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Wood as a Restorative Material in Healthcare Environments

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1 INTRODUCTION

This report seeks to draw the link between the use of wood in the built environment and pro health outcomes. While the study of wood and health is relatively new in the field of environmental psychology, a clear relationship between the presence of other natural elements has been established in built environments. Views to nature, natural sunlight, plants, and water elements all have been shown to provide pro health benefits both psychologically through positive affect and psychophysiologically by lowering stress reactivity of the autonomic nervous system. Early evidence suggests that the human relationship with wood is similar to previously investigated responses of our species to other natural materials and nature cues. That is, wood is a biophilic material that reduces stress reactivity when present.

The argument for increased use of wood in healthcare environments in this paper is based on research-based logic indicating that wood, other natural materials, and nature surrogates provide positive health effects for humans in any type of built environment. While some healthcare specific research is available, it is in reviewing the responses to multiple materials in multiple environments that the more general link between natural materials and pro health outcomes can be seen. In turn, the call for increased use of wood in healthcare environments is based on both wood specific studies and the associated non-wood studies that established the health link to nature. Summarizing, the mind and body are looking for a connection with nature when it is absent; the type of nature and the type of building are secondary. Wood is a natural building and finishing material and therein is the fit with using it more in healthcare settings.

The consideration of linking humans to nature in design is commonly referred to as biophilic design. The rise of the biophilic design movement has encouraged discussion of including natural materials such as wood in designed environments. Wilson (1984) defines biophilia as the affinity of humans for “life and life-like processes”. Biophilicly designed structures have been defined as spaces that “contain the essence of natural objects without being exact copies. They draw on design principles of natural forms” (Kellert quoting Judith Heerwagen; 2012). Kellert, an influential writer on biophilic design as well as a practitioner, includes the use of natural materials such as daylight, plants, and natural materials (including wood and stone), as one of the key elements of biophilic design (Kellert, 2012).

Much of biophilic design and the research field of environmental psychology deals with stress. Stress is a predictable part of modern life and biophilic design has been presented as a way to defuse it (Kellert, 2012). Stress is harmful to our health because it activates our autonomic nervous system for an extended period of time. Specific illnesses linked to stress include heart disease, arthritis and diabetes. This is in addition to its negative effects on our mood, memory and cognitive performance, for example (Beute and de Kort, 2014).

Mood and positive affect are another focus of the environmental psychology field. Positive emotions have been linked directly to better objective and subjective health (Salovey, Rothman, Detweiler, and Steward, 2000) and also influence the way in which we think, encouraging us to consider information more broadly, which supports higher levels of creative thinking. Broader thinking also supports our ability to get along with others (for example, Fredrickson and Joiner, 2002). Positive moods have even

been linked to enhanced functioning of the immune system (Salovey, Rothman, Detweiler, and Steward, 2000). The physical environment can significantly affect mood.

What follows is a review of appropriate research on the human response to natural elements in the built environment. There are many ways by which nature can be included in the built environment. These range from views to nature, natural light, and nature sounds through to materials inside the building such as water, plants and wood. These biophilic elements all share similar pro health attributes. Research results for these pro health attributes are discussed below. This paper starts with the response to views of nature then progresses to natural light. Material specific research on plants and wood then follows. This progression highlights the similarities in reactions to various natural elements employed in the built environment.

As this paper is focussed on building a case for wood in healthcare environments, each section begins with research directly related to the nature and health link in healthcare environments. Research in healthcare facilities consistently shows that adding nature to these environments improves patient and staff wellbeing, while enhancing and promoting health.

The conclusion of this paper is that it is reasonable and desirable to employ more wood in healthcare environments because patients and caregivers will benefit from the pro heath responses seen to wood and other natural elements.

2 VIEWING NATURE

Views to nature are perhaps the most direct and tangible avenue for biophilic architecture. Seeing natural views from interior spaces has been linked to improved health and its corollaries such as reduced need for pain medication. Similar effects are found whether the nature viewed is live, captured artistically, or in a photograph (moving or still). Cardiovascular function is improved after mental fatigue/stress are experienced and nature is viewed; and positive mood is more likely after a stressful event when nature scenes are present. The breadth of human's positive responses to nature scenes indicates that viewing nature has positive implications for both physical and psychological wellbeing. People also perceive their own health to be better when they have a view of nature at work, indicating that nature views may also contribute to a positive placebo effect.

2.1 Viewing Nature in Healthcare Environments

Views of nature reduce patient stress and improve mental health while facilitating healing.

- Ulrich found that after gall bladder surgery, patients with a view of nature spent less time in the hospital and needed less pain medicine than people without a nature view (1984).
- People have a higher tolerance for pain when looking at a videotapes of nature (Tse, Ng, Chung, and Wong, 2002).
- On days when a nature video was played in the waiting room at a blood donor center, blood donors had lower pulse and blood pressure readings than on days when ordinary daytime television or videos of urban scenes were played (Ulrich, Simons, and Miles, 2003).
- Danish cancer patients value outdoor views because they are "a way of connecting with personal life stories" (Timmermann, Uhrenfeldt, and Birkelund, 2013). Thinking about these life stories was found to block patients' negative thoughts and the positive ramifications of bringing life stories to mind were in addition to the desirable effects derived from being in natural light and seeing nature. It was particularly desirable for observed spaces to include some visible human activity.
- Women in the hospital after Cesarean sections were studied by Wang, Anthony, and Kuo (2014), who learned that "both window view and daylight exposure have significant impact on reduced recovery [time in the hospital], some dimensions of perceived pain, and general well-being." More nature in view and more daylight were best.

Healthcare environments also benefit from representations of nature in art.

- Ulrich and Gilpin recommend that art used in healthcare settings be realistic depictions of green (not arid) landscapes (this could also be flowers in a garden) with an open foreground and groupings of trees with broad canopies (2003). Visible Water should be calm. They also recommend that abstract art be avoided in patient areas as well as depictions of situations that could be seen as threatening. This sort of art has been shown to distract viewers from stressful

thoughts. Support for Ulrich and Gilpin's recommendations have been identified by other researchers (Nanda, Eisen, and Baladandayuthapani, 2008).

- When art consistent with Ulrich and Gilpin's guidelines was added in still or video form to an emergency department waiting room, researchers identified a "significant reduction in restless behavior and increase in socialization. A decrease in the number of people staring at other people was also found, which has implications for privacy. Significant reduction in noise levels was found at both sites as well" (Nanda, 2011).
- Study participants experienced a nature scene mural and a tape of nature sounds or looked at the blank ceiling of procedure room (Diette, Lechtzin, Haponik, Devrotes and Rubin, 2003). Pain control was improved in the people who experienced the nature-distraction intervention compared to those who looked at the blank ceiling. There was no difference in patient-reported anxiety and satisfaction among the two study groups.
- Heart surgery patients viewing art featuring water and trees required less pain medicine in one study, and were less anxious than other heart surgery patients looking at abstract images (Ulrich, Lunden, and Eltinge, 1993).
- Ulrich reports that abstract images on the walls in a mental health clinic were vandalized while nature images in the same clinic were not (1986).
- After investigating art to be used in spaces where war veterans with posttraumatic stress will be treated, researchers recommend that "waterscapes, containing calm or nonturbulent water" and "landscapes, containing visual depth or open foreground, trees with broad canopy, savannah landscapes, and verdant vegetation" (Nanda, Gaydos, Hathorn, and Watkins, 2010). Images in the art should not be reminiscent of places where the veterans fought. In addition, while cut flowers can be reminiscent of funerals, blooming flowers in natural settings can generate thoughts of "growth and regeneration" and therefore should be used in these spaces.

2.2 Heart Rate Responses to Nature Views

Our cardiovascular system responds positively to views of nature.

- There was greater physiological arousal reduction (heart rate decrease) in people looking at nature videos after mental fatigue/stress was induced by a proofreading assignment, than was found among people watching urban videos who completed the same proofreading assignment (Laumann, Garling and Stormark, 2003).
- Diastolic blood pressure fell more quickly for people in a room with a nature view than for people in a windowless room after researchers induced psychological stress (Hartig, Evans, Jammer, Davis, and Garling, 2003).
- After performing a stressful task, participants in a study run by Hartig and his colleagues recovered more quickly in a room with a nature view than with an urban view, as with recovery assessed using info on changes in diastolic blood pressure (Hartig, Mang, and Evans, 1991).

2.3 Nature Views and Perceptions of Health

Evidence links natural views and better perceived health.

- Office workers with a more natural view assess their own health more positively than people with less natural views (R. Kaplan, 1993).
- Inmates whose views from their cells are more natural were found to visit a prison infirmary less often than people whose cell windows opened onto a courtyard (Moore, 1981).

2.4 Effects of Nature Views on Mood

Improvements in mood have been linked to views of nature.

- After a stressful event, seeing unthreatening nature has been linked to an increase in positive affect and a decrease in negative affect. (Beute and de Kort, 2014).
- In general, after watching movies of nature scenes positive mood increased more while negative ones decreased more significantly than when movies of urban scenes were viewed (Beute and de Kort, 2014).
- People recovered faster physiologically from watching a stressful movie when they watched a second movie of a natural environment than when they watched an additional movie of an urban environment (Ulrich, 1991). The people watching the nature videos indicated that their moods were more positive and they were less scared and angry than those who watched the urban videos.

2.5 Experienced Stress and Nature Views

Stress is significantly decreased when nature is viewed.

- Parsons and his colleagues learned that the sympathetic nervous system seems to facilitate the link between seen nature and recovery from stress and response to stressful situations (1998). They came to this conclusion by collecting various physiological information from study participants, such as blood pressure, skin conductance, and tension in facial muscles during a study when participants were shown videotapes of car drives through natural and urban environments.
- When the intake officers at a country jail could see a large-scale photomural of a nature scene while working, they felt less stressed than they did when the mural was not present (Farbstein, Farling, and Wener with Nanda and Sollers, 2012).
- Men exposed to nature paintings are less stressed—and angry—than males working in view of abstract art (Kweon, Ulrich, Walker, and Tassinary, 2008).

2.6 Viewing Nature and Professional Performance

Below are a series of results with respect to nature and professional performance. While these studies did not take place in healthcare environments it would be logical to extend these results to the professional performance of healthcare workers as the mental and physical wellbeing of healthcare workers could have indirect implications for patient treatment.

- People are better able to do focused work after looking at images of natural environments but performance on focused work is not affected by looking at images of urban environments; "there is quite a body of experimental research supporting the idea that nature helps recovery from attention fatigue" (Beute and de Kort, 2014).
- Data collected from subjects in fMRI machines verifies that looking at nature cuts stress levels and helps us become more productive at doing work requiring concentration after we've become mentally exhausted doing work requiring us to focus (Kim, Jeong, Baek, Kim, Sundaram, Kang, Lee, Kim, and Song, 2010).
- People with views of green spaces are better able to pay attention than people without them (Kuo and Taylor, 2004).
- Executive function is better in people living in dorm rooms with natural views than it is for students living in spaces with lower levels of natural elements visible from their dorm windows (Tennessen and Cimprich, 1995).
- High school students with views of green spaces are better able to focus on their schoolwork. Li (2014) learned that "exposure to green spaces on high school campuses result in better attentional functioning than exposure to barren landscapes [views of built spaces] or no exposure to the landscape at all [i.e., spaces with no windows]. Students [randomly] assigned to classrooms with nature views performed significantly better than those assigned to barren and no-window conditions. This field experiment confirms that exposure to green space enhances students' attentional functioning."
- Korpela and his co-workers (in press) learned that "window views to natural elements buffer the negative impact of job stress on intention to quit; the more natural elements, the less the negative impact of job stress on turnover intentions. A [physiological study] has indicated that people are less nervous or anxious when looking at the window view to nature compared with the window view to the city or no window view. Also the amount of outdoor nature contact during breaks at work seems to be associated with less perceived stress and better self-rated health."
- Views of nature from a workspace have been linked to lower levels of job stress and better self-reported health. (Leather, Cox, and Farmsworth, 1990).

2.7 Effects of Nature Views on Self-control and Pro Social Behaviour

Exposure to nature does not only affect personal health. It can also affect interpersonal relations by way of enhancing self-control and pro social behaviours.

- After an ego-depleting task, humans' self control is better after looking at images of nature than after looking at pictures of urban environments (Beute and de Kort, 2011).
- When furniture or similar items must be added to natural environments, it is better if that furniture is made of wood than when it is made of metal. Pals (2012) reports that restorative environments are equally restorative whether they have wooden furniture in them or not: "metal furniture [in images viewed] negatively influenced perceived coherence as well as preference, pleasure and restoration, compared to wooden furniture and no furniture."
- When people experience "more beautiful" nature they are more likely to act in a pro-social way, such as being generous or trusting (Zhang, Piff, Iyer, Koleva, and Keltner, in press). More beautiful natural settings include "more water (e.g., lake, river), presence of sky, open space (e.g., large depth of field) and mixture of natural colors [(e.g., various leaves, trees, blue sky, flowers, etc.]."

Viewing nature slides has "beneficial effects of a short exposure to nature on lower order self-regulation (e.g., controlling impulses)." As Beute and de Kort (2014) detail, "Positive effects of exposure to nature have been reported for stress, mood, and executive functioning. We found indications for beneficial effects of a short exposure to nature on lower order self-regulation (e.g., controlling impulses). Furthermore, we found beneficial effects on mood and heart rate variability, a physiological measure related to exertion of self-control and stress. Importantly, beneficial effects of nature emerged even when participants had not been previously depleted, which challenges the current postulation that nature mostly has restorative benefits."

3 NATURAL LIGHT

Not all buildings have views to nature; however, even windows with non-nature views bring natural light into the built environment. There is a large body of knowledge linking exposure to natural light to positive health outcomes. Being in an interior space lit with natural light has been shown to improve health directly and also indirectly. However, these results are somewhat different that the results for views to nature, plants, or wood. That is, light is not a "viewed" material. However, pro health evidence for natural light is presented here as it is a major element in biophilic design.

3.1 Using Natural Light in Healthcare Spaces

Resources spent funneling natural light into healthcare spaces seems to be well spent. Research into the effects of natural light in healthcare spaces has uncovered benefits in cardiac patients, surgical patients, mental health patients, and in healthcare workers themselves.

- Cardiac intensive care unit patients on the sunny side of buildings have different outcomes than people on the non-sunny side (Beauchemin and Hays, 1998). Women on the sunny side of these units spent less time in the unit and mortality rates, in general, were lower in the brighter rooms.
- Women in the hospital after Cesarean sections were studied by Wang, Anthony, and Kuo (2014), who learned that "both window view and daylight exposure have significant impact on reduced recovery [time in the hospital], some dimensions of perceived pain, and general well-being." More nature in view and more daylight were best.[1]
- Among patients recovering from spinal surgery, people in brighter rooms needed less pain medication the day after surgery and indicated that they felt significantly less stressed when they were discharged from the hospital than people who recovered in dimmer rooms (Walch, Rabin, Day, Williams, Choi, and Kang, 2005).
- In 1996, Beauchemin and Hays reported that severely depressed patients spent fewer days in a mental health facility, on average, when they were assigned to a sunny room than when they were assigned to a dimmer room.
- Bright natural light helps relieve symptoms of depression and depressed bipolar patients spent less time in mental health facilities during the summer and fall when they had morning sun than when their rooms got afternoon sun (Benedetti, Colombo, Barbini, Campori, and Smeraldi, 2001). This study has implications for building orientation.
- Nurses in Turkey who experienced 3 more hours of daylight at work each day felt more satisfied at work and less stressed (Alimoglu and Donmez, 2005).

[1] This result also appears in the Views of Nature section.

3.2 Hormonal Effects of Natural Light

Experiencing natural light has an influence on our body's chemistry.

- Vitamin D is manufactured by human bodies when daylight touches our skins and having appropriate levels of vitamin D in our system has been linked to reduced levels of cancer and heart disease (Kauffman, 2009).
- Feelisch and Weller have learned that exposure to sunlight alters "levels of the small messenger molecule, nitric oxide (NO) in the skin and blood, reducing blood pressure" ("Here Comes the Sun to Lower Your Blood Pressure," 2014.).
- Daylight hitting human skin has been linked to the production of serotonin, which enhances mood (Landsdowne and Provost, 1998).
- Research has shown that levels of serotonin in the bloodstream are higher when it is sunny than when it is not (Lambert, Reid, Kaye, Jennings, and Esler, 2002)
- Research by Fell, Robinson, Mao, Woolf and Fisher in mice has shown that when they are in sunshine their bodies respond to the ultraviolet light they experience and produce beta-endorphin, which is an opiate-like molecule, a "feel-good drug" (Sanders, 2014).

3.3 Mood Effects Linked to Natural Light

The relationship between being in a day lit space and mood is both intuitive and supported empirically.

- The relationship between sunshine and mood seems linear; more sunshine at a particular time leads to better mood (Denissen, Butalid, Penke, and van Aken, 2008).
- People participating in a study who were in a day lit space for 30 minutes in about 3,000 lux of light were in a better mood than people in spaces lit by more moderate levels (less than 100 lux) of artificial light (Kaida, Takahashi and Otsuka, 2007).

3.4 Natural Light and Circadian Rhythms

Keeping our circadian rhythms synchronized with the world around us helps keep stress in check.

- Access to daylight helps keep a human's circadian rhythm coordinated with their physical location, which helps keep stress levels in check (Boyce, Hunter, and Howlette, 2003). When circadian rhythms become misaligned with the local light environments, people experience stress, which has negative implications for both mental and physical wellbeing.
- Circadian rhythms aligned with physical location have been linked with not only reduced psychological stress, but also improved mood and cognitive performance (Beute and de Kort, 2014).

3.5 Natural Light and Obesity

Spending time in spaces that are naturally lit can be good for our weight control.

- People are better able to exercise self-control in spaces where they are exposed to natural light (Beute and de Kort, 2012).
- Being in day lit spaces has been shown to reduce the amount of brown adipose tissue in humans and thus their body fat levels ("Daylight Could Help Control Our Weight," 2009).

3.6 Daylight and Cardiac Health/Stroke Risk

Being in day lit spaces has been linked to heart cardiovascular health.

- Researchers at the University of Colorado, Denver, have investigated the relationship between daylight and heart disease ("Intense Light Prevents, Treats Heart Attacks," 2012). Their work "'suggests that strong light, or even just daylight, might ease the risk of having a heart attack or suffering damage from one,' says Tobias Eckle, MD, PhD, an associate professor of anesthesiology, cardiology, and cell and developmental biology at the University of Colorado School of Medicine. 'For patients, this could mean that daylight exposure inside of the hospital could reduce the damage that is caused by a heart attack.'"
- A research team at the University of Edinburgh have learned that "Exposing skin to sunlight may help to reduce blood pressure, cut the risk of heart attack and stroke – and even prolong life. Researchers have shown that when our skin is exposed to the sun's rays, a compound is released in our blood vessels that helps lower blood pressure [for one hour following exposure to UV rays]. The findings suggest that exposure to sunlight improves health overall, because the benefits of reducing blood pressure far outweigh the risk of developing skin cancer. Production of this pressure-reducing compound – called nitric oxide – is separate from the body's manufacture of vitamin D, which rises after exposure to sunshine" ("Sunshine Could Benefit Health and Prolong Life, Study Suggests," 2013).

3.7 Natural Light and Mental Illness

Better mental wellbeing has been linked to more time spent in natural light.

- It is particularly important that people who are depressed are in day lit spaces because researchers have learned that their short-term recall and temporal orientation are impaired when they are in places without access to natural light; this effect is not seen in individuals who are not depressed (Kent, McClure, Crosson, Arnette, Wadley, and Sathiakumar, 2009).
- Adolescent depression has been linked to the amount of sunlight in the indoor spaces that the adolescents use; as levels of sunlight increase, levels of depression fall (Sansal, Edes, and Binatli, 2012).

3.8 Natural Light and Workplace Satisfaction

Natural light has been shown in two studies to increase workplace satisfaction.

- Access to daylight at work has been linked to increased job satisfaction (Boyce, Hunter, and Howlette, 2003).
- Higher levels of workplace sunlight (i.e., more light in a workspace) have been associated with greater levels of job satisfaction (Leather, Pyrgas, Beale, and Lawrence, 1998).

4 INDOOR PLANTS

The addition of plants into the indoor environment is a very literal way to bring nature indoors. Starting in the 1990's researchers began focusing on the effects of plants on health. Interestingly, many of the health benefits from indoor plants are similar to the benefits realized from views to and immersion in nature. Abundant evidence links indoor plants to improved mood and performance.

4.1 Implications of Plants in Healthcare Facilities

As much of the research into the effects of plants on health is very recent, there is also a greater focus on healthcare facilities as high-priority environments. Plants have been shown to reduce physiological stress indicators. However, much of the research in healthcare environments has been self-report based. From these studies it has been consistently found that plants positively influence patient experiences.

- Park and Mattson (2008) found that "Patients in hospital rooms with plants and flowers had significantly fewer intakes of postoperative analgesics, more positive physiological responses evidenced by lower systolic blood pressure and heart rate, lower ratings of pain, anxiety, and fatigue, and more positive feelings and higher satisfaction about their rooms when compared with patients in the control group [no plants]. Findings of this research suggested that plants in a hospital environment could be noninvasive, inexpensive, and an effective complementary medicine for patients recovering from surgery."
- Perceptions of hospital room attractiveness are affected by the presence of plants. Dijkstra, Pieterse and Pruyn (2008) report that when shown pictures of hospital rooms people find those with plants more attractive and relaxing than those without; "The presence of indoor plants in a hospital room leads to a higher perceived attractiveness of the room and this, in turn, leads to reduced feelings of stress in patients. This result would mean that, by basically making the environment more attractive, healing environments can contribute to the health and well-being of patients."
- Plants have been linked to enhanced patient well-being in healthcare waiting rooms (Arnell and Devlin, 2002).
- Plants in psychotherapists offices have been linked to perceptions of "the quality of care, comfort, therapist boldness, qualifications of the therapist, and the likelihood that one would choose a therapist based on the office, all of which were higher with increases in the office's softness/personalization and order" (Nasar and Devlin, 2011).
- Psychiatric patients evaluated staff working on a psychiatric ward more positively after plants were added to that physical environment (Devlin, 1992).
- The addition of plants to indoor common areas at a residential rehabilitation center improved the self-perceived well-being of pulmonary patients (Raanaas, Patil, and Hartig, 2010).

4.2 Cardiovascular Response to Indoor Plants

Being in an indoor space with plants improves our cardiovascular health.

- When plants are present in a space, blood pressure tends to be lower than when they're absent (Lohr, Pearson-Mims, and Goodwin, 1996).

4.3 Plants and Pain

The presence of plants seems to alter our experience of pain.

- When plants are placed in an environment, human pain thresholds are higher than when they're absent (Lohr and Pearson-Mims, 2000).

4.4 Plants and Perceived Health

Being in a space with plants has been linked to improved perceptions of our own health.

- People working in offices with plants perceive that their health is better than people working in the same space when plants aren't in place (Fjeld, Veiersted, Sandvik, Riise, and Levy, 1998).

4.5 Plants and Mood

Mood improves in when plants are present.

- After a review of the literature on human responses to indoor plants, Bakker and van der Voordt (2010) report that "Plants put people in a better mood and improve confidence and openness of the mind to the surrounding world. Plants have also a positive social effect in relation to alliance and morality."
- Including flowers in spaces have been linked to higher levels of positive mood, which has implications for social behavior and cognitive function, as described above (Haviland-Jones, Rosario, Wilson, and McGuire, 2005).

4.6 Plants and Professional Performance

Much of the plant research has focussed on professional performance. Researchers have uncovered positive links between being in an indoor space and professional performance on a variety of different tasks.

- Research by Shibata and Suzuki has found that our ability to do creative thinking seems to be enhanced by the presence of a leafy green plant (in the study, a potted pathos, Epipremum aureum) (2002). Plants in front of study participants had the greatest effects on their performance.

- Cognitive performance on knowledge work is better in offices with plants than without them (Raanaas et al., 2011).
- People believe that they are likely to be more creative in spaces with plants than in areas without them (Ceylan, Dui, and Aytac, 2008).
- People without window views from their workspaces are much more likely to bring potted plants and pictures of nature into their workplace than people with windows (Bringslimark, Hartig, and Patil, 2011).
- When Nieuwenhuis and his colleagues (2014) investigated plants in workplaces they learned that "enriching a previously lean office with [leafy] plants served to significantly increase workplace satisfaction, self-reported levels of concentration, and perceived air quality". In addition both perceived and actual productivity were increased. "Simply enriching a previously spartan space with plants served to increase productivity by 15%. Tasks were completed faster and— importantly—without any accompanying rise in errors."
- When plants are present in university classrooms students got the same sort of grades they did when the plants were absent (Doxey and Waliczek, 2009). However, "statistically significant differences were found in comparisons of overall course and instructor evaluation scores," with students in classrooms with plants feeling more positive about the course and instructor. Greater effects were found for students in classrooms without any visual access to nature except for the indoor plants.

5 OTHER NATURAL ELEMENTS

Research has uncovered pro health effects for several other natural elements. Research in these areas is generally less explored. However, as interest in biophilic design grows it is expected that research on other natural elements will increase.

5.1 Nature Soundscapes

- In healthcare settings, natural soundscapes, such as the sounds of the ocean, seem to reduce patient stress and improve the quality of their sleep (Schweitzer, Gilpin, and Frampton, 2004).

- Warmuth and Joseph have learned that when people with dementia hear the sound of indoor waterfalls, their systolic blood pressure decreases significantly (2008). Warmuth and Joseph conclude that "While the waterfall many not ever replace medication totally, the waterfall display may help to achieve reduced stress and stress-related decreases in systolic blood pressure readings."

5.2 Visual Fractals

Fractals are a seldom recognized but common element of nature. Visual fractals can be difficult to identify, but they have a consistent and desirable effect on human experience. Many natural materials are visual fractals. That means that all of the elements that make them up look the same, but are different sizes. For example, the same leafy shape is found in a fern frond overall and all of the smaller components, as well. Puffy white clouds are also visual fractals.

- When humans see the sorts of fractals seen in nature, whether those fractals are found in clouds or in the fabric covering a workplace or emergency room cubicle wall, they have the same sort of reaction (Joye, 2007). Seeing natural fractals is relaxing, which has positive implications for mental and physical health as well as cognitive performance. It's hard to identify fractal patterns that are natural without a lot of practice, so it's best for design practitioners and managers to use materials whose designers indicate that they meet the needed criteria.

6 WOOD

Wood is unique as a material for biophilic design because it is both a natural material and a structural/building material. That is, the pro-health benefits that come from natural elements (as indicated in the previous sections) may be incorporated into the design of a building through its structural or architectural building components. In other words, structural wood components, when exposed, may simultaneously serve two purposes – functional and biophillic.

Further, the application of wood does not rely on access to windows and natural light, as do most of the biophilic elements discussed in this report. This means that pro health benefits can be found in windowless rooms where natural light and views are not present, and plants do not grow. As a representation of nature, wood provides a high level of design and application flexibility.

Recently research has focused on the biophilic properties of wood. Both our physical wellbeing, as measured by criteria such as blood pressure, and our psychological welfare, as assessed by stress levels, are enhanced when wood is employed. However, as a new field of study the depth and the breadth of research on wood is limited. The research overview that follows covers both published and unpublished research results that are known to the authors of this report. The results found with respect to wood in the built environment are similar to results seen from other natural materials. Psychophysiological responses to wood indicate lower autonomic stress reactivity when wood is present. Further, self-report studies indicate a preference for wood and an expectation of pro health and productivity outcomes.

6.1 Wood and other Natural Materials in Healthcare Settings

To date, research on wood in healthcare settings has mostly been in combination with other natural materials. Researchers have probed the influence of natural materials on patient experiences, finding consistent positive relationships between the two.

- Adding cedar wood panels and rice straw paper to the walls of a hospital isolation room reduced the stress levels (measured by cortisol levels) experienced by people in the space compared to people who spent time in the room when it had its original concrete walls (Ohta, Marutama, Tanabe, Hara, Nishino, Tsujino, Morita, Kobayashi, and Shido, 2008).
- When plants and natural materials (wood, cane) for furniture are used in communal spaces in care homes, the subjective wellbeing of people living in those homes is enhanced compared to situations where these are absent (Weenig and Staats, 2010).
- More appealing hospital rooms are more apt to contain wood furniture than less appealing ones (Swan, Richardson, and Hutton, 2003). Coupled with more positive evaluations of hospital rooms were higher ratings for doctors and patient food at the hospital.
- Assisted living room facilities are seen as homier, by patients and their families, when more natural materials, such as wood (as in siding), are used on the outside of their structures (Marsden, 1999).

- In a wood dominant mental health ward in a new hospital in Ontario, medication costs are reported to be lower than they were before the move to the wood dominant ward. Although brought to the attention of Canadian researchers, this has not been confirmed through formal research, but a proposal for research is forthcoming.

6.2 Psychophysiological response to wood

While the volume of psychophysiological research on wood is low due to the newness of the subject matter, the studies that do exist are focussed on the autonomic nervous system responses and employ modern techniques. This makes the link between the presence of wood and physiological manifestations of stress very clear. The immediate effect of wood on lowering sympathetic nervous system reactivity is seen in four of the five studies below. That is, wood prevents us from becoming more stressed by our environment. This is seen through skin conductivity, heart rate and blood pressure. One of the studies below shows that when longer-term measures are taken wood can not only prevents us from becoming more stressed, it decreases stress levels. When engaged, the parasympathetic nervous system lowers stress levels and promotes healing, recovery, and concentration. This result was found by measuring heart rate variability in students over the course of a school year. Wood use in built environments has clear psychophysiological benefits, decreasing stress reactivity and lowering stress over the longer measurement periods.

- Kelz et al. (2011) studied stress levels in Austrian classroom students exposed to wood dominated and non-wood conventional classrooms. Over the course of the school year they found that heart rate variability increased in students in the wood classrooms. An increase in heart rate variability is an indication of parasympathetic nervous system activation. The parasympathetic nervous system acts to reduce stress levels and promote healing and recovery functions in the body.
- Fell (2010) studied the autonomic responses of 119 subjects in wood and non-wood offices before, during, and after a stressful mental task. In this study sympathetic nervous system activation was lower in the wood room. Skin conductance level was lower in the wood office during the pre-and post-test periods. Further, the rate of non-specific skin conductance responses, measurable divergent stressful thoughts, in the wood office was less than half that as in the non-wood office.
- Tsunetsugu and her colleagues investigated human responses to wood used in residential living rooms (2002). Heart rate and blood pressure were measured when study participants were in a test room with wood covered surfaces or no wooden surfaces. The blood pressure and heart rate of study participants in the wood room fell below levels measured before they entered it, while the blood pressure and heart rate of those in the room without wood increased compared to levels measured before they visited the room.
- In a study published in 2007, Tsunetsugu and colleagues investigated study participants' responses to being in a room with 0%, 45%, or 90% of surfaces covered with wood. Heart rate and blood pressure were lowest in the 90% wood room than in the 0% wood room. However, the 45% coverage room was the one most preferred by participants. When 45% of surfaces were covered with wood people said they felt most comfortable.

- Sakuragawa and colleagues studied the psychological and physiological implications of viewing either a wooden or white steel wall (2005). The blood pressure of people who like when wood is used as a finishing material dropped significantly when they faced the wooden wall, but if people disliked wood as a building material their blood pressure wasn't affected by viewing it. Liking steel did not seem to influence the blood pressure of people looking at white steel walls; however, the blood pressure of people who disliked white steel increased when they viewed the steel wall.

6.3 Self-report wood studies

Prior to the current focus on psychophysiological measurements of wood and health there were several studies of the self-report or cognitive response type. Self-report is the most common type of study in the field of environmental psychology[2]. These studies are executed through surveys, interviews, and activities such as sorting photographs of environments. They capture cognitive experience, expectations or beliefs, rather than pre-cognitive physiological reactions. In choosing a material to promote heath both types of studies are valid. It is important that a material such as wood promotes health at a pre-cognitive level, but also that people have the expectation that the material is healthy and desirable.

- In a 2004 UBC study respondents sorted architectural finishing photographs according to various health descriptions. Though this study did not measure actual health outcomes it found that respondents had an expectation that wooden surfaces contribute to human health and well-being (Rice, 2004).
- Masuda and Yamamoto investigated the messages sent by wood used in residential environments (1988). Nearly 50 photos from home decorating magazines and catalogues were shown to study participants after the proportion of surfaces in each image covered by wood were calculated. Spaces were seen as warm (i.e., pleasantly relaxed) places to be as the proportion of wooden surfaces increased up to a level of 43% wood, and fell after that proportion of wooden surfaces reached that level. Masuda teamed with Nakamura in 1990 to repeat the 1988 study. They determined that living rooms using 0% or 100% wood were classified as most novel, and rooms with other percentages of wood in use being classified as less novel.
- Sadalla and Sheets investigated the messages sent by weathered wood and wood shingles on the outside of homes (1993). They learned that "weathered wood and wood shingle are seen as warmer, more emotional, weaker, more tender, more feminine, and more delicate than are brick, concrete block or flagstone." These effects may, at least in part, result from the fact that "Emotionality, tenderness, and femininity are semantically related to warmth, and may derive from the relative perceptual qualities of wood and stone. Similarly, the relative weakness and tenderness ascribed to wood may be related to the physical characteristics of wood and stone."

[2] In the previous sections self-report studies are interspersed with psychophysiological studies. They are separated in the wood section to provide clarity in the psychophysiological benefits of wood.

- Two studies published by Ridoutt and colleagues in 2002, shed light on the nonverbal messages sent by wood used in interior design. Study participants were shown images of office lobbies, some of whose finishes were wood, and lobbies in which other materials were used. Firms with wooden finishes in their reception areas were seen as more prestigious than those using other materials, as well as more energetic, innovative, and comfortable. Firms using wood materials in their lobbies were felt to be more desirable organizations to work for.
- Based on a case study of libraries at the University of North Carolina Ashville, Sinclair concludes that wood promotes studying by undergraduates (2007).
- People believe they will think more creatively in spaces featuring exposed wood or stone than they think they will if these materials are absent (McCoy and Evans, 2002).

6.4 Contemporary Wood Research Unpublished in the English Language

During the literature review for this paper, Dr. Fell had the opportunity to attend a meeting of the Japanese wood and health researchers at Tokyo University. This meeting was attended by researchers from the Forestry and Forestry Products Research Institute of Japan, Tokyo University, Sumitomo Forestry, and FPInnovations. Below is a summary of research presented at the forum.

Yuko Tsunetsugu[3], Masaki Sugiyama[4], Seiichiro Ukyo4 are common collaborators in the field of wood and health. They focus on psychophysiological responses to wood. Techniques currently being employed are brain activity via near infrared spectroscopy, pulse rate, blood pressure, heart rate and heart rate variability.

- Olfactory responses have been found with respect to alpha-pinenes in wood. This adds scientific merit to the Japanese practice of Shinrin Yoku (forest bathing)
    - Lower heart rate and blood pressure were observed during stressful tasks in a lab setting when the alpha-pinenes scent was present (Tsunetsugu et al, 2014. Japanese Journal of Aromatherapy)
    - Alpha-pinene scent was linked to lower infant heart rates in a lab setting
- These researchers have also tested cardiovascular response to wood and non-wood rooms with subjects at rest
    - Heart rates were lower when alpha-pinene was present than when there was no odor in a room, or other wood extractives were present (Limonene)
- Visual effects comparing wood walls with white cloth finished walls.
    - Pulse rate lower by close to 3 beats per minute when walls finished in wood.
    - Heart rate variability increased in the wood wall room indicating activation of the parasympathetic nervous system which reduces stress and promotes recovery functions.

[3] Forest and Forestry Products Research Institute of Japan
[4] Tokyo University

Dr. Shida Shatoshi of Tokyo University has dual interests in wood and health and wood physics which have led to some interesting research.

- This researcher studied preferences for seating surface materials using long-term camera observation. In this study, wood seating surfaces were selected more frequently than plastic, metal, or stone/cement surfaces in all seasons. This selection bias was most pronounced during the winter when air temperatures were cold.
- This research on preferred seating materials led to the study of the heat loss due to contact with materials. Wood has a low heat transfer coefficient making it a good insulator. This may be one of the reasons it is an often chosen seating surface.

Dr. Yuki Kawamura is a researcher in wood and health at Sumitomo Forestry Research. Dr. Kawamura is very active in the field of wood and health. He also employs modern techniques for measuring health and stress response.

- Dr. Kawamura has studied brain surface response through electromyography (EMG). In this study, subjects sat in wood and non-wood booths. In the wood booth, higher Alpha wave activity was found during rest, indicating higher relaxation. During concentration tasks, respondents in the wood booth had higher beta waves, an indicator of focus. This result indicates that wood allows for deeper rest or concentration, depending on the circumstance.
- Further work in the wood and non-wood booths tested memory. Recall was faster in the wood booth, supporting the beta wave finding.
- In a study of bedroom environments Dr. Kawamura tested melatonin levels when artificial light was direct, reflected off a white ceiling, or reflected off of a wood surface. When light was reflected off of a wood surface, melatonin levels were higher in a bedroom setting, indicating that this space would be more conducive to sleep than the others tested.
- In one long-term study, the researcher observed time spent playing on four sections of floor in a daycare center. Each section had a different flooring material; solid wood, veneered wood, artificial wood surface, solid colour synthetic surface. The twenty-four subjects spent more time on the solid wood floor than any other surface thereby indicating a preference for natural wood.

7 THE CASE FOR WOOD IN HEALTH ENVIRONMENTS

The evidence provided in the above sections builds towards the conclusion that we are healthier, happier, and more productive when connected with nature. Unfortunately, we live and work in built environments with Canadians spending 88% of their lives indoors[5] (Leech et al., 1997). If this connection to nature is truly restorative, then we need to take every practical opportunity to bring natural elements into our indoor environments.

In the small but growing volume of research on wood and health, the results that are emerging mirror results we have seen from exposure to other natural elements, such as views and plants. Lower stress reactivity in the autonomic nervous system is found when wood, plant, or nature views are present. Lower sympathetic activation and higher parasympathetic activation result in measurably lower heart rate, lower blood pressure, lower skin conductivity, and higher heart rate variability. These results have been linked to exposure to wood. However, lower stress activation due to views and plants have also been shown to increase the ability to concentrate, lower pain perception, and speed recovery times. Though these benefits have not been identified for wood, they are tied to the same autonomic responses to nature seen with wood. Therefore, it is reasonable to expect that future research on wood will find many of these same results.

In healthcare environments, natural materials and views are associated with better patient outcomes with respect to recovery times, lower pain perception, and positive dispositions. This alone is reason for including more wood in in these buildings. However, healthcare facilities are populated not only by patients, but also by their visiting families and the practitioners that treat them. These people also benefit from the pro health effects of nature. Their health, in turn, benefits the patient. Visiting or accompanying family members with lower stress levels and more positive moods likely affect patient stress level and mood. Further, the link between natural elements and the ability to focus attention cannot be ignored for healthcare practitioners who work all hours and often do not have access to the benefits of natural light. For these workers, wood can bring many pro health benefits in the absence of a connection to outdoors and day lighting.

Wood can bring nature into hospitals and care facilities in very practical ways. First, wood use in buildings is not reliant on windows with views and natural light. Wood can be employed in windowless or non-day lit areas of a building to bring about the benefits of exposure to nature. Further, unlike other natural elements, wood can be used both in a visual and a mechanical role, for example, as an exposed structural material or furniture. Of course, good judgment must be used when employing wood surfaces. Design for durability and cleanability are key considerations when wood is used. However, recent wood-forward hospital construction and renovations in Canada and abroad have successfully employed the material to critical acclaim and high user satisfaction. The shift towards greater use of wood in healthcare environments is an important and practical step in reconnecting patients, families, and practitioners with the pro health benefits of exposure to nature.

[5] A 1989 EPA study in the US estimated Americans spend 90% of their time indoors.

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