utilized youth and adolescents from elementary, middle/junior, and high schools. Overall, these tended to include studies that took place over a longer period of time, and the possible effect this could have could be an area of future research. Other areas for future research could be replicating some of the studies with different age groups to be able to perform cross sectional studies and find how generalizable the results are to differing populations. Han (2017) directly examined the influence of passive and active interaction, and it would be interesting to replicate this study with a no interaction group. He also included proximity to plants, and although he found no effect, this warrants further research in differing contexts. Park

et al., (2008) found that infirmary visits decreased, and further investigation on whether or not it was related to stress would be beneficial to this body of literature. As with the university studies, there should be more research on how inducing stress differs from just interaction and baseline studies, and the perception of stress compared to experienced stress should be examined as well.

Hospital Studies

The fourth, and final, part of this literature review consists of four studies. They were conducted in Denmark and South Korea's hospitals. The participants in these studies were all seeking treatment for various conditions. One of the studies was conducted in Denmark, and only included psychological measurements. This study took place in less than a day and was a correlational study. The other three studies were conducted in South Korea by the same researchers and included psychological and physiological measurements. They were conducted over the course of a couple of days and implemented an experimental design.

Chart

Reference	Participants	Country	Plants	Methods	Measures	Results
Beukeboom, et. al., 2012	457 participants, 276 females and 181 males	Denmark	Zamioculcas and Spanthacea	Participants picked up a survey after checking in for their appointment. Had three rooms one with plants, one with posters of plants and a control with neither	Questionnaire that measured perceived attractiveness of the waiting room, experienced stress, and patient characteristics.	Elements of nature such as plants and posters of plants reduce feelings of stress in hospital patients. These elements also increase the perceived attractiveness of a room which also affect the stress of patients.
Park & Mattson, 2008	90 patients, 52 males and 38 females	South Korea	Dendrobium phalaenopsis, Spathiphyllum, Epipremnum aureum, Howea forsteriana, Syngonium podophyllum, Pteris cretica, Vinca minor, and Trachelospermum asiaticum	Patients recovering from appendectomy surgery were assigned to a plant or no plant room during their recovery	Length of hospitalization, analgesics used for pain control, vital signs, ratings of pain intensity, pain distress ratings, PPAF, STAI-Y1, EAS, PRSQ	Plant room patients used less analgesics, had lower systolic blood pressure, heart rate, self-rated pain intensity, pain distress, and fatigue. They also felt more positively about their room.

Park & Mattson, 2009	90 patients, 43 males and 47 females	South Korea	Dendrobium phalaenopsis, Spathiphyllum, Epipremnum aureum, Howea forsteriana, Syngonium podophyllum, Pteris cretica, Vinca minor, and Trachelospermum asiaticum	Patients recovering from hemorrhoidectomy surgery were assigned to a plant or no plant room during their recovery	Length of hospitalization, analgesics used for pain control, vital signs, ratings of pain intensity, pain distress ratings, PPAF, STAI-Y1, EAS, PRSQ	Plant room patients had lower systolic blood pressure and ratings of pain, anxiety, and fatigue. They also felt more positively about their room.
Park & Mattson, 2009	80 female patients	South Korea	Dendrobium phalaenopsis, Spathiphyllum, Epipremnum aureum, Howea forsteriana, Syngonium podophyllum, Pteris cretica, Vinca minor, and Trachelospermum asiaticum	Patients recovering from thyroidectomy surgery were assigned to a plant or no plant room during their recovery	Length of hospitalization, analgesics used for pain control, vital signs, ratings of pain intensity, pain distress ratings, PPAF, STAI-Y1, EAS, PRSQ	Plant room patients had a shorter hospital stay, less analgesic intake, lower self-ratings of anxiety and tension. They also felt more positively about their room.
Park & Mattson, 2008	90 patients, 52 males and 38 females	South Korea	Dendrobium phalaenopsis, Spathiphyllum, Epipremnum aureum, Howea forsteriana, Syngonium podophyllum, Pteris cretica, Vinca minor, and Trachelospermum asiaticum	Patients recovering from appendectomy surgery were assigned to a plant or no plant room during their recovery	Length of hospitalization, analgesics used for pain control, vital signs, ratings of pain intensity, pain distress ratings, PPAF, STAI-Y1, EAS, PRSQ	Plant room patients used less analgesics, had lower systolic blood pressure, heart rate, self-rated pain intensity, pain distress, and fatigue. They also felt more positively about their room.

Literature

Beukeboom et al., (2012) examined the effect of real compared to artificial nature on stress reduction. This study was done with patients that had an appointment with the Radiology Department for treatment. When patients went to check in for their appointment, they were requested to fill out a questionnaire as they waited. There were 748 questionnaires, 457 were completed, and out of those completed 276 were completed by females and 181 completed by males. The participants filled it out the questionnaire and dropped it off in a mailbox when it was completed, or they were called for their appointment. Only completed questionnaires were used.

There were three different types of rooms, and while participants were filling out the questionnaire in the waiting room, they were exposed to either real plants, posters of plants, or no nature as the control. The posters and plants were placed in eyesight. In the plant condition they had 5 foliage plants (Zamioculcas and Spanthacea), while in the poster condition, there were 4 posters that had close up colored photos of the same plants. The questionnaire that the participants filled out measured perceived attractiveness of the waiting room, experienced stress, and patient characteristics.

For analysis, the researchers found no differences in the patient characteristics across the three groups. They used univariate analysis of variance for stress and found that the plant and poster condition had lower levels of experienced stress. For attractiveness, waiting rooms were rated more attractive when elements of nature were present. There was no difference between the plant and poster groups in attractiveness or stress. There was a significant correlation between the perceived attractiveness of the room and stress levels, and the more attractive the room the less stress there was.

Since this was a correlational study, the researchers wanted to see if the attractiveness of the waiting room effected stress instead of just correlated with it. To test this, they used the Preacher and Hayes method which tests for indirect causal effect. They took 5000 bootstrapped samples with a 95% confidence interval, and those tests showed the direct effect of plants and posters on stress decrease. The researchers concluded that elements of nature such as plants and posters of plants reduce feelings of stress in hospital patients, and these elements also increase the perceived attractiveness of a room which also affect the stress of patients.

Park and Mattson, (2008) examined the effect of indoor plants on patients recovering from surgery. To do this, they used 90 patients (52 males and 38 females) recovering from appendectomy surgery. This surgery usually has a short hospitalization period of 3 days. Patients were randomly assigned to a control or plant room for their surgery recovery. The researchers had 10 rooms, and these rooms were identical except some had plants and some did not. There were 12 plants used from the Dendrobium phalaenopsis, Spathiphyllum, Epipremnum aureum, Howea forsteriana, Syngonium podophyllum, Pteris cretica, Vinca minor, and Trachelospermum asiaticum species, and patients not involved in plant upkeep. For the measures, the researchers looked at length of hospitalization, analgesics used for postoperative pain control (weak, moderate, or strong based on drug type, amount, narcotic or not), vital signs (systolic and diastolic blood pressure, body temperature, heart rate, respiratory rate), ratings of pain intensity, pain distress, anxiety, and fatigue (PPAF), STAI-Y1, EAS which has participants list three positive and three negative qualities of their room, and Patient's Room Satisfaction Questionnaire (PRSQ). PPAF, STAI-Y1, and EAS were taken the first day. For the first 3 days, PPAF and STAI-Y1 were administered midmorning. EAS was administered again and PRSQ on the last day.

The researchers found that the length of hospitalization did not differ between groups. On the third day, analgesic intake and ratings of pain intensity, pain distress, and fatigue on the PPAF was lower in the plant room group. PPAF for those categories, systolic blood pressure, and heart rate also had a significant day by group interaction with the plant group feeling better that the control. STAI-Y1 was the highest before surgery and decreased during the recovery periods for both groups, but there were group differences for STAI-Y1 itself and especially for self-rated anxiety and tension, with the plant group having lower scores. EAS showed that the plant group

felt that their rooms were more satisfying, relaxing, comfortable, colorful, pleasant smelling, calming, and attractive. PRSQ showed 93% of the patients in the experimental group viewed plants as the most positive qualities of their, and 91% the control said that the TV was their favorite part of the room. 91% of patients in the plant group also said that they would be willing to return to their room if needed in the future while only 71% of control patients said the same.

Park and Mattson, (2009) examined the effect of indoor plants on patients recovering from surgery again. This time, they used 90 patients (43 males and 47 females) recovering from hemorrhoidectomy surgery. This surgery usually has a short hospitalization period of up to 4 days. Patients were randomly assigned to a control or plant room for their surgery recovery. The researchers had 10 rooms, and these rooms were identical except some had plants and some did not. There were 12 plants used from the Dendrobium phalaenopsis, Spathiphyllum, Epipremnum aureum, Howea forsteriana, Syngonium podophyllum, Pteris cretica, Vinca minor, and Trachelospermum asiaticum species, and patients not involved in plant upkeep. For the measures, the researchers looked at length of hospitalization, analgesics used for postoperative pain control (weak, moderate, or strong based on drug type, amount, narcotic or not), vital signs (systolic and diastolic blood pressure, body temperature, heart rate, respiratory rate), PPAF ratings, STAI-Y1, EAS which has participants list three positive and three negative qualities of their room, and PRSQ.

They found that there were no differences in hospitalization duration or analgesic intake. However, there were significant difference in ratings on PPAF and STAI-Y1, and systolic blood pressure for day 1 between the groups, with the plant group having lower SBP. For PPAF, pain intensity, pain distress, and fatigue decreased for both groups, and pain intensity was lower for

the plant condition on days 1 and 2. Pain distress was lower in the plant group on day 2 after the surgery and fatigue was lower for the plant group on day 1. Plant group had less anxiety and tension. EAS showed that the plant room patients rated their rooms as more satisfying, clean, relaxing, comfortable, colorful, happy, calming, and attractive. 96% in the plant room said that the plants were the most positive quality of their room and in the control, 88% said it was the temperature. 93% in the plant room said they would return to the room if needed in the future and 73% in the control said the same.

Park and Mattson, (2009) examined the effect of indoor plants on patients recovering from surgery again. This time, they used 80 female participants who had undergone thyroidectomy surgery. This surgery usually has a short hospitalization period of 5 days. Patients were randomly assigned to a control or plant room for their surgery recovery. The researchers utilized 10 rooms, and these rooms were identical except some had plants and some did not. There were 12 plants used from the Dendrobium phalaenopsis, Spathiphyllum, Epipremnum aureum, Howea forsteriana, Syngonium podophyllum, Pteris cretica, Vinca minor, and Trachelospermum asiaticum species, and patients not involved in plant upkeep. For the measures, the researchers looked at length of hospitalization, analgesics used for postoperative pain control (weak, moderate, or strong based on drug type, amount, narcotic or not), vital signs (systolic and diastolic blood pressure, body temperature, heart rate, respiratory rate), PPAF ratings, STAI-Y1, EAS, and PRSQ. Vital signs were taken three times a day. After patients checked in for their surgery, they took the PPAF, STAI-Y1, and EAS. After the surgery they took the PPAF and STAI-Y1 on the first, third, and fifth days. They took the EAS again and PRSQ for the first time on the last day.

The plant group had a shorter hospital stay. The plant room group had lower PPAF pain intensity ratings on the 3rd and 5th day, lower pain distress and fatigue on the 5th day, lower self-ratings of anxiety and tension on the STAI-Y1, and lower analgesic intake on the 4th and 5th day. There were no differences in vital signs between groups. EAS showed differences for the plant room and they rated their room as more satisfying, relaxing, comfortable, colorful, happy, calming, and attractive compared to the control. PRSQ showed that 95% the plant group rated plants and the most positive quality of their room and 85% of the control group said it was TV. 93% of the plant room said that they would stay in the room again while 70% of the control said the same. Voluntary comments that the nurses collected from the patients said that the plants made them feel less anxious and in pain.

Overview

Out of the four studies included, three of them were done by the same two researchers, Park & Mattson. The studies done by them were practically identical except for the type of surgery participants recovered from. Their findings have big implications for the field and the replications show validity in their results. The inclusion of indoor plants in hospital rooms could decrease systolic blood pressure, analgesic intake, anxiety, and fatigue. It also makes patients feel more positively about their room. These studies could be furthered by including what Beukeboom et al., (2012) found, which is that the perception of attractiveness influences stress. Dijkstra et al., (2008) also found the same effect and concluded attractiveness mediates stress perception; this study was done with university students pretending to be in a hospital setting and is included in the university section above. Because of this, it is difficult to conclude that the indoor plants are what caused the wellbeing of the hospital patients in Park & Mattson's studies.

Another consideration that is worth examination is the differences in eastern and western culture. These cultural differences could impact results, as patients in South Korea could have perceptions that patients in Denmark do not share.

Conclusion

The purpose of this literature review was to determine if there is empirical support for the hypothesis that houseplants positively impact (i.e., reduce) stress and promote well-being in humans. In general, while many of the published studies offer some support for this supposition, there are several factors that do not allow an unequivocal affirmative answer. There are several possible confounding factors such as stress relief occurring due to improved air quality, the perception of attractiveness instead of the indoor plants themselves as well as environmental preference. It is also worth examining the roles that culture, gender, plant type, and proximity play. The way that people interact with plants, whether it be viewing them as a valued possession or a disposable object and the upbringing that they have in how they interact with plants and tend to them could be a big factor behind the results we see. Also within-group experimental designs allow better analysis of the differences in measurements at the baseline, during and after exposure to greenery compared to inducing stress and using a treatment that includes greenery and comparing passive, active, and no interaction could further this area of research. It is also worth noting that out of the 21 reviewed articles, 10 were conducted by the same research group which could have unknown implications on results. More empirical research should help provide a comprehensive and detailed understanding of the potential benefits natural environments provide when dealing with stress. Nonetheless, the available literature has not yet identified any observation suggesting a negative relationship between the two, and the current literature supports its use as a stress management approach, even with minimal improvements, as there is no notable shortcoming or loss from its utilization.

There are many possible applications, as indoor plants do not take up much space and certain species are low maintenance. Anecdotal evidence from astronauts shows the tolling effects of being disconnected from nature has on mental health, and this literature has been applied to those environments and has shown to improve mental health during isolation due to outer space (Odeh & Guy, 2017) as well as isolation due to the Covid-19 pandemic (Reis et al., 2020). Because of these known positive effects on humans, there is even a field of therapy called horticultural therapy and it has been shown to help with mental illness, cognition, rehabilitation, and socialization (American Horticultural Therapy Association). This shows the value that plants have through current and possible future implementation, just as how this literature review was written to help synthesize current literature to help future literature. The purpose of this literature review was to provide an analysis and review of the existing studies done, and based on this analysis, indoor plants do moderately help well-being and stress within differing populations.

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