An Update of the Literature Supporting the Well-Being Benefits of Plants: A Review of the Emotional and Mental Health Benefits of Plants [1]

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Abstract

Consumers have historically shown an inclination to purchase plants that enhance their quality of life, meaning they will purchase items that positively influence their social, physical, psychological, cognitive, environmental, and spiritual well-being. Plants in native and improved landscapes (and interiorscapes) have been documented to influence each of six quality of life constructs. This paper summarizes publications regarding the emotional and mental health benefits associated with plants, addressing reduced anxiety and stress, attention deficit recovery, fractals and visual response, decreased depression, enhanced memory retention, greater happiness and life satisfaction, mitigation of post-traumatic stress disorder (PTSD), increased creativity, enhanced productivity and attention, reduced effects of dementia, and improved self-esteem. This research should be strategically incorporated into both industry-wide and firm-specific marketing messages that highlight the quality of life value proposition in order to maintain the industry's sense of value and relevance to consumers of the future.

Index words: benefits of plants, emotional health, mental health.

Significance to the Horticulture Industry

This paper is the first of a four-part series that provides a review of the substantial body of peer-reviewed research that has been conducted regarding the economic, environmental, and health and well-being benefits of green industry products and services. This article focuses specifically on the health and well-being benefits. This research should be strategically incorporated into both industry-wide and firm-specific marketing messages that highlight these quality of life dimensions in order to enhance the perceived value and relevance of green industry products for gardening and landscaping consumers in the future.

Introduction

In 2011, Hall and Dickson published a forum article in the Journal of Environmental Horticulture (JEH) that summarized the economic, environmental, and health and well-being benefits associated with people-plant interactions. The proposition put forth in that article was that green industry firms needed to focus on these types of functional benefits in their marketing messages to consumers rather than simply base their value proposition on the features and benefits of the plants themselves (e.g. aesthetic aspects, disease resistance, cold/heat tolerance, salt tolerance, etc.). By doing so, the end consumer would see the inherent ways in which plants improve the quality of their lives and begin perceiving plants to be a necessity in their lives rather than a mere luxury they could cast aside during economic downturns, as they did during the "Great Recession" of 2008-2009.

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Since 2011, there has been a plethora of additional research conducted regarding these functional plant benefits and these voluminous studies provide compelling evidence that warrants further attention. Thus, this new series of forum articles attempts to update the findings summarized in the original article by Hall and Dickson by presenting a summary of the research on plant benefits that has been conducted since 2011. By doing so, this new information provides the basis for future innovative green industry marketing efforts, which may, in turn, positively influence the elasticity of demand for plants in general.

The first topic in the four-part series, *Emotional and Mental Health Benefits of Plants*, is one that has been shown to resonate with consumers of all demographic segments (Hall and Dickson, 2011). These benefits are segmented and discussed using the following categories: anxiety and stress reduction, attention deficit recovery, fractals and visual responses, decreased depression, enhanced memory retention, greater happiness and life satisfaction, mitigation of PTSD, increased creativity, enhanced productivity and attention, reduced effects of dementia, and improved self-esteem.

Reduced anxiety and stress

Significant correlations have been found between the use of open spaces and reduced stress. Time spent in natural settings can help reduce mental fatigue recovery time and improve concentration levels (Entrix 2010, Keniger et al. 2013, Kjellgren and Buhrkall 2010, White et al. 2017, Wolf and Housley 2014). Increased access to green spaces also reduces psychological distress, depression symptoms, clinical anxiety, and mood disorders in adults (Astell-Burt et al. 2013, Beyer et al. 2014, Brown et al. 2013, de Vries et al. 2013, Fan et al. 2011, Nutsford et al. 2013, Stigsdotter 2015, Triguero-Mas et al. 2015, White et al. 2013).

The term "stress recovery theory" was coined by van den Berg and Custers (2011) and includes the benefits derived when individuals immerse in nature, including

decreased anxiety, lower heart rates, skin conductance recovery, lower concentrates of cortisol, and positive changes in nerve activity (Alvarsson et al. 2010, Bowler et al. 2010, Park et al. 2010, Park et al. 2017, Russell et al. 2013). Controlling for socio-economic and demographic characteristics, positive relationships between green space and overall health and stress reduction have been reported (de Vries et al. 2003) and the effects are transcendent to viewing images of nature (Ryan et al. 2014). For patients in hospitals, exposure to real plants or even posters of plants, resulted in lower levels of experienced stress (Beukeboom et al. 2012). Exposure to natural scenes mediates the negative effects of stress; one can recover faster from the decrease of cognitive performance associated with stress, especially reflected in attention tasks. (Berto 2014).

Stress reduction and mental restoration occur when individuals live near green areas, have a view of vegetation, or spend time in natural settings (Abraham et al. 2010, Carrus et al. 2015, Watts 2017, Wolf and Housley 2014). The amount of green space in the neighborhood, and in particular access to a garden or allotment, were significant predictors of stress (Thompson et al. 2016). In fact, the amount of green space in residential areas is positively related to resident overall health (Groenewegen et al. 2012). White et al. (2013) also found that individuals have both lower mental distress and higher well-being when living in urban areas with more green space.

Women also seem to experience more stress than men do when away from nature. Roe et al. (2013b) found that there was a significant inverse relationship between green spaces and stress levels with higher levels of green space resulting in lower stress levels. Women were found to display higher stress levels than men when exposed to the same amount of (or less) green space. Coincidently, the percentage of green space effects showed a positive outcome on women by decreasing the mean cortisol concentration. Women who lived more than 1 km away from green spaces reported higher stress levels and perceived poorer health and quality of life than those who lived near of green spaces (Stigsdotter et al. 2010). Beil and Hanes 2013 also found there is greater benefit from exposure to natural settings as measured by pre-and-post changes in salivary alpha-amylase and self-reported stress with more of a significant reduction in females than in males.

Thompson (2012) found that those who lived in green spaces experienced less stress and participated in more physical activity. Thompson also found self-reported decreases in stress, diurnal patterns of cortisol secretion, and quantity of relative green space in the living environment to all be positively correlated.

Another study found that when comparing a group of elderly women who spent 15 sessions outside participating in gardening activities versus staying inside, those who had gone outside had improved muscle mass and hand dexterity, and decreased waist circumference, whereas the women who spent the same time indoors had decreased muscle mass and agility and increased symptoms of depression (Park et al. 2016).

Stress reduction through green environments has been achieved in office settings as well. When employees were exposed to roses in the workplace, they had significantly less heart rate variability than those who weren't exposed to roses (Callaghan and Mallory-Hill 2016, Ikei et al. 2014, Ikei et al. 2013, Smith and Pitt 2011). Interior plants can lead to healthy, productive workplaces through enhanced attention capacity, lower stress levels, and higher job satisfaction from viewing plants (Gilchrist et al. 2015, Hartig et al. 2014, Raanaas et al. 2011). This concept also carries over to break areas within the workplace (Berto 2014).

Biophilia is defined as humans' innate tendency to seek connections with nature and other forms of life. Biophilic design is the incorporation of biophilia into the built environment. There is a growing body of literature documenting the benefits of implementing plants on a large scale to capture the positive psychophysiological and cognitive benefits afforded by biophilia in architecture (Ryan et al. 2014). This type of architecture can reduce stress, enhance creativity and clarity of thought, and improve well-being in urbanized communities (Browning et al. 2016). This theory is also backed by Pouya (2016), who found that if these concepts were applied more widely, we would see more of a positive impact. The perceptual and physiological stress responses are correlated to the complexity of fractals in nature, art and architecture, and the predictability of the occurrence of design flows and patterns in nature (Bejan and Zane 2012, Salingaros 2012).

When young people, particularly students, have a view of green spaces during school, students exhibit significantly better performance on attention tests and stress recovery (Li and Sullivan 2016). Kelz et al. (2015) validated Li and Sullivan's findings by having children play on different types of playgrounds with varied levels of green space. The playground with high green space significantly reduced students' physiological stress levels and enhanced their psychological well-being. They also perceived the environment as being more restorative.

Lee et al. (2014) studied forest activities of Japanese citizens and found significant differences between the responses of the subjects in forest settings compared with those in urban environments in salivary cortisol concentration (an index of stress response), diastolic blood pressure, and pulse rate. Further, subjects felt more comfortable, soothed and refreshed when viewing a forest landscape than an urban landscape.

Mennis (2018) found urban green spaces are associated with lower stress when subjects are away from home, which is speculated to be due to the properties of stress reduction and attention restoration associated with exposure to natural areas, and to the influence of other family dynamics affecting stress levels within the home. Subjects may also seek out urban greenspaces at times of lower stress or explicitly for purposes of stress reduction.

Tree cover is also associated with stress reduction. Jiang et al. (2016) found a positive correlation between urban street tree density and self-reported stress recovery. Song (2015) also found that physiological effects of a forest environment can differ depending on a subject's initial levels of stress and that subjects with high initial blood pressure and pulse rate showed a decrease in these values

after walking in a forested area, whereas those with low initial values showed an increase. There was no physiological adjustment effect observed in an urban area; thus, these effects are specific to a forest environment.

Aspinall et al. (2015) also documents that forest-bathing can cause stress reduction by using an EEG headset to measure brain waves by amplitude and frequency. Participants were asked to walk through an urban shopping center to a 25-ha (62 acres) green space and a busy commercial district with heavy traffic. The walk took participants approximately 25 minutes each. When comparing the urban shopping center to the green space, frustration, engagement, and arousal all decreased which is consistent with restoration theory but meditation increased, which was novel. When participants moved from the greenspace to the busy commercial district, their arousal/engagement increased, indicating that stress/fear also increased.

Horiuchi et al. (2014) took another approach and used real viewings of forests and non-forested areas and compared near-infrared spectroscopy (NIRS) as well as mood state scores, heart-rate, blood pressure, and sAMY concentration (marker for stress). They found that the NIRS signal, cerebral oxygenation levels, and mood state levels were lower in forest settings than in non-forest conditions, but blood pressure, heart rate variability, and salivary amylase levels were similar. Interestedly, being in the forest also caused a spike in cerebral activity.

This is reinforced by results of Im et al. (2016), who looked at the effects of spending two hours in a forest in Japan. To test neurological effects, they collected blood and saliva samples and found that there was a significant change in the level of cytokines that contributing to the hyperactivity of the inflammatory response which is physiological reaction of a stress response.

Joung et al. (2015) showed through NIRS that total Hb (hemoglobin) concentration was significantly lower of forest scenery over urban scenery. A lower concentration of total Hb and oxy-Hb indicates that the quantity of oxygen transmitted to the prefrontal cortex tissue is small. In other words, the prefrontal cortex activity in a forest area is more stabilized than in an urban area.

Vedder et al. (2015) took a different approach. They used fMRI and asked individuals to imagine beautiful and non-beautiful environments. Functional magnetic resonance imaging (fMRI) showed significantly more cortical activations when subjects imagined non-pleasant environments than when they imagined pleasant environments. The results of this study show that a positive and a negative frame of reference elicit distinct neural patterns of environmental cognition. This means that non-beautiful and non-pleasant environments demand more mental processing than beautiful and pleasant environments. The results correlate with previous propositions to explain the experience of negative environments as characterized by the demand on more mental resources than the experience of positive environments. In other words, interacting with a negative environment requires an additional investment in emotion processing, cognitive control, and motor function. These results support Aspinall et al. (2015), Horiuchi et al. (2014), and Joung et al. (2015) with their claims of reduction in delta waves (brainwaves for agitation and excitement). Kim et al. (2010) found similar results when looking at stress reactions using fMRI.

Students were recruited from Edinburgh University by Roe et al. (2013a) to undergo an EEG study on natural settings (fields, forests, and parks) versus urban sceneries (buildings, roads, and walls). To control the effect of people and animals, both were withheld from being included in the pictures presented to the subjects. Subjects were asked to rate each slide on four criteria based on how attractive they found the scene, how likely are they to visit the scene, how the scene made them feel from sad to happy and also from calm to excited. The results for the ranking questions showed that the landscape scenes were perceived as more attractive, more inviting (willingness-to-visit), and greater valence. Arousal was strongly correlated to the urban scenes while interest was correlated to landscape scenes. This confirms restorative theory, indicating a positive psychological effect of natural scenes.

Rosenbaum used electroencephalogram (EEG) in a replication-type study with eye-tracking. Given the lack of neuroscience data in previous studies on consumer responses and biophilic design in retail settings, they had participants watch a video of a retail mall or lifestyle center (e.g. an upscale shopping center or mixed-use commercial development) with and without plants (biophilic and non-biophilic). Those participants who viewed the biophilic video were more enthused and interested and experienced a higher state of mental relaxation than participants who viewed the non-biophilic video. Participants who viewed the biophilic video also reported lower levels of stress, more attractiveness/focus, and were more emotionally involved. This finding confirms previous results that suggest that shoppers are becoming bored in their excursions to enclosed malls while lifestyle centers continue to proliferate.

Attention Deficit Recovery (Attention Restoration Theory or ART)

Natural landscapes, such as beaches, waters, forests, parks, and mountains, and availability of public open spaces used for public entertainment and sports reduce attention deficit disorders (ADD/ADHD) (Coutts and Hahn 2015, Frumkin 2013, Keniger et al. 2013). Green restoration improved preschooler spatial working memory (Schutte 2017) and cognitive functioning improved when participants walked in nature (Berman et al. 2008). Children with ADHD concentrated better after a walk in a park than after a downtown neighborhood walk (Taylor and Kuo 2009). Wilson (2015) showed that children who play in greenspace for 30 minutes had increased sustained mental ability and found greenspace to be restorative. Taking micro-breaks to view nature can help with attention restoration (Lee et al. 2015).

Fractals & Visual Response

We are so separated from nature that we make up for its lack by imbuing our surroundings with those geometric

qualities found in nature (Salingaros 2012). We try to shape our immediate vicinity so that those qualities reproduce our response to natural environments. From biophilia, natural forms have inherent qualities, reducible to a mathematical description, that induce a healing effect. Complex biophilic environments dramatically increase brain size and performance on intelligence tests (Salingaros 2012).

Decreased Depression

Being immersed in nature and vegetation were used as active components in a therapeutic horticulture intervention for clinical depression (Beute and de Kort 2018, Gonzalez et al. 2010). Garden walking and reflective journaling decreased depression scores in older adults (McCaffrey et al. 2010). With patients who have major depressive disorder (MDD), those who walked in nature exhibited significant increases in memory span after the nature walk relative to the urban walk. Green spaces also reduced stress and pain, and increased attention performance (McCaffrey et al. 2010). Participants also showed increases in mood, but the mood effects did not correlate with the memory effects, suggesting separable mechanisms (Berman et al. 2012). Bezold (2018) put extensive numbers to this idea, with a 6% lower incidence of high depressive symptoms associated with greenness and found this relationship to be stronger with highly populated areas. Comparing household medical records and natural amenities, those residents with only 10% green space within about half a mile had a 25% greater risk of depression and a 30% greater risk of anxiety disorders versus those with the highest degree of green space near the home (Wolf and Housley 2014).

In a Korean study involving patients with moderate to severe depression, participants were assigned to cognitive-behavioral therapy in either a hospital setting or a forest setting (arboretum), while a third group acted as a control and were treated using standard outpatient care in the community (Wolf and Housley 2014). Overall, depressive symptoms were reduced most significantly in the forest group, and the odds of complete remission were 20-30% higher than typically observed from medication alone. Moreover, the forest therapy group had more pronounced reductions in physiological markers of stress, including lower levels of the stress hormone cortisol and improvements in heart rate variability, a marker of adequate circulatory system response to stress. It appears that the settings where psychotherapy is conducted can actually become part of the therapy (Wolf and Housley 2014).

Enhanced Memory Retention

A 2012 experiment in Michigan found that people were better able to perform a test of working memory (which measures one's ability to focus or concentrate) after walking through a green arboretum, compared to those who walked on traffic-heavy urban streets (Berman et al. 2012). Subjects who walked through the arboretum had a 20% improvement in working memory. Another study determined that people who went for a 50-minute walk in nature, compared to those who went for a similar length walk in an urban environment, experienced less anxiety and rumination, along with increased working memory performance (Berman et al. 2012).

Being in nature and greenspace can also help improve memory retention of patients suffering from strokes and dementia (Detweiler and Warf 2005). In children, nature exposure can influence cognitive development through improved working memory and a reduction in inattentiveness (Dadvand et al. 2015).

Greater Happiness/Life Satisfaction

Interacting with nature, especially with the presence of water, can increase self-esteem and mood, reduce anger, and improve general psychological well-being with positive effects on emotions or behavior (Barton and Pretty 2010, Keniger et al. 2013, Mensah et al. 2016, Windhager et al. 2011, Wolf and Housley 2014). In fact, moving to homes with greener areas positively influences mental health even after three years post-move (Alcock et al. 2014). Moving to a less-green area significantly worsens mental health within one year post-move, but returns to pre-move mental health status thereafter (Alcock et al. 2014).This is true for public green spaces as well. City park area quantity and accessibility is a strong predictor of physical and community well-being (Larson et al. 2016). Similarly, studies in Perth, Australia found that people in neighborhoods with high-quality public open spaces had better mental health than those with low-quality public open space (Francis et al. 2012a). Features that made an open space "high quality" included irrigated lawns, walking paths, lighting, water features, playgrounds, and birdlife. Mental health was assessed based on symptoms of psychological distress such as nervousness and feelings of hopelessness (Francis et al. 2012b). Findings were not affected by the quantity of open space in the neighborhood, nor by how frequently residents used the open space (Francis et al. 2012a).

Pro-environmental behavior and subjective well-being are positively associated. Those who are more connected to nature and exhibit environmentally-conscious behaviors tend to experience more positive vitality and life satisfaction compared to those less connected to nature (Capaldi et al. 2014).

Van Dillen (2012) determined, through meta-analysis, that quality and quantity of green space was correlated to good health. Greater species diversity positively affects personal well-being (Dallimer et al. 2012) and neighborhood well-being (Luck et al., 2009). Visiting protected natural sites (e.g. state parks) improves perceptions of psychological, emotional, and social benefits (Lemieux et al. 2012). Results from a meta-analysis in Toronto, Canada suggest that people who live in neighborhoods with a higher density of trees on their streets report significantly less cardio-metabolic conditions. Having 10 or more trees in a city block, on average, improves personal health perceptions in ways comparable to a $10,000 increase in annual personal income or being 7 years younger (Kardan et al. 2015). The study also found that having 11 more trees in a city block, on average, decreases cardio-metabolic conditions in ways comparable to an increase in annual

personal income of $20,000 and moving to a neighborhood with $20,000 higher median income or being 1.4 years younger (Kardan et al. 2015).

Park et al. (2017) found that when subjects observed plants, Oxy-Hb (oxyhemoglobin) concentrations in the right prefrontal cortex were significantly lower, indicating a physiological state of relaxation. Subjects also reported more positive emotions (feeling more comfortable and relaxed) when viewing foliage plants.

Mitigation of PTSD

Veterans with PTS (post-traumatic stress) treated with Nature Adventure Rehabilitation (NAR) experienced an improvement in emotional and social quality of life, post-traumatic cognitive inventory, and hope and functioning (Gelkopf et al. 2013). NAR seems to work through a process of behavioral activation, desensitization, gradual exposure to anxiety evoking situations, and gaining control over symptomatology.

When victims of natural disasters, who are at a high risk of PTSD, participated in horticulture therapy (HT) programs, they showed an increase in regional gray matter volume (rGMV) of the left subgenual anterior cingulate cortex and left superior frontal gyrus compared with the stress education (SE) group (Kotozaki et al. 2015, Sekiguchi et al. 2015). They showed greater salivary cortisol and alpha amylase levels, which are all significantly reduced in individuals experiencing PTSD (Kotozaki 2014, Kotozaki et al. 2015, Sekiguchi et al. 2015). The HT group also showed improvement on PTSD reactions, post-traumatic growth, and positive states of mind (Kotozaki et al. 2015). Post-traumatic growth refers to the positive outcome of people who have experienced traumatic events through recovering their quality of life. People identified themselves with plant growth and gaining a chance to be happy once more (Kotozaki et al. 2015).

Increased Creativity

Ling and Dale (2011) found a link between landscape plants and creativity and considered how this may reflect the potential for cultural diversity and thus sustainable community development. Taking short walks in attractive green environments can boost creativity and vitality (Tyrvainen et al. 2014). These same areas can also be used for 'walking meetings' which help boost creativity (Oppezzo and Schwartz 2014).

Enhanced Productivity and Attention

Biophilic workplaces with views of nature and daylight can lead to higher productivity and attention with employees (Elzeyadi 2011, Windhager et al. 2011). Workers in offices with poor light quality and views used more sick leave hours and this effect contributes as much as 6.5% to sick leave use. Moisture released into the air by plants helps with a dry atmosphere, reducing headaches and improving concentration. Visible greenery, both indoors and out, reduces stress and increases the ability to concentrate (Alker et al. 2014, van Duijin et al. 2011). In one such concentration test, employees who had a view of plants completed the test 19% faster than employees in a room without a view of plants (Nieuwenhuis et al. 2014). Offices in the Netherlands and Great Britain experienced a 15% increase in worker productivity when plants were included in office space (Korpela et al. 2017, Nieuwenhuis et al. 2014).

The Heschong-Mahone Group studied productivity at the Sacramento Municipal Utility District Call Center where employees were either seated with views of vegetation through large windows or were excluded from the vegetation view. Employees who had a vegetation view made 6-7% more calls per hour than those with no view. The initial investment of installing the windows was recovered in 4 months by improved productivity (Alker et al. 2014).

Jumeno and Matsumoto (2013), however, did not find that plants in the workplace had a significant effect on productivity or attention but found a significant difference in the employee perceptions of friendliness, comfort, freshness, and cleanliness of the workplace. Erzsebet et al. (2014) suggests that improved employee productivity and attention can be positively affected by the air-purifying qualities of plants in the workplace by reducing various allergies, irritations, hypersensitivity, asthma, drowsiness, and eye problems, while also improving mood. Jumeno and Matsumoto (2016) sought to quantify the number of plants in a room that it would take to generate positive results and found the more plants in a room, the better the mood of the subjects. Their study also found that the number and the size of plants affected the perceived air quality and reaction times and as few as three small-to-medium sized plants can make a positive difference. Even a brief view of a green roof can have positive effects on mood and productivity (Lee and Maheswaran 2011).

When asked about plants in the workplace, 97% of employees would like to have more plants (Husti et al. 2015) because they perceive plants provide a sense of relaxation, make the work environment more similar to space at home, cheer up the image of the office, give a sense of relief, and improve work motivations. Employees without an outdoor view from their desk are five times more likely to put a plant in their office than those with an outdoor view (Bringslimark et al. 2011). Office employees with an outdoor green view were happier and had positively associated higher productivity and job satisfaction levels (Lottrup et al. 2015).

In elementary-level classrooms, green walls (described as a wall with green plants) can provide restorative impacts to school children. Results show that children in classrooms where a green wall was placed scored better on tests for selective attention (van den Berg et al. 2017). The green wall also positively influenced children's classroom evaluations. When integrating a school garden into the curriculum, children's physical activity was increased and sedentary behavior decreased (van den Berg et al. 2017). Children who received breaks and time outside exhibited improved concentration (Duvall and Sullivan 2016). Just placing plants in the classroom improved performance, with children progressing through school curriculum 20-26% faster (van Duijin et al. 2011).

Reduced effects of dementia

Participants in outside horticultural therapy activities such as gardening or landscaping are more actively engaged, have reduced incidents of aggressive behavior, and improved cognitive capacity (Gigliotti and Jarrott 2005).

Improved Self-Esteem

Natural green space has long been used in the promotion of human well-being through green exercise (exercise in a greenspace or outdoors) for improvements on mental health and self-esteem (Townsend and Weerasuriya 2010). A multi-study analysis assessed the best regime of green exercise that is needed to improve self-esteem and mood (Barton and Pretty 2010). Dose responses for both intensity and duration showed large benefits from short engagements in green exercise, and then diminishing but still positive returns (Barton and Pretty 2010). Every green environment improved both self-esteem and mood and the presence of water generated greater effects. Both men and women exhibited similar improvements in self-esteem after green exercise, though men showed a more positive difference in mood.

Summary

Consumers have historically shown an inclination to purchase products that enhance their quality of life (Hall and Dickson 2011), meaning they will purchase items that positively influence their social, physical, psychological, cognitive, environmental, and spiritual well-being. Plants in native and improved landscapes (and interiorscapes) have been documented to influence each of six quality of life constructs. This paper focused on providing evidence from the literature regarding the emotional and mental health benefits associated with plants, thereby influencing the psychological and cognitive well-being constructs of quality of life. This research should be strategically incorporated into both industry-wide and firm-specific marketing messages that highlight the quality of life value proposition in order to maintain the industry's sense of value and relevance to consumers of the future.

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