**WOOD IN THE HUMAN ENVIRONMENT:
RESTORATIVE PROPERTIES OF WOOD IN THE BUILT INDOOR ENVIRONMENT**

by

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ABSTRACT

In this study, the stress-reducing effects of wood and plants were studied in the context of an office environment. This study took a psychophysiological approach to stress and attempted to assess the sympathetic and parasympathetic branches of the autonomic nervous system. Four office environments were studied in this factorial design: wood and plants, wood and no plants, no wood and plants, and no wood and no plants. One hundred and nineteen university undergraduate students were assigned to one of four test conditions. Skin conductance and inter beat interval were continuously monitored throughout the experiment. The experiment consisted of a 10-minute baseline period, a 12-20 minute stressful task, and a 10-minute recovery period. Wood effects were found with respect to skin conductance level (SCL) and frequency of non-specific skin conductance responses (F-NS-SCR), both indicators of sympathetic system activation. Subjects exposed to wood had lower SCL in the baseline period and lowers F-NS-SCR in all periods of the study. No plant effect was found with respect to sympathetic activation. Further, there was no evidence of wood-plant interactions. Spectral analysis of HRV data was used to measure parasympathetic activation. No treatment effects were found with respect to parasympathetic activation. This study provides evidence that wood provides stress-reducing effects similar to the well studied effect of exposure to nature in the field of environmental psychology. The practical implication of this effect is that wood may be able to be applied indoors to provide stress reduction as a part of the evidence-based and biophilic designs of hospitals, offices, schools, and other built environments.

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GLOSSARY

Environmental psychology – "The scientific study of social, psychological, and behavioral phenomena as related to and revealed through physiological priciples and events in functional organisms." (Cacioppo et al., 2007. p.4)

Biophilia - the innate attraction that humans have to living organisms and life-like processes (Wilson, 1984).

Psychophysiology – the study of the interrelationship between psychological and physiological processes in humans

Autonomic nervous system – regulates involuntary bodily functions such as the heart, smooth muscle, and glands. Consists of sympathetic and parasympathetic branches that work in tandem to adapt to environments and stress.

Sympathetic nervous system – part of the autonomic nervous system that prepares the body to react to stress. Often characterized as the "fight or flight" response.

Parasympathetic nervous system – part of the autonomic nervous system that relaxes the body and allows for maintenance and recovery functions. It is often characterized as the "rest and digest" response.

Evidence-based design – "Evidence-based design is the conscientious, explicit, and judicious use of the current best evidence from research and practice in making critical (design) decisions…" (Hamilton and Watkins, 2009. p.9)

Electrodermal activity (EDA) - is regulated by the sympathetic nervous system. When the sympathetic nervous system is engaged, eccrine glands in the skin secrete sweat, lowering electrical resistance of the skin. Three measures of EDA are used in this study. These are skin conductance level (SCL), frequency of non-specific skin conductance responses (F-NS-SCR), and amplitude of non-specific skin conductance responses (A-NS-SCR).

Heart rate variability (HRV) - Variability in heart rate can indicate the degree of parasympathetic activation. In periods of high parasympathetic regulation, heart rate is less uniform.

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DEDICATION

To my family.

1 Introduction

1.1 *Background*

Environmental and architectural psychology can provide insight into the human relationship with wood. These fields look at the interaction of humans with their surrounding environments. Environmental and architectural psychology also look at human preferences for different environments.

Early studies in environmental psychology focused on the negative effects of environments on people. Ittelson (1960) studied the effect of institutional design on patients with mental illness, and later coined the phrase “environmental psychology”. Much of this track of research focused on the negative effects of crowding, noise, and pollution (Garling, 2001). It also spawned the field of architectural psychology where such negative effects are reduced through design.

Research into people’s choice of environments led to important progress in identifying positive environments. In the search for positive environments, nature appears as a constant theme. Borrowing from aesthetic preference literature, Wohlwill (1968) hypothesized that natural scenes with moderate levels of visual complexity would be most preferred. This hypothesis failed to adequately explain scene preferences. Kaplan *et al*. (1972) added scene content as a variable, comparing natural and urban scenes. It was found that while complexity could not predict preference, content could. Studies have since have pointed to a preference for nature (Stamp, 1996; Herzog *et al.*, 1997).

The consistent preference for nature and natural scenes in the literature led researchers to question why this occurs. Balling and Falk (1982) point to an innate or evolutionary preference for natural scenes. Kaplan (1987) suggests that such a preference would evolve or be learned if natural scenes afford an advantage or benefit. Such advantages are apparent even in our modern world. Ulrich (1984) found that patients recovering from similar surgeries differed in their recoveries and demands for pain medication based on their room view. Those with a building view recovered slower and required more pain medication than those with views of a park. Vederber (1986) and Moore (1981) provide evidence of the same phenomenon. The above studies led back to the focus of the effect of the environment on people, but the focus became the positive effects that environments may have.

Kaplan and Kaplan (1989) refer to these positive environments as "restorative environments". The major focus of their studies and theories is attentional fatigue and its reduction by immersion in natural environments. Ulrich (1991) put forward a parallel restorative environment theory, with natural settings holding a greater potential for psychophysiological stress recovery.

Natural settings appear to offer restoration to humans (Kaplan and Kaplan, 1989). Further, people seem to know that natural environments are more restorative (Herzog *et al.*, 2002) and they prefer natural environments (Kaplan and Kaplan, 1989).

Lohr *et al.* (1996) took the step of moving natural elements into an indoor environment. They studied the effects of plants on task performance and stress levels in the indoor environment. Lohr and Pearson-Mimms (2001) did a similar study of plants in indoor environments with pain perception being the test effect. They found that subjects in a room with plants had a greater pain threshold than subjects in a room with no plants. Shibata and Suzuki (2002) looked at the effect of plants on task performance. They found that the presence of plants increased performance on creative tasks. These studies are important in that they bring natural elements into a built environment.

Finally, there have been three psychophysiology studies looking at wood use in built environments. Tsunetsugu *et al.* (2002) found heart rate and diastolic blood pressure to be lower in room featuring prominent wood décor. Sakuragawa *et al.* (2005) found diastolic blood pressure to be lower when viewing a wood surface than a painted metal surface. Finally, Tsunetsugu *et al.* (2007) found mixed results with respect to wood content in a room. Unfortunately, these three studies all suffered from small sample sizes and a high potential for serial effects. While these studies may suggest a stress reduction effect of wood use in the built environment, their methodological shortcomings preclude meaningful conclusions.

1.2 *Rationale for study*

The stress recovery potential of nature is a remarkable phenomenon; however, it is of little practical day-to-day relevance for the urban majority. In 1995, Canadians spent over 88% of their time indoors and a further 6% in their cars (Leech *et al.*, 1997). This leaves only 6% of our time spent in potentially restorative natural environments. If stress reduction by environment is to have meaningful benefits, we must either spend more time outdoors or we must find a way to reduce stress during the 88% of our time spent indoors. The focus of this study is on the latter.

Previous research shows that the beneficial effects of nature can be brought into the built environment in the form of plants (Lohr *et al.,* 1996; Lohr and Pearson-Mimms, 2001; Shibata and Suzuki, 2002). However, the application of plants to provide nature in built environments is limited by the availability of natural light, another stress reducer (Leather *et al.*, 1998). The advantage of wood is that it can be applied in rooms lacking natural light and the ability to support plants. If wood is proven to provide a nature effect on stress reduction, further use of wood as a visual material would be appropriate in architecture. This is especially true in an era of evidence-based design where human health and performance are express goals of building design.

1.2.1 Research objectives

The overarching research question for this study is simply;

- *Does wood reduce stress in the built environment?*

Stated in this fashion, the objective of this study is very practical and straightforward. However, this simple question contains three key components of interest.

The first component is stress. In this study, we define stress from a psychophysiological perspective, looking at autonomic responses to the surrounding environment. We break out the autonomic nervous system into its sympathetic and parasympathetic components to analyze stress responses.

The second component of interest in the research question is the built environment. Environmental psychology has documented the stress-reducing properties of outdoor natural environments (*e.g.* Stamp, 1996; Herzog *et al.*, 1997; Parsons *et al.*, 1998). However, as modern humans exist primarily in the built indoor environment, the stress characteristics of these environments is of practical interest.

The final component of interest in the research statement is wood. Wood used in the structure, furniture, and décor of the built environment is a biological, but non-living material. It has previously been demonstrated that plants, a living biological material, can be brought into the built environment to provide some of the same stress-reducing effects as outdoor nature (Lohr *et al.,* 1996; Lohr and Pearson-Mimms, 2001; Shibata and Suzuki, 2002). This study takes these results one step further and asks if wood, a non-living biological material, can provide the same stress-reducing effects as outdoor nature.

After considering these three components of the basic research question we can further refine the objective into a set of more specific research questions. More specifically;

Does the application of wood in the built environment reduce stress?

How does the application of wood in the built environment affect autonomic responses to stress?

Does the application of wood in the built environment provide the same stress-reducing health effects as indoor plants?

2 Literature review

2.1 *Environmental psychology*

Environmental psychology is broadly defined as the "impact of the physical environment on people and the impact of people on the physical environment" (Garling, 2001. p. 4551). Though this applied field of psychology only emerged in the 1960s, it in turn has been applied to many other fields, including design (Kellert, 2008), architecture (Hildebrand, 2008), health sciences (Ulrich, 1984; Diette *et al.* , 2003), and urban design (Kou and Sullivan, 2001; Beatley, 2008).

Garling (2001) provides a contemporary overview of terms and approaches to environmental psychology. First, Garling (2001) points out that for all environmental psychology problems there exist three facets. These are the individual or group, the environment in which they are immersed, and the activity or situation in which they are engaged.

While all research questions in environmental psychology contain the three elements identified above, there are three very distinct research focuses that pervade most applications of the subject. The first two research focuses come directly from the definition of environmental psychology: the effect of the environment on people, and the effect of people on the environment. The third is the choice of environment.

The first research direction to emerge was the impact of the environment on people. This began with the study of psychiatric facility design on patients (Ittelson, 1960). In fact, it was Ittelson who first introduced the term "environmental psychology" in 1964 (Bonnes and Secchiaroli, 1995). This research orientation has since expanded to non-clinical subject matter including architecture, design, and urban planning. However, much of the focus of this research is on negative effects such as noise, crowding, pollutants, and other irritants (Garling, 2001). Garling (2001) points out that the complementary field, the positive effects of environments, has recently attracted more attention. This includes the study of environments that reduce stress and pain, aid recovery, and increase productivity.

The second research focus is the impact of humans on the environment. The focus of this type of research is on promoting pro-environmental behavior to lessen the effect of humans on their environment (Garling, 2001). This research complements a wealth of information from sociology on environmental movements, attitudes, and behaviors.

The final research focus is people's choice of environment. Garling (2001) asks a simple question which calls upon many disciplines: is choice "deliberate, habitual, or forced" (p. 4653)? If environmental choice is deliberate, it is implied that people recognize the positive and negative impacts of their environment.

It is the combination of the effect of environments on people and people's choice of environments that is of interest in this study and in architectural psychology generally. While the questions are being posed by researchers, there are few answers as to the psychological and health benefits of certain environments, let alone public awareness to make such choices. Deliberate choice may be more apparent with respect to social aspects of environments. People may choose environments based on the social cues their choice suggests to others (Ritterfeld and Cupchik, 1996; Ridoutt *et al.,* 2002a and 2002b). Considering choice as habitual can point to either conditioned or innate responses (Balling and Falk, 1982). This is the nature or nurture debate of sociobiology (Bechtel, 1997).

2.1.1 Environmental choice

It is important to recognize that, in many situations, people are able to choose the environment they are in. It is these free choice situations that are most interesting in the application of environmental psychology. The answers to the questions of how and why we choose certain environments are of interest to architects, designers, marketers, and planners.

Choice of environment has been approached from many different perspectives. Choice can be based on such factors as aesthetics, expected outcomes, and social cues, among others (Wohlwill,1968; Ridout *et al.,* 2001). One fundamental perspective from which to look at these factors is to distinguish which types of choices are innate, which are conditioned, and which are cognitive. It is expected that choice of environment contains all of these factors, with unique choices having been driven by varying levels of each type of factor.

2.1.2 Evolutionary responses to environments

When examining preferences for environments, one key consideration is whether these preferences are innate or conditioned. Zajonc (1980) argued that humans come hardwired with a set of affective responses that are pre-cognitive. He termed these innate preferences as “preferenda”. An example of a preferendum would be the innate fear response to snakes. This pre-cognitive response is a defense mechanism that is both immediate and certain. If cognitive evaluation and previous knowledge of snakes were required before reacting, there would be a lot more snake bites. Other preferenda include light, fire, clouds, flowers, water, and mountains (Orians and Heerwagen, 1992).

Ulrich (1983) discusses aesthetic and affective responses in natural environments. He states that affect or emotion is both innate and cross-cultural, and has characteristic physiological components. These pre-cognitive reactions are evolved adaptive responses that afford all humans a certain level of survival instinct. Ulrich (1983) does, however, leave room for cognition in our response to our environments. While initial reactions are affective, these reactions are often followed by cognition to provide a more complete appraisal of a stimulus that benefits from learned culture and experience.

Kaplan (1987) develops a comprehensive hypothesis of environmental preference. He argues “there may be great advantages in making a quick, automatic prediction about the informational possibilities of a place that one approaches” (p. 23). These “automatic” decisions or reactions can be the result of adaptation. However, adaptation must be learned and relearned by each generation. Kaplan argues that the evolutionary development of innate preferences is a plausible explanation of results such as Balling and Falk’s (1982) finding of a universal preference for savanna-like environments. With evolutionary adaptation, “the individual would intuitively be drawn away from unpromising places, and towards places that afforded more positive opportunities” (Kaplan, 1982. p.24).

2.1.3 Evolutionary theories

2.1.3.1 Complexity theory

The earliest research into choice of environments focused on the complexity of visual stimuli. This orientation is borrowed from the field of aesthetics. Studies into visual preferences have repeatedly supported a moderate level of complexity as ideal (Berlyne, 1971). An inverted U-shaped relationship has been empirically established between preference on the vertical axis and complexity on the horizontal axis (Day, 1967). This is believed to be an innate rather than a learned reaction (Ulrich, 1983).

Wohlwill (1968) applied the complexity hypothesis to outdoor settings. Though this study suggested the inverted U-shaped preference/complexity relationship, it did not provide sufficient evidence to support it (Kaplan, 1987). Kaplan *et al.* (1972) introduced content as a preference variable when evaluating outdoor environments. They showed respondents a series of photographs ranging from natural to built environments. In this study, the natural environments were almost uniformly preferred, but complexity was not predictive. Wohlwill (1976) followed up the Kaplan *et al.* (1972) study by systematically incorporating content and complexity. He found a positive linear relationship between complexity and preference, but also an overwhelming preference for natural scenes.

Clearly, complexity theory does not provide an adequate explanation of preference. This was tested in the Martindale et al. (1990) in the field of experimental aesthetics. Using simple shapes, they found that when size and complexity were varied, preference followed the inverted U-shaped curve described by Berlyne (1971) according to the level of complexity. However, when “meaningful” stimuli were added, measures of “meaningfulness” accounted for most of the variation in preference making the complexity effect negligible. In the context of environmental psychology, nature may be this meaningful stimulus.

2.1.3.2 Savannah theory

Balling and Falk (1982) provided some of the earliest evidence of evolutionary or innate influences on the choice of environment. In their study, five different types of natural settings were used as independent variables. These were desert, rain forest, savanna, mixed hardwoods, and boreal forest. Balling and Falk (1982) studied preferences for these five natural environments by age cohorts. They found that the youngest respondents, ages 8 and 11, preferred savannah settings. By age 15, respondents started to prefer mixed hardwood settings, the natural setting prevalent in the region where the study took place (Eastern United States). Balling and Falk (1982) interpret this result as evidence for evolutionary preferences for natural settings. The argument goes that savannah is the natural environment from which humans evolved, and that humans have an innate preference for this environment. As people get older, they are conditioned to prefer the environment that surrounds them. Therefore, as children have the least years of conditioning, their preference for savannah can be considered innate, and the product of evolution.

A recent study by Han (2007) refutes the savannah hypothesis and supports a forest hypothesis. In a study of six biomes, coniferous forests and tundra were the most favored. However, Balling and Falk (1982) base their savannah theory on populations under 12 years old while Han (2007) studied college-aged students. This age distinction is key in savannah theory as, by the logic of Balling and Falk (1982), one would argue that university students would have already developed preferences for biomes other than savannah.

2.1.3.3 Prospect-refuge theory

Prospect-refuge theory suggests that humans innately prefer environments that provide prospect and refuge, both of which offer distinct survival advantages (Appleton 1975). Environments with prospect are environments that provide views of or imply an environment of mystery and potential bounty. Refuge refers to the safety an environment provides from predators and the elements. It has been observed that trees provide both refuge and prospect, because you can climb one to hide or to get a view of your surrounds. This may account, in part, for a universal preference for trees and wood (Stewart-Pollack, 1996).

2.1.3.4 Biophilia - the preference for nature

The preference for nature is also addressed by the more general biophilia hypothesis (Wilson, 1984; Kellert and Wilson, 1995). Biophilia is the innate attraction that humans have to living organisms and life-like processes. It is hypothesized that biophilia is inherent and evolutionary and that it confers a competitive advantage to humans. The innate attraction to nature and the competitive advantage it affords humans is also cited in Balling and Falk (1982) and Kaplan (1987).

The carry-over from these biophilic effects is apparent in the modern world, even when prospecting for food and shelter in urban environments is not connected to nature. For example, Ulrich (1984) found that patients recovering from similar surgeries differed in their recoveries and demands for pain medication based on their window view. Those with a building view recovered more slowly and required more pain medication than those with views of a park. While this effect can be attributed to biophilia, the competitive or survival advantages afforded patients by either room were equal in a modern or practical context. The innate attraction to nature, though not grounded in immediate competitive advantage, provided for better health outcomes.

The above studies led back to the focus of the effect of the environment on people, but the focus became the positive effects that environments may have.

2.1.4 Positive environments – the need for nature

Accepting a psychoevolutionary or "biophilic" preference for nature, the next question is, why is it important to be immersed in a preferred environment in modern times? Two major theories address the need for nature, and both revolve around the concept of restorative environments. One focuses on the ability to focus attention (Kaplan and Kaplan, 1989), while the other focuses on psychophysiolological stress (Ulrich *et al.*, 1991). What both of these lines of research have in common is a focus on rural and urban outdoor environments. This rural versus urban comparison also extends to views from windows. Views of built environments have been compared to views of green space (Ulrich, 1984; Tennessen and Cimprich, 1995).

2.1.4.1 Attention restoration theory

Kaplan and Kaplan (1989) propose the widely accepted attention restoration theory (ART), which describes the difference between involuntary attention and directed attention. Directed attention involves tasks such as reading, studying, or driving, which require a person to focus and ignore easier stimuli which attract their involuntary attention. After prolonged periods of directed attention, people become fatigued, no matter the nature of the task. Attention fatigue leads to a lack of concentration, mistakes, irritability, indecisiveness, and a lack of inhibition. In ART, the inability to focus attention is a result of draining mental resources (Kaplan, 1995).

Exposure to restorative environments is one way of recovering from attention fatigue. Natural environments have repeatedly been found to aid in the restoration of attention. Tennessen and Cimprich (1995) tested students with different views (natural and urban) for their level of directed attention. They used several standard attention tests and found that students with a dormitory facing greenspace were better able to focus attention. Hartig *et al.* (1991) found a better proofreading proficiency after wilderness vacations than urban vacations. Hartig *et al.* (2003) found that attention improved when walking in nature and decreased when walking in an urban setting. Cimprich (1992) tested focused attention of breast cancer recovery patients; the group undertaking restorative activities, many associated with nature, showed a better ability to focus attention. The positive effect of nature to help focus attention is a well-established cognitive phenomenon. However, it does not address physiological stress and health.

2.1.4.2 Psychoevolutionary theory – psychophysiology

Ulrich (1983) takes a stress reduction approach to restorative environments. There are a handful of studies in environmental psychology that have looked at physiological indicators of stress and stress reduction. Ulrich *et al.* (1991)

measured pulse transit time (blood pressure), skin conductance, and frontalis muscle tension. These physiological indicators of stress were measured at a baseline timeframe, during stress application, and during recovery when exposed to urban and natural environments. They found that recovery from stress was faster and more complete when exposed to a natural environment.

Parsons *et al.* (1998) measured systolic and diastolic blood pressure, inter beat interval, skin conductance, and facial muscle tension across a spectrum of four videotaped car-rides in natural to urban settings. The authors found that subjects were more autonomically responsive to non-natural environments than to nature-dominated environments. Interestingly, there was no link between somatic response, as measured by brow (corrugator supercilli) and cheek (zygomaticus major) muscle tension, and autonomic responses. They found evidence of stress recovery and immunization from stress with exposure to natural and golf course settings. Based on the pattern of results found, the authors suggest the sympathetic nervous system may mediate environmental responses.

Hartig *et al.* (2003) measured systolic and diastolic blood pressure during and after a stressful task. They compared stress recovery in both urban and natural environments. Diastolic blood pressure was found to drop more in the short term after a stressful task when subjects recovered in a room with a view of nature than in a room with an urban view.

Laumann *et al.* (2003) measured heart rate response of subjects in natural and urban environments. In this study, subjects performed a proofreading task to induce mental stress. They were then subjected to a video of either a natural or urban setting. Laumann *et al.* (2003) found that subjects watching a video of a natural scene had greater heart rate decreases towards baseline than those watching the urban video.

The above studies establish a psychophysiological link between exposure to nature and stress activation. Results for sympathetic and mixed autonomic measures suggest that nature reduces stress in humans.

2.2 *Built environments*

If we are to accept biophilia as an innate evolutionary response, there is one key problem to how we live today: we have not lived in urban and built environments long enough to adapt to them from an evolutionary perspective (Kellert, 2008).

2.2.1 Urban living

Urban living is relatively new in the grand scale of human history. At the beginning of the 19th century, only 6.1% of Americans lived in cities (US Department of Census). At the beginning of the 20th century, the US urban population swelled to 39.6%. Finally, at the beginning of the 21st century, 79.1% of the US population lived in urban areas[1]. Life in the urban built environment is now the *status quo* but is less than 200 years old from a practical perspective.

Comparable world data and projections are available from 1950 onwards from the United Nations Populations Division (2009). It is clear that the shift to urbanization will continue (Table 1). Worldwide, the urban population was 29.1% in 1950. It is projected to be 50.6% in 2010 and 69.6% by 2050.

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[1] The US Census Bureau definition of urban area has evolved over the years to adjust for modern demographics. The basis of the current definition is based on a population of 50,000 or more.

Table 1 Percentage urban population

Year	World	More Developed	Canada
1950	29.1	52.5	60.9
1955	30.9	55.6	65.7
1960	32.9	58.7	69.1
1965	34.7	61.7	72.9
1970	36.0	64.6	75.7
1975	37.3	67.0	75.6
1980	39.1	68.8	75.7
1985	40.9	70.0	76.4
1990	43.0	71.2	76.6
1995	44.7	72.2	77.7
2000	46.6	73.1	79.5
2005	48.6	74.0	80.1
2010	50.6	75.0	80.6
2015	52.7	76.2	81.2
2020	54.9	77.5	82.p
2025	57.2	79.0	82.9
2030	59.7	80.6	84.0
2035	62.2	82.1	85.1
2040	64.7	83.5	86.1
2045	67.2	84.8	87.0
2050	69.6	86.0	87.9

Source: United Nations Population Division (2009)[2]

2.2.2 The indoor environment

Advances in agriculture and division of labour have not only allowed for the growth of urbanism, they have also decreased the need to spend time outdoors. Canadian adults spend over 88% of their time in indoor environments (Leech *et*

[2] United Nations Population Division classifies areas as urban based on the domestic definition of urban in each country or area.

al. 1997, Table 2). They spend a further 6% in they cars, leaving less than 6% of their time for the outdoors. If restoration is to be achieved in a meaningful way, the indoor environment must be addressed.

Table 2 Average time spent in environments by Canadians, 1995

Location	Adults	Youth	Children
Indoors at home	64.3%	67.8%	71.6%
Work/school	10.1%	11.7%	5.7%
Indoors-other	11.9%	7.8%	10.9%
Bar/restaurant	2.1%	1.0%	0.6%
Total Indoor	**88.4%**	**88.3%**	**88.8%**
In vehicle	6.0%	3.2%	3.6%
Total Built	**94.5%**	**91.4%**	**92.4%**
Total Outdoors	**5.50%**	**8.60%**	**7.60%**

Source: Leech *et al.*, (1997)

To date, most environmental psychology studies have dealt with outdoor environments. However, two of the cornerstone works in the field actually took place in the built environment (Ittleson, 1960; Ulrich, 1984). The indoor environment has also been approached more recently with the introduction of plants, a living natural material, into the built environment (Lohr *et al.*, 1996; Lohr and Pearson-Mimms, 2001; Shibata and Suzuki, 2002; and Haviland-Jones *et al.*, 2005).

It is interesting to note that many of the studies of natural outdoor environments used pictorial and video presentation of natural outdoor stimuli from an indoor test room (Parsons *et al.*, 1998; Ulrich *et al.*, 1991; Laumann *et al.*, 2003; Lee *et al.*, 2004; and Miller *et al.*, 1992). This provides some evidence that the introduction of nature surrogates into the built environment has restorative qualities.

The response to pictures and video presentations of nature indoors also introduces the issue of environmental surrogates. Ulrich and Gilpin (2003) suggest that hospital artwork can be used to promote healing. They suggest that depictions of water, landscapes, flowers and positive cultural artifacts and faces are most appropriate for hospitals.

This was supported by Nanda *et al.* (2008), who surveyed hospital patients on a series of art images. Patients rated art representative of nature more positive on an emotional scale and higher on a preference scale. Best selling art and abstract art not depicting nature were consistently rated lower. Similarly, Kweon *et al.* (2008) looked at self-reported anger measures when nature posters, non-nature posters, or no posters were present. They found an anger effect in males only. Men had the lowest anger scores when exposed to nature posters. However, anger was also lower in the non-nature poster setting than in the no poster setting. The above studies support the potential for nature surrogates to also provide restoration in the built indoor environment.

2.3 *Biophilic design*

Biophilic design (Kellert 2008) is the application of the biophilia hypothesis (Wilson, 1984) to built environments, including the urban landscape and built indoor environments. Kellert *et al.* (2008) released a book on biophilic design featuring chapter contributions from leading environmental psychology researchers, writers, and practitioners. This book has brought considerable attention to environmental psychology in design. Biophilic design also complements green building and the general push for sustainable construction.

Kellert (2008) lists six elements of biophilic design: environmental features, natural shapes and forms, natural patterns and processes, light and space, place-based relationships, and evolved human-nature relationships. The use of plants and natural materials fall under the category of environmental features.

Salingaros and Masden (2008) state that there are two types of biophilic design. One approach is to apply natural materials (Kellert's natural features) into conventionally designed structures to offer some biophilic effect.

> "One aspect of biophilic architecture, therefore, is the intimate merging of artificial structures with natural structures. This could involve bringing nature into a building, using natural materials and surfaces, allowing natural light, and incorporating plants into the structure".
> Salingaros and Masden (2008, in Biophilic Design. p. 63)

The second approach is to reconsider the building and site and design based on all aspects of biophilia to make a more complete connection to the user through biomimicry. The authors note, however, that this more holistic approach to biophilic design is much more involved and in its infancy as an architectural practice. They concede that a natural materials-based approach has an advantage as it is better aligned with current design and economic practices.

2.3.1 Biophilic materials

Within the field of biophilia, the consideration of the materials that can be used to achieve biophilic design has not been thoroughly examined. Biophilic materials may include plants, water, stone, leather, wood, natural fibres, and other natural materials. For example, McCoy and Evans (2002) looked at the expectations of creative potential of indoor environments. They found that environments scoring highest in expected creative potential feature some type of exposed wood or stone, both natural materials.

2.3.1.1 Plants

Perhaps the easiest way to bring nature into a built environment is through plants. There have been several studies from the environmental psychology and horticulture fields that have shown stress-reducing effects of plants.

Lohr *et al.* (1996) studied the effects of plants on task performance and stress levels in the indoor environment. They found blood pressure to be lower and task performance to be better in the presence of plants. Lohr and Pearson-Mimms (2001) did a similar study of plants in indoor environments with pain perception being the test effect. They found that subjects in a room with plants had a greater pain threshold than subjects in a room with no plants.

Fjeld *et al.* (1998) looked at health conditions of office workers in offices with and without plants. They found that workers in offices with plants reported 23% fewer health conditions. Fjeld (2000) looked at health conditions reported by radiology technicians that worked in a room devoid of windows. After introduction of plants to their working environment, a 25% decrease in health complaints were reported.

Shibata and Suzuki (2002) studied the effect of plant foliage on mood and the performance of two different types of tasks. A concentration task was performed by sorting cards and a creative task was achieved through a word association activity. Mood was not affected by the presence or absence of plant foliage, though the authors suggest the short duration of the experimental task may not have allowed for a mood affect. With respect to task performance, the presence of plants did not affect the concentration task. The presence of plants did, however, improve performance on the creative task.

Studies into plants have also focused on flowers. Kim and Mattson (2002) studied the effects of flowering and non-flowering plants on EEG beta activity and electrodermal activity. They found lower beta activity and electrodermal activity in female subjects exposed to flowering geraniums. There were no effects found for male subjects. Haviland-Jones *et al.* (2005) demonstrated changes in emotion, memory, and social behaviours brought about by the presentation of flowers in built environments. One theory is that this is an innate response, because flowers provide prospect of fruit in the future.

Recent work by Park and Mattson (2008, 2009) have mirrored Ulrich's (1984) research of hospital patients, but with an indoor plant treatment. They found less frequent pain medication intake in both studies. Like Ulrich (1984), they also found slightly shorter hospital stays (Park and Mattson, 2009). There were mixed results between the two studies with respect to blood pressure and heart rate.

Bringslimark *et al.* (2009) provide a review of a literature related to the psychological benefits of plants in the built environment. While they acknowledge the potential for stress and pain reduction of plants, they did not find strong evidence for any one effect or context. They conclude that that methodologies and results vary too widely in the existing literature and put forward recommendations for future research.

2.3.1.2 Wood

While plants have been actively discussed as a source of restoration in the built environment, there has been little attention paid to wood. The application of wood for structure and décor in built home environments is common practice in North America (Fell, 2005). However, wood as a biophilic material is not explicitly mentioned by any of the chapter authors of Biophilic Design (Kellert *et al.* 2008). Interestingly, a review of the colour plates in the book reveals that 25 of the 30 interior environments given as examples of biophilic design feature the application of wood visual surfaces.

There are only four studies that directly address biophilia and well-being with respect to wood in the built environment. Three of these studies are from Japan and have only recently been published in English journals.

Sakuragawa *et al.* (2005) measured mood and blood pressure of subjects exposed to either a wood or a white steel wall. In addition to these measures, they surveyed respondents as to their like and dislike for different materials. For those who liked wood, blood pressure decreased significantly. Those who disliked wood did not see an increase or decrease in blood pressure from baseline. With the steel wall, those who liked steel saw no increase or decrease in blood pressure. Those who disliked steel had increased blood pressure when exposed to the white steel wall. This study was completed prior to 1998, but not reported in a journal until 2005. The sample size in this study was low (n=14). The study methodology also made the study questions apparent to the subjects, because they were asked to directly observe the wall materials. Further, they were shown both materials, albeit in randomized order. Finally, this study presented materials without the context of a finished built environment. The wood and steel walls were the only features in an otherwise empty room. While this study provides some evidence of wood as a restorative material, design and sample size limitations preclude general conclusions.

Tsunetsugu *et al.* (2002) looked at psychophysiological responses to wood applied to living room environments. Subjects were immersed in three different environments. First, they were preconditioned in a room with some wood application. Baseline heart rate and blood pressure measurements were taken in this preconditioning room. They were then randomly assigned a test room to start in. There was a test room with no wood and one with heavy use of wood. Blood pressure and heart rate decreased from baseline in the wood room and increased from baseline in the non-wood room. Like Sakuragawa *et al.* (2005), sample size was small (n=10) and subjects were immersed in both test rooms making habituation and serial effects possible confounds.

Tsunetsugu *et al.* (2007) again measured psychophysiological responses to three treatment rooms. These rooms had 0% wood coverage, 45% wood coverage, and 90% wood coverage. Again, sample size was low (n=15) and subjects were exposed to all environments. In this study, the 90% wood coverage room yielded lower heart rate and blood pressure than the 0% room. However, the 45% wood coverage room actually saw an increase in heart rate and blood pressure over the 0% room. Interestingly, the 45% room was the most favoured room among respondents on a preferences question. This is an interesting result as it indicates that preferences may not always be for optimal environments.

The research questions in the above studies (Tsunetsugu *et al.*, 2002, 2007; Sakuragawa *et al.*, 2005) are central to the pursuit of psychophysiological restoration and biophilic design with wood material. Unfortunately, the sample sizes employed are not sufficient to draw conclusions about innate responses. These are, however, the only wood-focused psychophysiological studies.

Rice *et al.* (2004) used various methods to explore the general belief that wood in interior environments contributed to heath and well-being. Using a survey, personal interviews, and an experimental Q-sort activity, it was found that people believe in the health effects of wood interior surfaces. The study serves as evidence of a widespread belief in the restorative qualities of wood, but it does not provide experimental evidence of such restoration.

Ridout *et al.* (2001) studied the meaning and experience of wood in the built environment and the connotation of wood in interior design. In this investigation, subjects were shown several office receptions finished with wood and non-wood materials. They were then asked to describe the firm and to indicate their desire to work for each firm. Subjects generally associated the use of wood in a corporate setting with prestige and were more likely to want to work at these firms. The “wood” organizations were most often described as energetic, innovative, and comfortable.

2.3.2 Wood as a visual material

Dr. Minoru Masuda of Kyoto University was a pioneer of the study of wood as a visual material. His earliest work in the field (Masuada and Nakamura, 1987) looked at the influence of knots on the perceptions of wood panel surfaces. In the study, respondents evaluated a series of wood images based on a set of descriptors. They found that the natural colour of knots conveyed the images of “calm” and “agreeable”. Wood panels clear of knots scored highest on the descriptors “agreeable”, “elegant”, “calm”, and “clear”.

Masuda and Yamamoto (1988) studied the wood ratio in interior spaces and compared this ratio with a set of psychological descriptors about the rooms. They chose 48 images out of home decorating magazines and home catalogues and computed the proportion of the image comprised of wood surfaces. They tested the hypothesis that as the proportion of visual wood surface increased, the ratings of “calm” and “warm” would also increase. What they found was an optimum proportion relationship with these descriptors rather than a positive linear relationship. The “warm” descriptor increased with wood surface ratio to a maximum of 43% wood surfaces, then decreased. Masuda and Nakamura (1990) redid the Masuda and Yamamoto (1988) study, focusing on the descriptors of “natural” and “novel”. The relationship between wood ratio and “novel” was significant. Rooms with wood ratios approaching zero or 100% were seen as most novel. The wood ratio relationship with “novel” (U-shaped) is the opposite of the “warm” relationship (upside down U-shaped) in the first study.

Masuda (1992) discusses the physical properties of wood that contribute to its visual effect. He first comments on the reflection of ultraviolet light. Wood absorbs rather than reflects ultraviolet light, making it easy on the eyes of the observer compared to other materials. He then comments on the colour hues of wood. Wood generally is in the yellow-red range of hues. Brighter woods are more yellow, and darker woods are redder. These yellow-red hues are associated with the perception of warmth.

Besides colour, wood has other physical properties that contribute to its visual effect (Masuda. 1992). Masuda first addresses perhaps the most abstract wood feature: wood lustre. Most materials have a lustre based on the smoothness of surface finish; however, wood often has a “depth” to its lustre. This is most evident in birds-eye maple or curly grain, but most wood has some visual effect of depth to it. This effect is produced by light penetrating wood cells on the surface, then reflecting back off the cell lumen. This variable reflectance is a key visual clue that a surface is real wood, because it has not yet been adequately copied by false wood surfaces.

Masuda (1992) discusses the contribution of wood grain and annual rings to the visual effect of wood. Nakamura *et al.* (1994) studied the psychological images evoked by wood and stone in pursuit of a “natural” hypothesis. They found that flat grain (cathedral) patterns were associated with wood, regardless of colour. When patterns were more ambiguous, respondents relied more on colour in judging whether something was wood-like or stone-like. With respect to “warmth”, colour (red/yellow) was more important than pattern.

Survey methods have found that descriptors such as “natural”, “warm”, and “classic” are used by people to describe wood surfaces (Fell, 2002; Broman, 1995). Broman (1995) studied the visual impressions people had of scots pine (*Pinus syvestris*). The outcome of this exercise was a map of features that people see in wood. The general properties were spirit, nature, purity, temperature, exclusiveness, and feeling. Each of these properties has a set of associated desciptors, some of which were used in this study.

Broman noted that people evaluate wood surfaces in two ways. First, they noticed divergent features such as knots, planer marks, heartwood sapwood transition, and other abrupt features. In the absence of divergent features, people evaluate wood based on the blending of features. This is a more subjective evaluation that varies from person to person.

Researchers at the USDA Eastern Research Station have focused much research on the natural variability of wood and what Broman (1995) would term as “divergent features”. Jaune *et al.* (1999) and Bumgartner *et al.* (2000, 2001) studied the preference for wood character marks. Bumgardner and Bowe (2002) studied the perceptions of a set of major commercial species used in secondary products in North America. Bumgardner and Bowe (2002) conclude that major species are not equal with respect to the psychological image they contribute to a product. However, the psychological image of an individual species most often differed depending on whether evaluations were being made visually or on species name alone. Respondents also had strong perceptions of species based solely on their names.

Wood has been studied as a visual material for over twenty years. There have been three primary avenues of research. First, descriptors of wood and preference for wood as a visual material has been a strong area of research (Masuda and Yamamoto, 1988; Masuda and Nakamura, 1990; Broman, 1995; Rice *et al.,* 2004). The second field of research has been the contribution of wood anatomical features to the visual impression of wood visual surfaces (Jaune *et al.*, 1999; Bumgartner *et al.*, 2000, 2001; Broman, 1995). Finally, the third direction of research on wood as a visual material is the effect of these visual surfaces on human health (Tsunetsugu *et al.*, 2002, 2007; Sakuragawa *et al.*, 2005; Rice *et al.*, 2004). It is this third avenue of enquiry that the current research follows.

3 Methodology

3.1 *Participants*

Participants for this study were recruited from the University of British Columbia undergraduate population. A student population was chosen for this study for several reasons. Firstly, students are a readily available population for campus studies. Secondly, most studies in the field involve student samples, and the results will be more comparable to other studies. The use of students is commonplace in empirical psychological studies. Students were the primary population for 86% of studies reported in Personality and Social Psychology Bulletin and the Journal of Consumer Psychology (Barrett, 2005; Peterson, 2001). Finally, a student population also has the benefit of being a relatively homogeneous sample in terms of demographics. This relatively homogenous sample eliminates some of the noise that a more diverse sample would impart.

Peterson (2001) performed a meta-analysis on the use of student and non-student populations for psychology studies. He found that the directionality of the effect was different among student and non-student populations in 19% of studies reviewed. In addition, the magnitude of effect differed by more than two times in 29% of studies. However, James Cutting commented in Barrett (2005) that in studies of attention, perception, memory, and cognitive science the use of students may not matter, as students share the same core neural networks as the general population. Much of the research in the environmental psychology area has drawn upon undergraduate students for subjects (Parsons *et al.*, 1998; Ulrich *et al.*, 1991; Tennesson and Cimprich, 1995; Hartig *et al.*, 2003; Laumann *et al.*, 2003; Lohr and Pearson-Mimms 2001).

3.2 *Population parameters*

The population for this study was based on a set of qualifying and disqualifying parameters. The following population parameters were set for inclusion in the study:

- Full-time UBC undergraduate students
- Ages 18 – 30
- No exams on the day of experiment

In addition, a set of health conditions that could interfere with psychological and physiological measurements disqualified subjects. Many of these health-related exclusion criteria come from Peters *et al.* (1998).

Disqualifying health conditions:

- Hypertension
- Heart conditions
- Prescription and non-prescription mood-altering drugs
- Coffee on the same day
- Smoker
- Hearing problems
- Illness in the past 2 weeks

3.2.1 Recruitment

Students were recruited using on-campus postering. Postering began during the week of fall term 2008. The recruitment poster appears in Appendix 1. A $25 incentive was offered for participation in the study. Students were told that they would be committing to a one-hour appointment and that during 12-20 minutes of that hour they would be performing a mental task.

Contact by both telephone and email were used for recruiting and to schedule appointments. Appointments were made according to the availability of the student. Only one treatment room was available at any one time, so assignment to treatment rooms was also driven by student schedules.

Upon scheduling of an appointment time, students were sent a confirmation email. This email restated the qualifying population parameters and the disqualifying health conditions. In order to avoid imparting bias, no references to the resident department of the study were made in the recruiting process.

3.2.2 Sampling

A non-probability quota sample was used for this study. Students responding to the request for subjects were accepted given they met the population and health parameters.

A total of 120 students were recruited, with one last-minute cancellation bringing the total sample to 119 subjects.

3.3 *Design*

3.3.1 Factorial design

A stress-reducing plant effect in built environments has been shown in past studies (Lohr and Pearson-Mimms, 2001; Shibata and Suzuki, 2002). This study seeks to find out whether there is a similar stress-reducing effect associated with wood visual surfaces applied in built environments. For this reason, a two-by-two factorial experimental design was employed (Table 3). Factor 1 was wood / non-wood and factor 2 was plants / no plants. A total of 30 subjects per cell was targeted for a total of 120.

Table 3 Factorial design

Plant		Wood		
		Wood	**Non-wood**	**N**
	Plant	WP	NP	60
	Artifact	WA	NA[3]	60
	N	60	60	120

3.3.2 Test environments

The experimental measure of physiological stress and attention required the creation of control and treatment environments. In this study, we were interested in the effect of wood in the built environment. Therefore, both a wood treatment room and a non-wood control room were needed. The plant treatment was achieved by moving plants in and out of the rooms.

These rooms took the form of an office environment. Offices have been used successfully as experimental test environments in environmental psychology (Maslow and Mintz, 1965; Lohr *et al.,* 1996; Lohr and Pearson-Mimms, 2001; Ridout *et al.,* 2002; Shibata and Suzuki, 2002).

[3] Due to the cancellation of a scheduled appointment, the non-wood / artifact treatment had only 29 subjects.

3.3.2.1 Rooms

Offices were secured on the fourth floor of the MacLeod building on the Vancouver campus of the University of British Columbia. The MacLeod building was constructed in 1961 and is a 3-storey concrete structure.

The initial plan was to set up a wood office and a non-wood office with a reception and equipment room in between the two. The study rooms were of identical size and room layout. They were 10' by 16' with a door on the right side of the corridor wall. Opposite the corridor wall was a wall with windows. The windows started 3'6" above the floor and were 6'2" high. Ceilings were 12" high with banks of fluorescent lights suspended 3 feet from the ceiling.

The rooms were prepared to be identical. Both rooms received fresh white paint to the walls and ceiling. A grey office-grade carpet was laid in both rooms. Below the window in both rooms, a 3'6" wood surface was wallpapered over with a commercial-grade white to remove the wood visual surface from the room. Unfortunately, during the pre-testing stage the wallpaper in one of the rooms discolored and stained. After a similar result from refurbishing the wall section, the decision was made to run all tests in the one flawless room.

3.3.2.2 Wood treatment

A line of identical furniture available in wood and non-wood finishes was sourced from Ikea. The wood furniture had birch veneer with a clear finish. The non-wood furniture had a white painted and melamine foil surfaces.

Furniture:

- Billy bookshelf tall 32”w x 11”d x 80”h (birch/white)
- Billy bookshelf short 32”w x 11”d x 42”h (birch/white)
- Gallant desk top 63”w x 32”d (birch/white)
- 2 x Jules visitor chair (birch/white)
- Lack coffee table 46”w x 31”d x 18”h (birch/white)
- Lindmon blinds 1.5” (limewood/white)

3.3.2.3 Plant treatment

Three plants were employed for the plant treatment.

- 10” (plus trailing) *Chlorophytum comosum* (spider plant)
- 14” *Dracaena marginata* (variegated red)
- 54” *Schefflera actinophylla* (Amate)

For the non-plant treatment, the plants were replaced by non-natural items of the same general size. These items were:

- Blue glass vase
- Plastic inbox / outbox filer
- Stand fan

3.3.2.4 Room setup

The same test room was used for all of the test conditions. Only the wood and plant treatments changed within the room. This helped control for non-treatment room effects. The view to the outside was blocked by closed blinds as different views have been found to influence the constructs of interest (Kaplan, 2001; Ulrich, 1984). A north-facing room was chosen to limit direct sunlight on the blinds, because the penetration of sunlight into an office has been found to influence general well-being (Leather *et al.,* 1998). Miwa and Hanyu (2006) also found that the level of light in a room affected the perception of counselors and the level of self-disclosure by study participants. For these reasons, the level of light in the room were kept as consistent as possible during the study.

The furniture setup appears in Figure 1 and Figure 2. The desk was placed on the left side of the room facing the window. On the desk was the Dracaena plant / inbox. In the left window corner of the room was the tall Amate plant / stand fan. The wood finish / white blinds covered the wall-to-wall windows. Also on the window wall, was the birch / white coffee table and a birch / white chair. On the right wall, starting from the door, was a birch / white chair occupied by the researcher during the PASAT test, but empty and visible during the baseline and recovery periods. Beside the researcher chair was the short birch / white bookshelf. On this bookshelf was the spider plant / vase. Finally, a tall birch / white bookshelf was on the right wall closest to the window. These shelves were stocked with text books kept in the same order in each test setup.

Only one room was used, so there was considerable effort involved in changing furniture and blinds from non-wood to wood treatments. For this reason, all non-wood treatments were completed first before moving on to wood treatments. The plant treatments were easier to change and were changed over more frequently based on the need for the plants to get sunlight, as the blinds were shut.

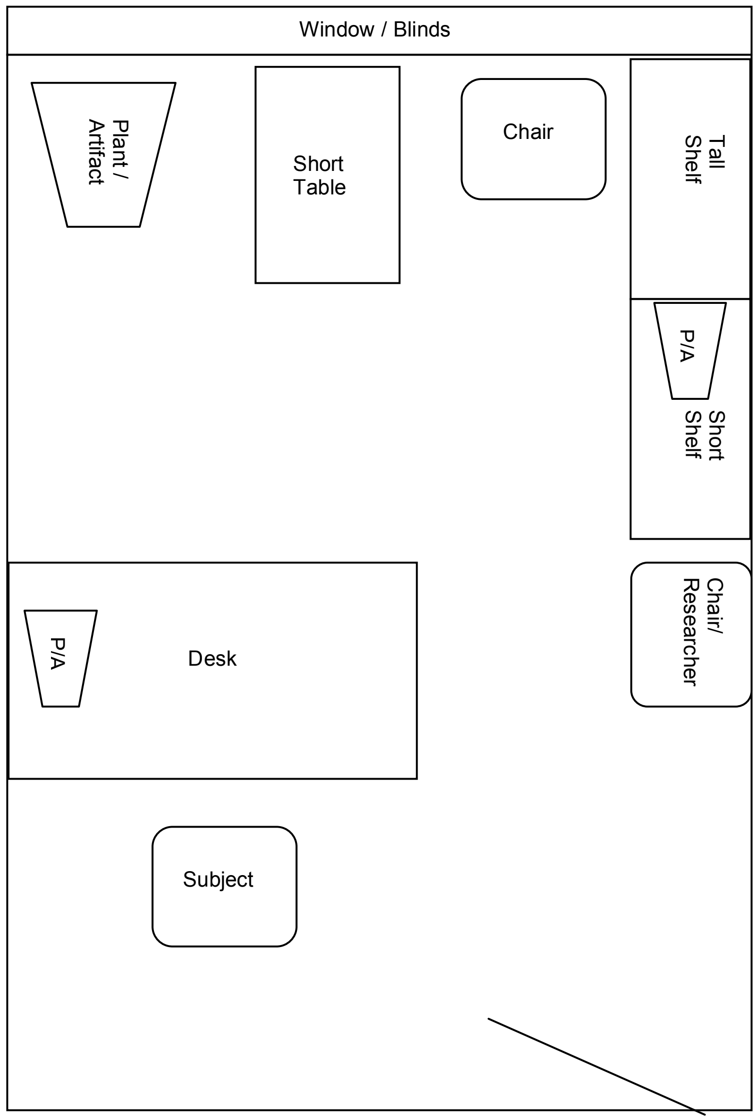

Figure 1 Room plan

Figure 2 Sample room (non-wood / plants)

Figure 3 displays pictures of all four test environments for comparison. On the left is the non-wood treatment and on the right is the wood treatment. Non-plant treatments are in the top pictures and plant treatments on the bottom. Of note is that the pictures in the wood room show a wood rail below the window. A wood rail was not visible during data collection. As detailed above, all data was collected in one room. This was the room on the left in Figure 3 with no wood rail. After all non-wood data was collected, blinds and furniture were changed to wood.

Figure 3 Four office test environments (clockwise from top left: non-wood / no plants, wood / no plants, wood / plants, non-wood / plants)

3.4 *Stressor*

Parsons *et al.* (1998) used a version of the Paced Auditory Serial-Addition Task (PASAT) (Gronwall, 1977) to impart a mild stress on subjects. The PASAT is a test of attention originally designed to monitor recovery from head injuries (Gronwall, 1977). It was adapted by Rao *et al.* (1989) to diagnose multiple sclerosis.

The standard PASAT was used as a stressor in this study. The PASAT is challenging because it combines several processes. Subjects must comprehend auditory stimuli (numbers), add numbers, respond verbally, and not encode their verbal response into memory as they do the test numbers.

The task involves adding every two digits in a series of numbers. Numbers are given audibly at a rate between 2.4 and 1.2 seconds per number. This test was administered from a digital audio file created by BrainMetric PASAT Software. The primary purpose of the PASAT test in this study is to impart stress on the subject. For this reason, the researcher was in the room recording right and wrong answers on a clipboard as the test progressed.

3.5 *Constructs and variables*

The goal of this study was to compare autonomic activation in environments featuring natural and man-made materials. The two main autonomic constructs measured were sympathetic and parasympathetic activation. Unfortunately, these two systems work in tandem and there are few pure measures of either. This study looked at skin conductance, an unmoderated measure of sympathetic activation, and heart rate variability, an unmoderated measure of parasympathetic activation.

3.5.1 Electrodermal

Electrodermal activity (EDA) is regulated by the sympathetic nervous system (Dawson *et al.* 2007, in Handbook of Psychophysiology). When the sympathetic nervous system is engaged, eccrine glands in the skin secrete sweat, lowering electrical resistance of the skin. Eccrine glands provide thermoregulation for the body. They are densest in the hands and feet. EDA is often assessed by measuring skin conductance. This is measured by passing a constant voltage between two electrodes on the hands or fingers and measuring changes in the current (amperage).

Sympathetic nervous system activation is responsible for the “fight or flight” response when humans are stressed. One pure measure of sympathetic activation is skin conductivity. When a person is stressed, the sympathetic nervous system causes the eccrine glands in the skin to fill with sweat. This increases the conductivity of the skin. A series of skin conductance variables are available to analyze the sympathetic responses to stress.

3.5.1.1 Skin conductance level

Skin conductance level (SCL) is a measure of the tonic level of skin conductivity. SCL is a common measurement used in environmental psychology (e.g. Ulrich *et al.*, 1991; Parsons *et al.*, 1998).

3.5.1.2 Skin conductance responses

Skin conductance responses (SCR) are temporary spikes in skin conductivity. These can be “event-related” to a stimulus such as a loud noise or they can be “non-specific” to any discrete stimulus. Non-specific skin responses (NS-SCR) are elicited by thoughts or cognition (Nikula, 1991). A greater number of NS-SCRs per minute are associated with a higher level of stress (Dawson *et al.* 2007, in Handbook of Psychophysiology). The amplitude of SCR’s is an indication of how stressed a subject is. The greater the response amplitude, the greater the stress. Wilken *et al.* (1999) found that high-stress subjects had larger SCR responses than low-stress subjects to the same stimuli.

3.5.2 Cardiovascular

The heart is innervated by both the sympathetic and parasympathetic nervous systems. Measures of heart rate or interbeat interval (IBI) are, therefore, indicative of general autonomic tone and not direct measures of sympathetic or parasympathetic activity. There is one type of cardiovascular analysis that allows researchers to separate out the parasympathetic component. This analysis is known as heart rate variability (HRV). HRV is based on a specialized analysis of interbeat interval. In this study, we analyze both IBI and HRV.

3.5.2.1 Inter beat interval

Inter beat interval (IBI) is a measure of the time between R–spikes in the electrocardiogram (ECG) waveform. The R-point is the largest upward deflection in the ECG. A longer IBI corresponds to a lower heart rate and a shorter IBI corresponds to a higher heart rate.

IBI is regulated by both the sympathetic and parasympathetic nervous systems. Upon introduction of stress, IBI may decrease due to sympathetic activation or parasympathetic withdrawal. Changes in IBI are very normal as our body reacts to changing activities throughout the day. However, in environmental psychophysiology, we are interested in the effects of environments on IBI during the same activity and context. Laumann *et al.* (2003) found that when subjects were exposed to natural environments, IBI was higher than when they were exposed to urban environments. Parsons *et al.* (1998) found that IBI recovered more completely when exposed to natural environments. Dawson *et al.* (2000) point out that sometimes no IBI reaction will be seen from a mild stressor as the systems will balance each other out.

3.5.2.2 Heart rate variability (HRV)

Variability in heart rate can indicate the degree of parasympathetic activation. During periods of high sympathetic activation, IBI is very uniform with little variability. However, in periods of high parasympathetic regulation, IBI is less uniform and displays a higher degree of variability called respiratory sinus arythmia (RSA). At rest, IBI is shorter on inhalation and longer on exhalation (Kawachi, 1997).

There are many methods for measuring HRV. These can be broken down into time-based and frequency-based measures. The duration of epochs used in this study was 2.5 minutes each. This short time recording is not appropriate for time-based analysis of HRV (Task Force, 1996).

Frequency-domain measures of HRV are based on power spectral density. The frequency spectrum between 0.15 Hz and 0.4 Hz is defined in HRV literature as the high frequency (HF) band. This band is associated with parasympathetic activation (Askelrod *et al.*, 1981). The power of HF is a common measure of HRV.

3.5.3 Attention

Tests of attention are common in environmental psychology experiments. When humans are stressed, there is a decreased ability to focus attention. Common tests of focused attention are the Necker Cube (Tennessen and Cimpich, 1995; Kaplan, 1995; Hartig *et al.*, 2003) and the symbol-digits modality (Tennessen and Cimpich, 1995). These tests could not be fit into the experimental procedure as the time they take to explain and administer would compromise the physiological measures in the test. However, the PASAT test used as a stressor in this study is a test of focused attention. As it was already incorporated into the study design, the PASAT was also used as an attention measure.

3.5.3.1 PASAT

The stressor used to elicit psychophysiological responses is also a measure of focused attention. The PASAT is formally used as a “test of cognitive function that assesses auditory processing speed and flexibility" (National Multiple Sclerosis Society, 2010). Sherman *et al.* (1997) found some evidence that the PASAT was a measure of focused attention. Unfortunately, PASAT performance is moderated by several extraneous factors. PASAT performance differs by age (Weins *et al.*, 1997), a factor which is somewhat controlled by the narrow age range in this study. Weins *et al.* (1997) used an age range of 20-29 to compare to other groups. This study covers only an age range from 18-30. Baseline mathematical ability also affects PASAT scores (Weins *et al.* 1997). This could not be controlled in this study without further information on mathematical ability. Therefore, PASAT scores are being used in this study as indicators of focused attention, but no strong associations can be made.

3.5.4 Survey

The environment satisfaction survey is the only self-reported portion of the study. Self-reported data gives the respondent time to actively ponder their response and is subject to various forms of response bias (Shadish *et al.*, 2001). The physiological data is considered to be involuntary responses and less subject to such biases. While the environmental satisfaction survey does not capture these unconditioned psychologically-based responses, it better reflects the thought-out approach consumers take in purchase decisions.

In the environmental satisfaction survey (Appendix 5), subjects were asked to rate how well a list of attributes describes the room they sat in. The rating scale was from "1=not at all a good description" to "5=describes very well". The following 9 descriptors were presented verbally to the subjects. No clarifications were made on the attributes other than that they were to describe the "look" of the room.

The attributes were:

- Clean
- Restful
- Warm
- Artificial
- Modern
- Natural
- Productive
- Healthy
- Sustainable

3.6 *Measurement*

Two channels of autonomic activity data were recorded. Channel one was an electrocardiogram and channel two was skin conductance. Data were collected by a Biopac MP100 Data Acquisition System. Data acquisition was controlled by a PC running Biopac Acknowledge 3.9.

The skin conductance signal was relayed to a Biopac GSR 100C amplifier set up as per Biopac Note 187 (Electrodermal Response Guidelines). Gain was set to 5 μmho based on the level of activation expected in the experiment. The low pass filter was set to 1 Hz as recommended for EDR studies. Finally, the high pass filter was set to DC (no filtering) to provide absolute skin conductivity measurements. Data acquisition was set to 250 Hz.

Figure 4 BIOPAC data acquisition and amplifier setup

Skin conductance was collected from the index and middle fingers of the non-dominant hand. One EL507 EDA pre-gelled isotonic Ag/Ag-Cl disposable electrode was placed on the distal phalange of each finger. These were secured by medical tape. Biopac LEAD110A leads were connected via snap connectors to the electrodes. These leads connected to a 20-foot MEC100C extension cable. The extension cable connected to the GSR100C amplifier in the equipment room.

The electrocardiogram signal was relayed to a Biopac ECG 100C amplifier and set up as per Biopac Note 233 (Heart Rate Variability). Gain was set to 1000 and the amplifier mode was set to normal. The 35Hz low pass filter and the 0.5 high pass filters were set to on. Data was collected at 1000Hz.

ECG data were collected from the right and left wrists in a LEAD I configuration. The choice of wrists as a data collection site was made to avoid imparting stress from the placement of electrodes on the torso. This study tests very subtle differences in stress, and it was felt that the placement of electrodes on the torso may impart more stress on respondents than the treatment differences. This same setup was used in de Kort *et al.* (2006). The tradeoff for placing electrodes on the wrists instead of the torso is an increase in artifact noise from movement. Therefore, subjects were asked to minimize movement of their arms and to keep the electrodes from contacting the table.

Wrists were prepared by cleaning with isopropyl alcohol. Adhesive EL503 pre-gelled electrodes were placed on the wrists and secured by medical tape. A Biopac Lead 100 lead was snapped on the right wrist and a Lead 100S on the left. These leads were secured by tape on the underside of each arm to minimize feedback from movement of the leads. No ground was used per Biopac Note 233 as the GSR100C setup grounds the subject.

3.7 *University ethics approval*

This experiment was subject to approval of the University of British Columbia Behavioural Research Ethics Board (BREB). The BREB certificate appears in Appendix 2.

As deception was involved with respect to withholding the faculty of residence of the study, a full board review was undertaken. The BREB responded with two *provisos*. First, they requested that consent forms (Appendix 3) be provided to subjects prior to appointments. This was accommodated by emailing the consent forms to subjects. The second *proviso* asked that after debriefing subjects be allowed to choose to have their data excluded from the study. This was accommodated by having subjects sign a data consent form (Appendix 4) after debriefing. All subjects consented to the use of their data.

3.8 *Procedure*

Upon arriving at the reception office, subjects were asked for their consent form (Appendix 3). The consent form was sent out by email prior to appointments. Copies were also available to sign in the office. Subjects were reminded of the parameters for inclusion in the study and the disqualifying health conditions. They were then sent to wash their hands with soap and water. They were instructed to dry their hands well so as not to affect the conductivity of their skin once testing started. Once they returned to the office, electrodes were placed on the subjects as outlined in section 3.6 above.

Subjects were then briefed on the outline of the study appointment. They were told what each set of electrodes were measuring, but not why. They were informed that the wrist electrodes were used to measure heart rate by creating an ECG readout on the monitor in the next room. With respect to skin conductance they were informed that a 0.5V potential was being established between their two fingers and the conductivity was being measured.

They were then told that they would be left alone in the room for 10 minutes to get baseline measurements before the interviewer would return to administer a mental task. The time spent briefing the subject allowed the electrode gel to make adequate contact with the skin.

The interviewer then left the room to check the ECG and GSR waveforms. If these were sufficient, the 10-minute baseline period began. If electrode adjustment was needed, the interviewer would re-enter the test room and troubleshoot the electrodes. Only after satisfactory waveforms were being produced did the 10-minute baseline period begin.

After the 10-minute baseline, the interviewer reentered the test room to administer the PASAT test. The test was administered from a digital audio file created using BrainMetric PASAT software. Subjects were given the standard instructions for the PASAT test and then administered a five number sample set to complete. The sample set presented numbers 2.4 seconds apart. If subjects made more than one error on the sample set, the instructions and the sample set were repeated. Upon completing the sample set subjects were informed about the PASAT test they were about to take. They were told that they would be completing 4 sets of 50 numbers with a 30-second break between sets.

During the PASAT test, the interviewer sat to the right of the subject beside the desk. Answers were scored on paper and clipboard within view of the subject. The four PASAT sets differed in the interval between numbers presented. Starting with set one, intervals were 2.4, 2.0, 1.6, and 1.2 seconds, respectively.

Upon completion of the PASAT, the 10-minute recovery period began. Subjects were instructed to relax for 10 minutes and to wait for the interviewer to return and wrap up the testing. Subjects were then left alone for 10 minutes. At the end of the rest period, physiological recording was stopped and the interviewer reentered the room to remove the electrodes for the subject. The short room attributes survey was then administered.

Upon completion of the survey, subjects were fully debriefed. The two main points of the debrief centred on information withheld from respondents during the study which were considered deception by the Behavioral Research Ethics Board. First, it was disclosed that the study proponents were housed within the Faculty of Forestry. This information was withheld to prevent subjects from making the connection between the Faculty of Forestry and the wood materials in the room. The second piece of information disclosed in the debrief was that four environments were being evaluated. Subjects were initially told that the study was on “office task performance”; they were not told that the focus was on the offices rather than the task itself.

Once the debriefing was completed, subjects were asked to sign a data consent form (Appendix 4), which was necessary because the study involved deception and full consent could only be given after full disclosure. While respondents were told they would receive their $25 incentive whether they consented or not, there were no refusals.

A summary of the test procedure steps and their timings appears in Table 4.

Table 4 Test activities and timings

Step	Description	Minutes
1.	Informed consent and hand washing	Up to 5
2.	Attachment of electrodes and study briefing	Up to 10
3.	Baseline physiological measures	10
4.	PASAT test	15.5-18
5.	Recover to baseline	10
6.	Survey	Up to 5
7.	Debrief	Up to 5

3.9 *Research questions*

This study tested the following hypotheses:

Hypothesis 1 : There is no difference in sympathetic nervous system activity between built environments featuring natural materials and environments devoid of natural materials.

> *Hypothesis 1-1: There is no difference in skin conductance level between environments featuring natural materials and environments devoid of natural materials.*
>
> *Hypothesis 1-2: There is no difference in the frequency of non-specific skin conductance responses between built environments featuring natural materials and environments devoid of natural materials.*
>
> *Hypothesis 1-3: There is no difference in the amplitude of skin conductance responses between built environments featuring natural materials and environments devoid of natural materials.*

Hypothesis 2: There is no difference in interbeat interval between environments featuring natural materials and environments devoid of natural materials.

Hypothesis 3: There is no difference in parasympathetic nervous system activation between built environments featuring natural materials and environments devoid of natural materials.

> *Hypothesis 3-1- There is no difference in high frequency power of the ECG signal between built environments featuring natural materials and environments devoid of natural materials.*

Hypothesis 4: There is no difference in attention between built environments featuring natural materials and environments devoid of natural materials.

> *Hypothesis 4-1:There is no difference in PASAT test errors between built environments featuring natural materials and environments devoid of natural materials.*

3.10 *Data analysis*

3.10.1 Analysis periods

There are three main periods in the experimental design. These are the baseline period, the test period, and the recovery period. Each of these periods was broken down into shorter epochs for analysis. The length of epochs in the analysis was 2.5 minutes. Epoch length was driven by two factors. The first factor was a desire to have epochs within the three experimental periods to allow for analysis of stress differences within periods. The second factor in deciding on epoch length was the demands of HRV analysis. For purposes of comparability, all epochs were required to have the same duration, because HRV results differ by duration (Pinna *et al.*, 2006). Further, it is suggested that when performing frequency-domain analysis that a minimum of one minute is desired for high frequency components and two minutes for low frequency (Pinna *et al.* 2006).

There are two epochs in the baseline period. Epoch B1 starts at minute 2.5 of the 10-minute baseline period. Epoch B2 starts at minute 5. This covers the middle five minutes of the baseline period. It is believed that this provides the best indicator of baseline physiological measurement because it allows for some recovery time after subjects get wired up for measurement, which may impart a low level of stress. Further, as subjects knew that the baseline period was ten minutes, stress builds in anticipation of the test period. Therefore, the first and last 2.5 minutes of the baseline period were clipped from the analysis.

The test period included four epochs. The first 2.5 minutes of the test period were captured as epoch T1. This period consisted of the interviewer re-entering the test room, explaining the PASAT, and running through the sample set with the subject. Skin conductance was generally very high in this epoch even though the PASAT had not yet commenced. The next three test epochs occurred during PASAT testing. The instruction and sample set timing varied by subject, so epochs T2 to T4 were measured back from the end of the test period. T2 began ten minutes before the end of the test period. Epochs T3 and T4 were rolling time periods after T2.

There were three recovery epochs in this study. Epoch R1 started at immediately after the interviewer left the test room following the administration of the PASAT. Epochs R2 and R3 were rolling epochs following immediately after R1.

3.10.2 Analysis

Data were extracted for each of the nine epochs. The nine epochs were marked on the time record to allow for automated and manual extraction of data. A overview of epoch timings and measures is presented in Table 5.

3.10.2.1 Electrodermal

A skin conductance channel was collected by the Acqknowlege software. This channel was used to compute all electrodermal statistics. Skin conductance level was a simple calculation of average skin conductance for each 2.5 minute epoch.

The Acqknowlege software contains an automated SCR detector. For each SCR, the time, SCL, SCR amplitude, and SCR rise time was recorded. To be scored as an SRC, amplitude had to be at least 0.05 μS above the tonic SCL. No maximum amplitude was placed on SRC. However, large amplitude SCRs were manually checked in the waveform to see that they were SCRs and not an increase in SCL or multiple SCRs. A maximum rise time was set at four seconds for SCRs.

Once SCRs had been confirmed, F-NS-SCR and A-NS-SCR were calculated. F-NS-SCR is simply a count of SCRs in each baseline and recovery epoch. A-NS-SCR was calculated as the average amplitude of SCRs within each test epoch.

3.10.2.2 Cardiovascular

Both IBI and HRV measures are based on the interval between R-spikes in the ECG waveform. The R-spike is usually the largest upward deflection in the ECG and is, therefore, often used for measuring the interval between heartbeats. Acqknowlege has an automated QRS detector used in calculating the interval between R-spikes to calculate interbeat interval.

IBI

Due to the fact that ECG data was collected from the wrists, there was some noise to clean up in the ECG waveform. The IBI waveform for each subject was checked manually for anomalies such as too long or too short an IBI. When these were found, the ECG waveform was checked to see if the QRS detector had accurately detected the R-spike at the waveform section in question. When the R-spike had not been accurately detected, various transformations[4] were employed to amplify the R-spike(s) in question. A new IBI waveform would be created after transformation to check that the QRS detector worked properly on the transformed waveform. The ECG data for ten subjects were dropped from the analysis of IBI due to irreparable noise in the waveform. One subject from the wood and plant room was excluded. Three subjects from each of the other three treatments were excluded form the IBI analysis. Once there were no errors in the IBI waveform average, IBI for each epoch was calculated.

[4] Transformations were performed to help the QRS detector properly identify R-spikes. Two strategies were used; the amplitude of the R-spike would be increased and/or noise between R-spikes would be flattened. Neither of these transformations changed the timing of R-spikes in the record.

HRV

Acqknowlege contains an automated routine for frequency-based HRV based on the parameters set out by the HRV task force in the European Heart Journal (1996). A modified Pan-Thompkins QRS detector is applied to the ECG waveform. A cubic-spline interpolation is then applied to generate frequency power sums. To check that the QRS detector properly detected R-spikes, the tachograms for each HRV calculation were observed. When there were errors in the tachogram, transformations to sections of the ECG waveform were made to correct them.

On short-term recordings, frequency-domain HRV is very sensitive to any anomalies in the tachogram. Further, the sensitivity of the QRS detector used for HRV meant that anomalies were more difficult to fix. Only 92 of the 119 subjects had perfectly clean ECG waveforms that were usable for the HVR analysis. Final group sizes for each treatment were; 24 for wood/plant, 23 for wood/no plant, 20 for non-wood/plant, and 25 for non-wood/no plant.

For each epoch, the normalized units of high-frequency power were analyzed. An HF n.u. score was calculated for each epoch.

Table 5 Psychphysiological measures by period

Period	Epoch start (2.5 minutes duration)	Measures
Baseline	B1=2.5 minutes B2=5 minutes	SCL F-NS-SCR A-NS-SCR IBI, HRV (HF n.u.)
Task	T1=start test T2=end test – 10 minutes T3=end test – 7.5 minutes T4=end test – 5 minutes	SCL F-NS-SCR A-NS-SCR IBI, HRV (HF n.u.)
Recovery	R1=start recovery R2=2.5 minutes R2= 5 minutes	SCL F-NS-SCR A-NS-SCR IBI, HRV (HF n.u.)

4 Results

The methodological goal of this study was to observe whether psychophysiological responses to a mental stressor were moderated by experiencing the stress in rooms characterized by natural and non-natural materials. Two natural materials were employed: wood and plants. Comparable non-natural materials were employed in place of wood and plants for controls. This yielded a two-by-two experimental design. The first factor was wood/non-wood, and the second was plants/no plants. Participants were assigned to one of the four experimental conditions. The target was to assign 30 subjects to each block. This was achieved in all but the non-wood/no plant treatment, where there was one unrecoverable appointment cancellation.

Table 6 displays demographic frequencies related to the study subjects. Convenience sampling yielded a sample that was 62.2% female and 37.8% male. The average age of respondents was 21.3 years (s=2.48), with a range of 18 to 30. All subjects were undergraduate students. Arts was the most common faculty (40.3%), followed closely by science at 36.1% of respondents. Commerce, engineering, and other faculties were each below 10% of respondents.

Table 6 Gender and faculty frequencies

Variable	Category	n	Percentage
Gender	female	74	62.2
	male	45	37.8
Faculty	Arts	48	40.3
	Science	43	36.1
	Engineering	6	5.0
	Commerce	11	9.2
	Other	11	9.2

Table 7 displays select variable frequencies related to treatment assignment. As discussed above, all treatment blocks received 30 subjects except for the non-wood / no plants treatment, which had only 29 subjects. This means that, overall, there were 60 wood treatments and 59 non-wood treatments. With respect to plants, there were 60 plant treatments and 59 non-plant treatments. These categories form the basis for comparisons related to the major hypotheses of the study and are discussed throughout the results section.

Four possible confounding variables are also listed in the table. These are day, time, week, and weather. Differences based on these variables could have confounding effects on this study. For example, subjects may be more or less stressed due to the day of the week, time of the test, week of the term, or outside weather. These measurable potential confounds are discussed in 4.3.1. Other possible confounds are discussed in 5.6.

Table 7 Select treatment and confounding variable frequencies

Variable	Category	n	Percentage
Room Treatment	Wood/Plant	30	25.2
	Wood/No Plant	30	25.2
	Non-wood/Plant	30	25.2
	Non-wood/No plant	29	24.4
Wood Treatment	Wood	60	50.4
	Non-wood	59	49.6
Plant Treatment	Plants	60	50.4
	No plants	59	49.6
Day	Monday	21	17.6
	Tuesday	31	26.1
	Wednesday	25	21.0
	Thursday	23	19.3
	Friday	19	16.0
Weather	sun	29	24.4
	cloud	61	51.3
	rain	29	24.4
Time	0800	6	5.0
	0900	12	10.1
	1000	16	13.4
	1100	12	10.1
	1200	12	10.1
	1300	16	13.4
	1400	14	11.8
	1500	12	10.1
	1600	16	13.4
	1700	3	2.5
Term Week	3	32	26.9
	4	37	31.1
	5	34	28.6
	6	16	13.4

4.1 *Physiological measures*

Physiological measures in this study can be broken down into two categories: electrodermal and cardiovascular. Multiple measures and analyses took place under these two categories. Each measure and the related hypothesis will be explained below.

Results for physiological measures appear in two different time-based measurements below. Epoch based results report each of the 150-second epochs in the study. There are two baseline epochs, four test epochs, and three recovery epochs. Period-based results average all epochs within each of the baseline, test, and recovery periods. The results presented are largely driven by period-based results. There were few differences among epochs within periods.

4.1.1 Electrodermal activity

Three electrodermal activity (EDA) measures were considered. These were skin conductance level (SCL), frequency of non-specific skin conductance responses (F-NS-SCR), and amplitude of non-specific skin conductance responses (A-NS-SCR).

4.1.1.1 Skin conductance level

Skin conductance level (SCL) is a measure of the average electrical conductivity of the skin for a given period. SCL is moderated by the sympathetic nervous system.

> *Hypothesis 1-1: There is no difference in skin conductance level between environments featuring natural materials and environments devoid of natural materials.*

Baseline period

During the baseline period, subjects spent 10 minutes alone in the test environment. In this period, the only test-related stimuli were the fixtures placed in the room. Data for two epochs were collected during this period. Baseline epoch 1 started at 150 seconds and baseline epoch 2 started at 300 seconds. These two epochs represent the middle five minutes of the 10-minute test period. Baseline period descriptive statistics appear in Table 8.

The average skin conductance level in the baseline period was 9.479 micro siemens (μS) (s=5.322). A two-way analysis of variance yielded a main effect for wood, F(1,115)=121.35, p=0.039, such that SCL was significantly lower in the wood room ($\bar{x}$ =8.474, s=4.480) than in the non-wood room ($\bar{x}$ =10.502, s=5.924). The main effect of plants was non-significant, F(1,115)= 0.00, p=0.995. Further, the interaction effect was not significant, F(1,115)=24.43, p=0.879.

Table 8 SCL baseline period descriptive statistics

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	8.474	4.480	0.578
Non-wood	59	10.502	5.924	0.771
Plant Treatment				
Plants	60	9.481	5.495	0.709
No Plants	59	9.478	5.186	0.675
All Rooms				
Wood/Plant	30	8.018	4.535	0.823
Wood/No Plant	30	8.930	4.453	0.813
Non-wood/Plant	30	10.944	6.038	1.102
Non-wood/No plant	29	10.044	5.875	1.091
Total	**119**	**9.479**	**5.322**	**0.488**

Test period

The average skin conductance level (SCL) in the test period was 13.389 μS (s=4.617). A two-way analysis of variance yielded no main effect for wood, F(1,115)=23.36, p=0.300. The main effect of plants was non-significant, F(1,115)=9.836, p=0.500. Further, the interaction effect was not significant, F(1,115)=6.727, p=0.577. Test period descriptive statistics appear in Table 9.

Table 9 SCL test period descriptive statistics

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	12.949	4.487	0.579
Non-wood	59	13.836	4.742	0.617
Plant Treatment				
Plants	60	13.680	4.354	0.562
No Plants	59	13.093	4.889	0.636
All Rooms				
Wood/Plant	30	13.475	4.115	0.751
Wood/No Plant	30	12.424	4.843	0.884
Non-wood/Plant	30	13.885	4.642	0.847
Non-wood/No plant	29	13.786	4.924	0.914
Total	119	13.389	4.617	0.423

Recovery period

The average skin conductance level (SCL) in the recovery period was 11.314 μS (s=4.39). A two-way analysis of variance yielded no main effect for wood, F(1,115)=43.170, p=0.137. The main effect of plants was non-significant, F(1,115)=2.406, p=0.725. Further, the interaction effect was not significant, F(1,115)=15.148, p=0.377. Recovery period descriptive statistics appear in Table 10.

Table 10 SCL recovery period descriptive statistics

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	10.718	3.871	0.500
Non-wood	59	11.919	4.828	0.629
Plant Treatment				
Plants	60	11.463	4.242	0.548
No Plants	59	11.163	4.576	0.596
All Rooms				
Wood/Plant	30	11.218	4.023	0.734
Wood/No Plant	30	10.220	3.713	0.678
Non-wood/Plant	30	11.709	4.507	0.822
Non-wood/No plant	29	12.138	5.211	0.968
Total	119	11.314	4.395	0.403

Figure 5 through Figure 7 display the means and 95% confidence intervals for the wood treatment, plant treatment, and all treatments, respectively.

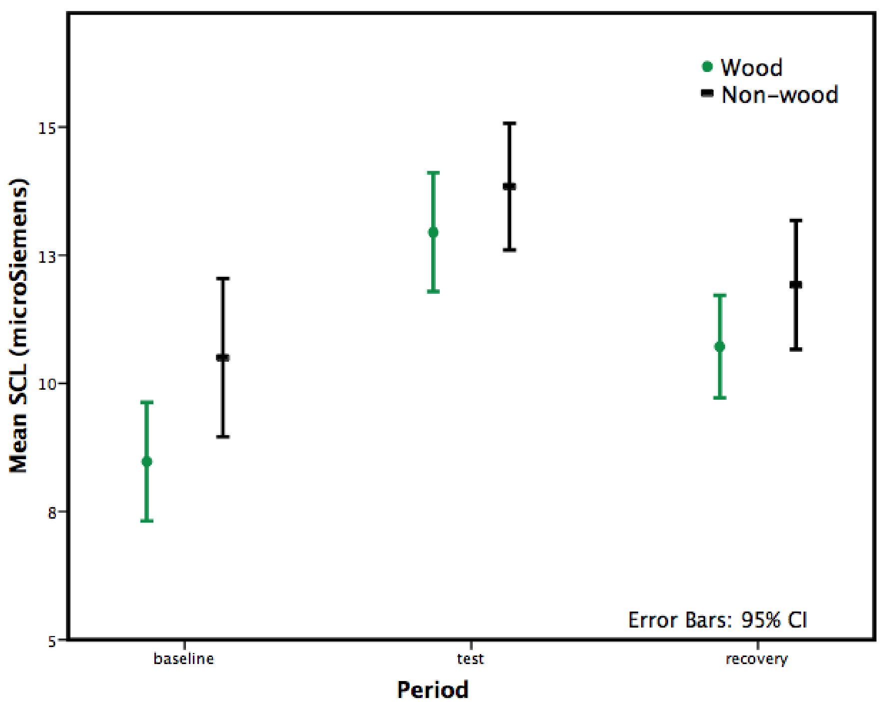

Figure 5 Mean SCL and 95% confidence intervals for wood and non-wood rooms by period

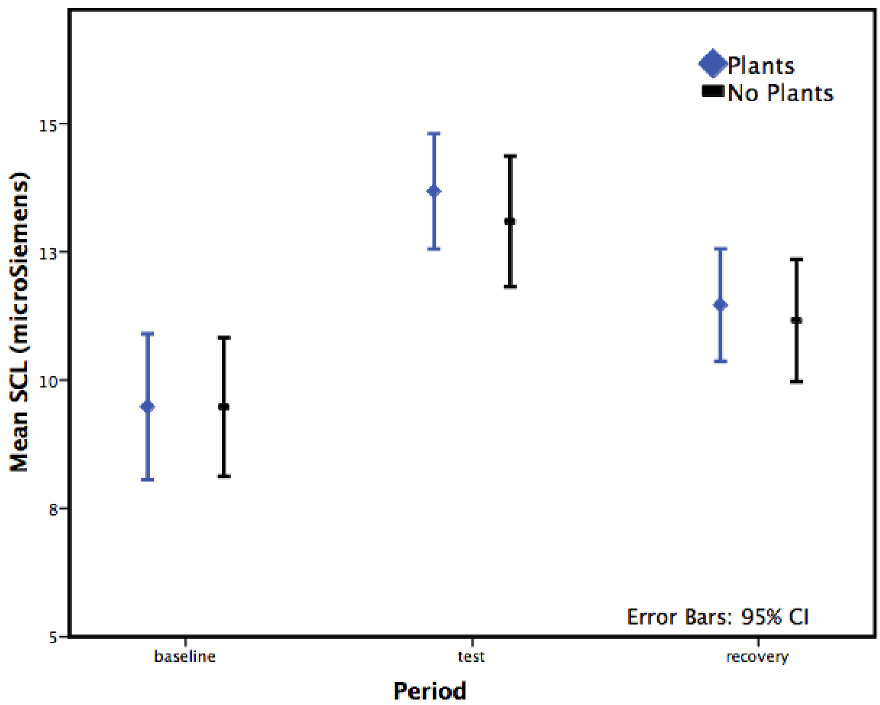

Figure 6 **Mean SCL and 95% confidence intervals for plant and no plant rooms by period**

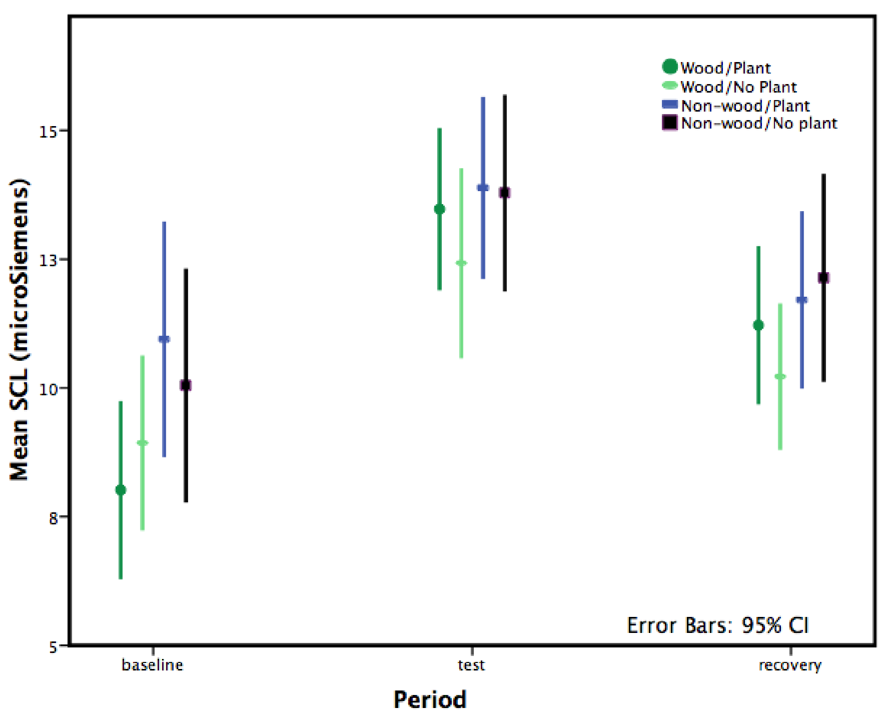

Figure 7 **Mean SCL and 95% confidence intervals for all room setups by period**

Immunization and recovery

Immunization was analyzed by subtracting test period SCL from the baseline period SCL. A two-way analysis of variance yielded a main effect for wood at the $p<0.10$ level, $F(1,115)=3.302$, $p=0.072$. SCL increased significantly more in the wood room ($\bar{x}=4.475$, $s=3.541$) than in the non-wood room ($\bar{x}=3.335$, $s=3.371$) (Table 11). The main effect of plants was not significant, $F(1,115)=10.046$, $p=0.354$.

The interaction effect for immunization was significant, $F(1,115)=4.906$, $p=0.029$. SCL increased most in the wood and plant condition between the baseline and test. However, the SCL in the wood rooms (plants and no plants) remained lower than in the non-wood room during the test period (Table 9).

Recovery was measured by subtracting recovery period SCL from test period SCL. This represents the final recovery epoch and the highest test epoch of SCL. A two-way analysis of variance yielded no main effect for wood, $F(1,115)=1.301$, $p=0.256$ (Table 12). The main effect of plants was non-significant, $F(1,115)=1.083$, $p=0.300$. The interaction effect was not significant, $F(1,115)=0.727$, $p=0.396$. There is no evidence of a recovery effect on SCL.

Table 11 Immunization effects on SCL

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	4.475	3.541	0.457
Non-wood	59	3.335	3.371	0.439
Plant Treatment				
Plants	60	4.199	4.007	0.440
No Plants	59	3.616	2.877	0.443
All Rooms				
Wood/Plant	30	5.457	3.994	0.621
Wood/No Plant	30	3.494	2.749	0.621
Non-wood/Plant	30	2.941	3.665	0.621
Non-wood/No plant	29	3.742	3.047	0.632
Total	119	3.909	3.490	0.312

Table 12 Recovery effects on SCL

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	2.231	1.721	0.222
Non-wood	59	1.917	1.288	0.168
Plant Treatment				
Plants	60	2.217	1.340	0.197
No Plants	59	1.931	1.688	0.197
All Rooms				
Wood/Plant	30	2.257	1.514	0.278
Wood/No Plant	30	2.205	1.931	0.278
Non-wood/Plant	30	2.177	1.167	0.278
Non-wood/No plant	29	1.648	1.370	0.283
Total	119	2.072	1.523	0.140

4.1.1.2 Frequency of non-specific skin conductance responses

The frequency of non-specific skin conductance responses (F-NS-SCR) is a measure of the average number of skin conductance responses per minute.

> *Hypothesis 1-2: There is no difference in the frequency of non-specific skin conductance responses between built environments featuring natural materials and environments devoid of natural materials.*

Baseline period

The average number of SCR's per minute in the baseline period was 1.208 (s=1.584). The number of responses per minute differed based on the wood treatment. A two-way analysis of variance yielded a main effect for wood, F(1,115)=18.434, p=0.006. The average number of responses in the wood room was 0.817 (s=1.208) compared to 1.607 (s=1.816) in the non-wood room. The main effect of plants was non-significant, F(1,115)=0.378, p=0.692. Further, the interaction effect was not significant, F(1,115)=0.635, p=0.427. Baseline period summary statistics appear in Table 13.

Table 13 F-NS-SCR baseline period descriptive statistics

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	0.817	1.208	0.156
Non-wood	59	1.607	1.816	0.236
Plant Treatment				
Plants	60	1.267	1.768	0.228
No Plants	59	1.149	1.383	0.180
All Rooms				
Wood/Plant	30	0.760	1.219	0.222
Wood/No Plant	30	0.873	1.215	0.222
Non-wood/Plant	30	1.773	2.085	0.381
Non-wood/No plant	29	1.434	1.506	0.280
Total	119	1.208	1.584	0.145

Test period

The average F-NS-SCR per minute in the test period was 8.291 (s=4.105). A two-way analysis of variance yielded a main effect for wood, F(1,115)=4.192, p=0.043. The average number of responses in the wood room was 7.523 compared to 9.055 (Table 14) in the non-wood room. The main effect of plants was non-significant, F(1,115)=0.227, p=0.634. Further, the interaction effect was not significant, F(1,115)=0.046, p=0.831.

Table 14 F-NS-SCR test period descriptive statistics

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	7.525	3.960	0.527
Non-wood	59	9.055	4.139	0.531
Plant Treatment				
Plants	60	8.112	3.908	0.527
No Plants	59	8.458	4.323	0.531
All Rooms				
Wood/Plant	30	7.267	3.478	0.745
Wood/No Plant	30	7.783	4.435	0.745
Non-wood/Plant	30	8.958	4.183	0.745
Non-wood/No plant	29	9.155	4.165	0.758
Total	119	8.291	4.105	0.374

Recovery period

The average F-NS-SCR per minute in the recovery period was 0.636 (s=0.778). A two-way analysis of variance yielded a main effect for wood, F(1,115)=4.059, p=0.010. The average number of responses in the wood room was 0.453 compared to 0.823 (Table 15) in the non-wood room. The main effect of plants was non-significant, F(1,115)=0.172, p=0.679. Further, the interaction effect was not significant, F(1,115)=0.119, p=0.731.

Table 15 F-NS-SCR recovery period descriptive statistics

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	0.4533	0.57843	0.07468
Non-wood	59	0.8226	0.90741	0.11813
Plant Treatment				
Plants	60	0.6089	0.77876	0.10054
No Plants	59	0.6644	0.78433	0.10211
All Rooms				
Wood/Plant	30	0.4	0.39148	0.07147
Wood/No Plant	30	0.5067	0.72219	0.13185
Non-wood/Plant	30	0.8178	0.99515	0.18169
Non-wood/No plant	29	0.8276	0.82453	0.15311
Total	119	0.6364	0.77871	0.07138

Immunization and recovery

Immunization was analyzed by subtracting test period F-NS-SCR from the baseline period F-NS-SCR. A two-way analysis of variance yielded no effect for wood, $F(1,115)=0.130$, $p=0.719$. The main effect of plants was not significant, $F(1,115)=0.335$, $p=0.564$. The interaction effect for immunization was not significant, $F(1,115)=0.300$, $p=0.585$.

Recovery was measured by subtracting recovery period F-NS-SCR from test period F-NS-SCR. This represents the final recovery epoch and the highest test epoch of F-NS-SCR. A two-way analysis of variance yielded no main effect for wood, $F(1,115)=0.139$, $p=0.710$. The main effect of plants was non-significant, $F(1,115)=0.295$, $p=0.588$. The interaction effect was not significant, $F(1,115)=0.082$, $p=0.775$. There is no evidence of immunity or recovery effects on F-NS-SCR.

4.1.1.3 Amplitude of non-specific skin conductance responses

Amplitude of non-specific skin conductance responses (A-NS-SCR*)* is a measure of the average size of skin conductance responses.

> *Hypothesis 1-3: There is no difference in the amplitude of skin conductance responses between built environments featuring natural materials and environments devoid of natural materials.*

In the calculation of A-NS-SCR, the subjects with no skin conductance responses in a period were excluded from the analysis. Therefore, the number of subjects in each period differs.

Baseline period

A-NS-SCR in the baseline period was 1.353 μS (s= 0.892). A two-way analysis of variance yielded no main effect for wood, F(1,66)=0.750, p=0.784. The main effect of plants was non-significant, F(1,66)=0.007, p=0.933. Further, the interaction effect was not significant, F(1,66)=0.625, p=0.432. Descriptive statistics for the baseline period appear in Table 16.

Test period

A-NS-SCR in the test period was 1.115 μS (s= 0.723). A two-way analysis of variance yielded no main effect for wood, F(1,113)=0.320, p=0.633. The main effect of plants was non-significant, F(1,113)=1.961, p=0.164. Further, the interaction effect was not significant, F(1,113)=0.946, p=0.333. Descriptive statistics for the test period appear in Table 17.

Table 16 A-NS-SCR descriptive statistics during baseline period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	29	1.386	1.051	0.169
Non-wood	41	1.324	.773	0.142
Plant Treatment				
Plants	35	1.355	0.899	0.157
No Plants	35	1.345	0.898	0.157
All Rooms				
Wood/Plant	14	1.287	0.913	0.243
Wood/No Plant	14	1.479	1.190	0.234
Non-wood/Plant	21	1.400	0.910	0.198
Non-wood/No plant	20	1.245	0.612	0.203
Total	70	1.353	0.892	0.110

Table 17 A-NS-SCR descriptive statistics during test period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	58	1.083	0.768	0.101
Non-wood	59	1.148	0.681	0.089
Plant Treatment				
Plants	59	1.208	0.784	0.102
No Plants	58	1.022	0.649	0.085
All Rooms				
Wood/Plant	29	1.242	0.782	0.145
Wood/No Plant	29	0.925	0.734	0.136
Non-wood/Plant	30	1.176	0.798	0.146
Non-wood/No plant	29	1.119	0.546	0.101
Total	117	1.115	0.723	0.067

Recovery period

A-NS-SCR in the test period was 1.313 μS (s= 0.877). A two-way analysis of variance yielded no main effect for wood, $F(1,48)=0.029$, $p=0.865$. The main effect of plants was non-significant, $F(1,48)=0.267$, $p=0.607$. Further, the interaction effect was not significant, $F(1,48)=0.483$, $p=0.491$. Descriptive statistics for the recovery period appear in Table 18.

Table 18 A-NS-SCR descriptive statistics during recovery period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	21	1.372	0.962	0.208
Non-wood	31	1.273	0.829	0.161
Plant Treatment				
Plants	30	1.357	0.862	0.164
No Plants	22	1.253	0.914	0.205
All Rooms				
Wood/Plant	14	1.478	0.993	0.240
Wood/No Plant	7	1.159	0.932	0.339
Non-wood/Plant	16	1.251	0.746	0.224
Non-wood/No plant	15	1.253	0.935	0.232
Total	52	1.313	0.877	0.131

4.1.2 Cardiovascular

Two cardiovascular measures were analyzed in this study. These were interbeat interval (IBI) and heart rate variability (HRV). Both of these require that the R-spike of the electrocardiogram (ECG) be identified. Both IBI and HRV measures are based on the interval between R-spikes, or R-R interval.

4.1.2.1 Interbeat interval

Interbeat interval is moderated by both the sympathetic and parasympathetic systems. IBI is not a pure measure of activation of either system, but it is generally reduced when humans are under stress.

> *Hypothesis 2: There is no difference in interbeat interval between environments featuring natural materials and environments devoid of natural materials.*

When considering the responses of all subjects, interbeat interval behaved as expected based on the study design. Interbeat interval decreased during the test period and recovered in the recovery period to just above the baseline period. The average interbeat interval in the baseline period was 0.771 seconds (s=0.111). This decreased to 0.725 seconds (s=0.102) during the test, and recovered to 0.791 seconds (s=0.112) during the recovery period. Although IBI responses were as expected, there were no treatment effects or interactions among wood or plant groups.

Baseline period

A two-way analysis of variance on IBI yielded no main effect for wood, $F(1,105)=2.623$, $p=0.108$. The main effect of plants was non-significant, $F(1,105)=0.006$, $p=0.938$. Further, the interaction effect was not significant, $F(1,105)=0.342$, $p=0.560$. Descriptive statistics for IBI in the baseline period appear in Table 19.

Table 19 IBI descriptive statistics during baseline period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	56	0.788	0.120	0.015
Non-wood	53	0.754	0.100	0.015
Plant Treatment				
Plants	56	0.772	0.094	0.015
No Plants	53	0.771	0.128	0.015
All Rooms				
Wood/Plant	29	0.783	0.097	0.021
Wood/No Plant	27	0.794	0.141	0.021
Non-wood/Plant	27	0.761	0.091	0.021
Non-wood/No plant	26	0.747	0.110	0.022
Total	109	0.771	0.111	0.011

Test period

The average IBI in the test period was 0.725 seconds (s= 0.102). A two-way analysis of variance yielded no main effect for wood, $F(1,105)=1.120$, $p=0.292$. The main effect of plants was non-significant, $F(1,105)=0.297$, $p=0.587$. Further, the interaction effect was not significant, $F(1,105)=0.004$, $p=0.948$. Descriptive statistics for IBI for the test period appear in Table 20.

Recovery period

The average IBI in the recovery period was 0.791 seconds (s= 0.112). A two-way analysis of variance yielded no main effect for wood, $F(1,105)=2.276$, $p=0.135$. The main effect of plants was non-significant, $F(1,105)=0.239$, $p=0.626$. Further, the interaction effect was not significant, $F(1,105)=1.442$, $p=0.233$. Descriptive statistics for IBI for the recovery period appear in Table 21.

Table 20 IBI descriptive statistics during test period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	56	0.735	0.119	0.014
Non-wood	53	0.715	0.080	0.014
Plant Treatment				
Plants	56	0.720	0.081	0.014
No Plants	53	0.730	0.121	0.014
All Rooms				
Wood/Plant	29	0.731	0.089	0.019
Wood/No Plant	27	0.740	0.146	0.020
Non-wood/Plant	27	0.709	0.070	0.020
Non-wood/No plant	26	0.731	0.091	0.020
Total	109	0.725	0.102	0.010

Table 21 IBI descriptive statistics during recovery period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	56	0.806	0.124	0.015
Non-wood	53	0.774	0.095	0.015
Plant Treatment				
Plants	56	0.785	0.097	0.015
No Plants	53	0.796	0.127	0.015
All Rooms				
Wood/Plant	29	0.789	0.103	0.021
Wood/No Plant	27	0.825	0.143	0.021
Non-wood/Plant	27	0.782	0.091	0.021
Non-wood/No plant	26	0.767	0.101	0.022
Total	109	0.791	0.111	0.011

Immunization and recovery

IBI Immunization was analyzed by subtracting the test-period IBI from the baseline-period IBI. A two-way analysis of variance yielded no main effect for wood, $F(1,105)=1.891$, $p=0.172$. The main effect of plants was non-significant, $F(1,105)=1.553$, $p=0.215$. Further, the interaction effect was not significant, $F(1,105)=1.914$, $p=0.169$.

Recovery was measured by subtracting the test period IBI from the recovery period IBI. A two-way analysis of variance yielded no main effect for wood, $F(1,105)=2.272$, $p=0.135$. The main effect of plants was non-significant, $F(1,105)=0.239$, $p=0.626$. The interaction effect for IBI recovery was not significant, $F(1,105)=1.442$, $p=0.233$.

Table 22 IBI recovery descriptive statistics

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	56	0.071	0.050	0.007
Non-wood	53	0.060	0.050	0.007
Plant Treatment				
Plants	56	0.065	0.046	0.007
No Plants	53	0.066	0.055	0.007
All Rooms				
Wood/Plant	29	0.058	0.041	0.009
Wood/No Plant	27	0.084	0.056	0.009
Non-wood/Plant	27	0.073	0.049	0.009
Non-wood/No plant	26	0.046	0.047	0.010
Total	109	0.065	0.050	0.005

4.1.2.2 Heart rate variability

For short-duration measures of heart rate variability (HRV), spectral analysis methods are most appropriate (Task Force, 1996). In this study, the high-frequency component of the spectrum was analyzed. This band is associated with parasympathetic activation (Askelrod, 1981). It captures the variability in heart rate with respiration when one is relaxed.

> *Hypothesis 3-1: There is no difference in high frequency power between built environments featuring natural materials and environments devoid of natural materials.*

For comparability, the high frequency power scores are normalized with the sum of high- and low-frequency bands. The overall scores provide a check of the test setup. We would expect normalized high frequency (HF n.u.) to be lowest in the test period for all subjects due to the stress imparted by the PASAT test.

The average HF n.u. score in the baseline period was 0.1868 (s=0.010). In the test period, the average dropped to 0.1859 (s=0.009). Using a paired t-test, the baseline and test periods are not significantly different ($t(91)=0.854$, $p=0.395$). In the recovery period, HF n.u. increased to 0.1881 (s=0.010). This increase in HF was statistically significant ($t(91)=-2.076$, $p=0.041$).

There is moderate evidence to support the validity of HF n.u. as a measure of parasympathetic activation in this study. While HF n.u. was lowest in the test period, it was not statistically lower than in the baseline period. However, HF n.u. was statistically higher in the recovery period than in the test period as expected in the experimental design.

One possible explanation of this result may be that even in the baseline period, there was stress associated with the uncertainty of an upcoming test which subjects did not know the nature of. This may explain the lack of parasympathetic activation in the baseline period. In the recovery period, subjects knew that testing was completed, causing parasympathetic activation to increase.

While parasympathetic activity was shown to differ between the test and recovery periods, there were no treatment or interaction effects found.

Baseline

A two-way analysis of variance yielded no HF n.u. main effect for wood, $F(1,92)=0.048$, $p=0.827$. The main effect of plants was non-significant, $F(1,92)=0.165$, $p=0.685$. Further, the interaction effect was not significant, $F(1,92)=1.260$, $p=0.265$. Descriptive statistics for baseline period HF n.u. appear in Table 23.

Table 23 HF n.u. descriptive statistics during baseline period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	47	0.187	0.011	0.001
Non-wood	45	0.186	0.008	0.002
Plant Treatment				
Plants	44	0.186	0.011	0.002
No Plants	48	0.187	0.009	0.001
All Rooms				
Wood/Plant	24	0.185	0.013	0.002
Wood/No Plant	23	0.189	0.009	0.002
Non-wood/Plant	20	0.187	0.010	0.002
Non-wood/No plant	25	0.185	0.009	0.002
Total	92	0.187	0.010	0.001

Test period

A two-way analysis of variance yielded no HF n.u. main effect for wood, $F(1,92)=0.042$, $p=0.839$. The main effect of plants was non-significant, $F(1,92)=0.000$, $p=0.988$. Further, the interaction effect was not significant, $F(1,92)=0.025$, $p=0.874$. Descriptive statistics for baseline period HF n.u. appear in Table 24.

Recovery period

A two-way analysis of variance yielded no HF n.u. main effect for wood, $F(1,92)=0.079$, $p= 0.779$. The main effect of plants was non-significant, $F(1,92)=0.486$, $p=0.487$. Further, the interaction effect was not significant, $F(1,92)=0.015$, $p=0.902$. Descriptive statistics for recovery period HF n.u. appear in Table 25.

Table 24 HF n.u. descriptive statistics during test period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	47	0.186	0.009	0.001
Non-wood	45	0.186	0.007	0.001
Plant Treatment				
Plants	44	0.186	0.008	0.001
No Plants	48	0.186	0.008	0.001
All Rooms				
Wood/Plant	24	0.186	0.009	0.002
Wood/No Plant	23	0.186	0.009	0.002
Non-wood/Plant	20	0.186	0.006	0.002
Non-wood/No plant	25	0.186	0.007	0.002
Total	92	0.186	0.008	0.001

Table 25 HF n.u. descriptive statistics during recovery period

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	47	0.188	0.013	0.002
Non-wood	45	0.188	0.007	0.002
Plant Treatment				
Plants	44	0.187	0.011	0.002
No Plants	48	0.189	0.009	0.002
All Rooms				
Wood/Plant	24	0.188	0.013	0.002
Wood/No Plant	23	0.189	0.012	0.002
Non-wood/Plant	20	0.187	0.008	0.002
Non-wood/No plant	25	0.189	0.007	0.002
Total	92	0.188	0.010	0.001

4.2 *PASAT scores*

The Paced Auditory Serial Addition Task (PASAT) was employed primarily as a stressor in this study. However, the test itself is a measure of the ability to maintain concentration (Sherman *et al.*, 1997). While the PASAT is not normally employed in environmental psychology studies (exception Parsons *et al.*, 1998), it is worth analyzing the scores because the ability to focus attention decreases when stressed. If the PASAT test is a sensitive enough instrument to capture stress differences, we would expect PASAT errors to be lower in built environments featuring natural materials.

> *Hypothesis 4-1: There is no difference in PASAT test errors between built environments featuring natural materials and environments devoid of natural materials.*

Respondents in the non-wood treatment generally made fewer errors on the PASAT test than those in the wood room. The PASAT test consists of four sets of forty-nine answers for a total of 196. The average number of errors in the non-wood room was 23.950 (s=20.014) (median=19). Errors in the wood room were higher at an average of 30.517 (s=22.873) (median=26).

PASAT errors were very similar in the plant and non-plant set-ups. The average number of errors in the plant room was 26.767 (s=21.249) (median=22). Errors in the non-plant room were 27.763 (s=22.250) (median=19).

The distribution of PASAT errors is bound on the lower end by zero; consequently, the distribution is skewed right. A square root transformation of the data provides a distribution better approximating the normal distribution. Means appear in Table 26.

A two-way analysis of variance yielded no main effect for wood, $F(1,119)=2.685$, $p=0.104$. The main effect of plants was non-significant, $F(1,119)=0.232$, $p=0.631$. Further, the interaction effect was not significant, $F(1,119)=2.613$, $p=0.109$.

Table 26 Square root of PASAT errors descriptive statistics by treatment

	n	Mean	Std. Deviation	Std. Error
Wood Treatment				
Wood	60	5.090	2.165	0.279
Non-wood	59	4.452	2.049	0.267
Plant Treatment				
Plants	60	4.682	2.220	0.287
No Plants	59	4.867	2.035	0.267
All Rooms				
Wood/Plant	30	5.309	2.278	0.416
Wood/No Plant	30	4.871	2.060	0.376
Non-wood/Plant	30	4.055	2.007	0.366
Non-wood/No plant	29	4.863	2.046	0.380
Total	119	4.774	2.124	0.195

4.3 *Survey measures*

When the recovery period was completed, subjects were administered a short environmental attribute survey. Subjects were asked how well a series of nine descriptors represented the room they were in. The scale was from 1 - “does not describe at all” to 5 – “describes very well”.

The means for each room appear in Table 27 and Figure 8. The mean ratings differed among rooms on only 2 of the nine attributes. These are warm ($f(3,113)=3.151$, $p=0.028$) and natural ($f(3,114)=8.883$, $p=0.000$). Subjects in the wood / plant room rated their rooms significantly warmer than subjects in the non-wood / no plant room (Least Squares Difference (LSD) *post hoc* test). The largest difference was on the “natural” attribute. The non-wood / no plants was rated lower than all other rooms. In addition, the wood / plant room was rated as significantly more natural than the wood / no plant room.

The “healthy” attribute did not have significant differences at the $p<0.05$ level, but was suggestive of a difference at $p<0.10$ ($f(3,114)=2.574$, $p=0.057$). An LSD *post hoc* test found two room differences on health. The non-wood / no plants room was rated significantly less healthy than the wood / plant and non-wood / plant rooms.

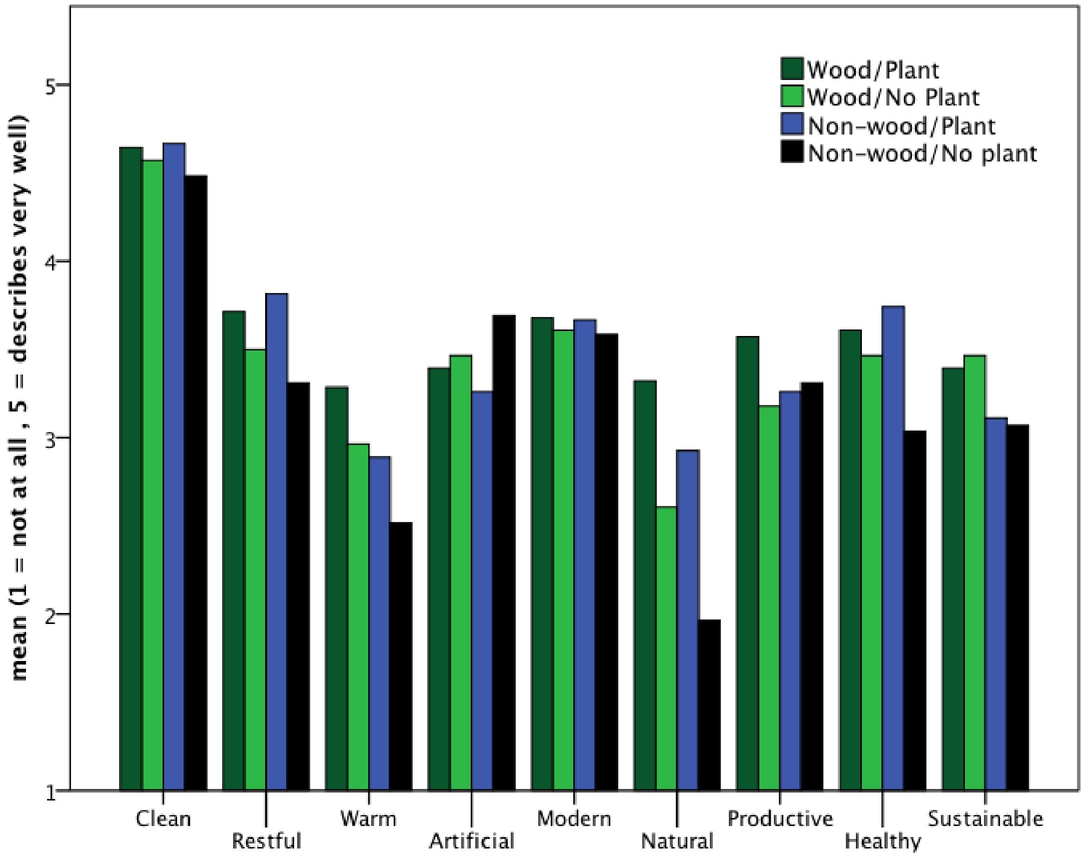

Figure 8 Mean attribute scores by room

There were also differences in room evaluations by gender. Women rated the wood room more natural than men, with a mean rating of 3.33 (s=0.917) compared to 2.16 for men (s=1.068). This difference is significant at p=0.000 (t(57)=4.352). Conversely, men rated the non-wood room warmer than women did. Men rated the warmth of the non-wood room to be 3.04 (s=0.862) while the mean rating by women was 2.48 (s=1.004). This result is significant at p=0.021 (t(56)=-2.374).

Table 27 Room attribute descriptive statistics

		n	Mean	Standard Deviation	F	Sig.
Clean	Wood/Plant	29	4.66	0.553	0.494	0.687
	Wood/No Plant	30	4.57	0.626		
	Non-wood/Plant	30	4.67	0.547		
	Non-wood/No plant	29	4.48	0.871		
	Total	118	4.59	0.657		
Restful	Wood/Plant	29	3.69	0.891	0.987	0.401
	Wood/No Plant	30	3.53	1.279		
	Non-wood/Plant	30	3.77	1.006		
	Non-wood/No plant	29	3.31	1.168		
	Total	118	3.58	1.097		
Warm	Wood/Plant	29	3.34a	1.143	3.151	0.028
	Wood/No Plant	30	2.9	1.029		
	Non-wood/Plant	29	2.97	1.017		
	Non-wood/No plant	29	2.52a	0.911		
	Total	117	2.93	1.056		
Artificial	Wood/Plant	29	3.38	1.049	1.037	0.379
	Wood/No Plant	30	3.47	1.042		
	Non-wood/Plant	29	3.24	0.912		
	Non-wood/No plant	29	3.69	0.967		
	Total	117	3.44	0.995		
Modern	Wood/Plant	29	3.69	0.891	0.075	0.973
	Wood/No Plant	29	3.59	0.78		
	Non-wood/Plant	30	3.63	1.098		
	Non-wood/No plant	29	3.59	1.053		
	Total	117	3.62	0.953		
Natural	Wood/Plant	29	3.34a,d	1.045	8.883	0
	Wood/No Plant	30	2.57a,b	1.04		
	Non-wood/Plant	30	2.9c	1.299		
	Non-wood/No plant	29	1.97c,b,d	0.823		
	Total	118	2.71	1.17		
Productive	Wood/Plant	28	3.57	0.997	0.825	0.483
	Wood/No Plant	30	3.17	1.085		
	Non-wood/Plant	30	3.2	1.126		
	Non-wood/No plant	29	3.31	1.105		
	Total	117	3.31	1.078		
Healthy	Wood/Plant	29	3.66a	1.045	2.574	0.057
	Wood/No Plant	30	3.47	1.008		
	Non-wood/Plant	30	3.7b	0.988		
	Non-wood/No plant	29	3.03a,b	1.052		
	Total	118	3.47	1.043		
Sustainable	Wood/Plant	29	3.41	1.211	1.334	0.267
	Wood/No Plant	29	3.48	0.785		
	Non-wood/Plant	29	3.1	1.012		
	Non-wood/No plant	29	3.07	0.884		
	Total	116	3.27	0.99		

Cells sharing the same letter are significantly different at the p<0.05 level based on a LSD post hoc test.

4.3.1 Confounding variables

There are a number of possible confounding variables that could have had an effect on the stress levels of subjects. These are weather during appointment, time of day, day of week, and week of appointment. The electrodermal and cardiovascular measures were analyzed based on these variables to identify any confounds.

Weather

Stress levels and mood differ based on the weather (Barnston, 1988). To control for weather effects hour by hour, weather information was collected from the National Climate Data and Information Archive. Vancouver International Airport is the closest weather station to the University of British Columbia campus. Weather for the hour leading up to an appointment was coded as sun, overcast, or raining. This captures the weather encountered as subjects made their way to the appointment. There were no differences found on any of the physiological variables (by test period) based on weather.

Time

Appointments in this study took place between 8 am and 6pm. There is no evidence for a time of day effect in the study.

Day

Appointments were scheduled from Monday to Friday. There were no day of week effects found.

Week

Data collection took place starting the Monday of week three of the fall term and concluded on Wednesday of week 6. Due to the time-consuming task of setting up room environments, all appointments in one test room were carried out before moving on to the next test room scenario. This left the possibility of serial or history effects. However, there is no evidence for serial or history effects in the data.

5 Discussion

5.1 *Summary of findings*

The goal of this research study was to determine if wood reduces stress in occupants of built environments. This study provides some evidence that such an effect exists. Below are three questions posed in the research objectives section.

Does the application of wood in the built environment reduce stress?

Based on the results of this study, wood may reduce stress in the indoor environment. Subjects in the wood office displayed lower stress activation in all periods of the study. In the baseline period, both skin conductance level and the frequency of non-specific skin responses were lower in the wood room. During the stressful test period, skin conductance level did not differ between the wood and non-wood rooms. However, the frequency of non-specific skin responses was lower in the wood room during the test period. Finally, during the recovery period non-specific skin responses were lower in the wood room. Though not statistically lower in the recover period, skin conductance levels in the wood room began to move lower than in the non-wood room.

How does the application of wood in the built environment effect autonomic responses to stress?

A stress-reducing effect was found in relation to the sympathetic nervous system in this study. Sympathetic activation was assessed by measuring skin conductivity throughout the study. Two of the three skin conductivity analyses showed a wood effect; these were skin conductance level and non-specific skin conductance response. Skin conductance level was lower and non-specific skin conductance responses fewer in the wood room during the baseline and recovery periods. There is no evidence of a difference in parasympathetic nervous system activation in this study.

This result is consistent with the findings of Parsons *et al.* (1998) with respect to sympathetic and parasympathetic responses to natural environments. Upon reviewing the results of their study, Parsons *et al.* (1998) suggest that responses to natural environments may be driven by the sympathetic branch, but not the parasympathetic branch, of the autonomic nervous system.

> *Does the application of wood in the built environment provide the same stress-reducing health effects as indoor plants?*

This study found no plant effect on stress. Therefore, no conclusions can be drawn as to plants and wood providing the same effects. Past studies have found plant effects on mood (Shibata and Suzuki, 2002), blood pressure (Lohr *et al.*, 1996), pain perception (Lohr and Pearson-Mimms, 2001), number of health conditions (Fjeld *et al.*, 1998), and task performance (Lohr *et al.*, 1996). However, these studies do not separate out sympathetic and parasympathetic effects. We strove to compare wood and plants effects in this study. However, no plant effect was found in this study so no comparisons can be made. The failure to find a plant treatment is discussed in detail in 5.4.

Table 28 Overview of wood effects

Autonomic Branch	Measure	Baseline Effect	Test Effect	Recovery Effect
SNS	SCL	Yes	No	Suggestive
	F-NS-SCR	Yes	Yes	Yes
	A-NS-SCR	No	No	No
PNS	HF n.u.	No	No	No
Mixed	Inter beat interval	No	No	No

5.2 *On analysis periods*

The three analysis periods of this study capture different states of mental arousal. It is in the context of these states that results should be viewed.

The study began with a 10-minute baseline period in which no discrete external stimuli are presented. It would seem that this period should be relatively stress-free. However, there were two unavoidable sources of stress at play in the baseline period. First, there was an initial level of stress associated with having electrodes attached and being monitored from outside the room. This was especially true in the baseline period as the electrodes had just been placed, and they were the only truly novel stimuli in the room. SCL was generally observed to decrease over the first five minutes of the baseline period. The second source of stress in the baseline period was test apprehension. Subjects were told that, at the end of 10 minutes, the researcher would return to administer a mental task. Over the second half of the baseline period, SCL increased in many subjects in anticipation of the test. The two sources of stress likely contributed to non-specific skin conductance responses being higher in the baseline period than in the recovery period.

In the test period, the PASAT test was the introduced stressor. This test was all-consuming with respect to attention, because numbers were presented every 2.4 down to 1.2 seconds. Regardless of environment, all subjects found the test to be moderately to highly stressful with large increases in SCL and a decreasing IBI. Upon analyzing the data, it is clear that the high levels of sympathetic activation and individual variability in absolute measures make finding differences in the subtle test manipulations difficult in this period.

Further, it was observed that some subjects tended not to look at their surroundings during testing. While they were focusing their concentration on the PASAT test, some subjects tended to focus their gaze on one place or close their eyes. When their eyes were open, they often focused down on their hands or upwards on the front wall and ceiling. The degree of visual interaction with the office environment during this period of high concentration and stress was observed to be low. Thus, we would expect the treatment effects during this period to be lessened unless an immunization effect was present (no immunization effect was found).

The recovery saw SCL and IBI return to baseline levels. In fact, these indicators showed some recovery even during the latter minutes of the PASAT test. This is commonly observed as stimuli are repeated (Dawson et al, 2000). Of note is that F-NS-SCRs were lower in the recovery period than in the baseline period. This is an indication that underlying stress was lower in this period. The two sources of stress noted above for the baseline period were reduced or eliminated in the recovery period. Firstly, the stress associated with electrodes and physiological recording are reduced because subjects had been accustomed to them by the recovery period. Secondly, the stress of an upcoming test in the baseline period was not there in the recovery period because subjects knew they were finished testing.

Overall, the baseline period may best represent chronic stress activation. The stress in this period revolves around the unknown and a lack of control. It translates to a moderate stress level. The test period represents stress associated with high levels of concentration and focus on a single task. In this period, stress was high in the context of this study. Finally, the recovery period represents a low level of stress.

5.3 *On effects*

The primary goal of this study was to research the effect of natural materials on human stress in the built environment. The autonomic nervous system regulates stress responses to environments, and it was the focus of the study. Of the two branches of the autonomic nervous system, differences in environmental effects were only found in relation to the sympathetic nervous system.

Hypothesis 1 : There is no difference in sympathetic nervous system activity between built environments featuring natural materials and environments devoid of natural materials.

There were three measures of sympathetic activation in the study. These were skin conductance level (SCL), frequency of non-specific skin conductance responses (F-NS-SCR), and amplitude of skin conductance responses (A-NS-SCR). Both SCL and F-NS-SCR produced wood treatment effects. No wood treatment effects were found for A-NS-SCR. Further, no plant effects were found on any of the sympathetic measures.

> *Hypothesis 1-1: There is no difference in skin conductance level between environments featuring natural materials and environments devoid of natural materials.*

Treatment effects were found for wood with respect to SCL. SCL was lower for the wood treatment in the baseline period of the study. This leads to the conclusion that sympathetic activation, or stress, was lower in subjects exposed to wood visual surfaces. This conclusion applies to the baseline period where stress was low to moderate. During the high-stress test period, stress levels did not differ between wood and non-wood treatments. Though not statistically significant, in the recovery period, SCL in the wood room trended lower than in the non-wood room. In fact, during the third recovery epoch, SCL in the wood room was statistically lower than in the non-wood room at the $p<0.10$ level. Like the baseline period, the recovery period is characterized by low to moderate stress. A review of SCL findings appears in Table 29.

Interestingly, when testing for immunization, effect an interaction was found. Subjects in the wood and plant room had a greater increase in SCL from the baseline period to the test period than subjects in other treatments. Mean SCL for subjects in the wood and plant room during the test period did not differ significantly from other treatment groups. However, during the baseline period the wood room was lower ($p<0.05$) and the mean of the wood and plant room was the lowest of all treatments. Therefore, the interaction found may indicate the lack of a immunization effect. Based on this interpretation, the SCL evoked from the PASAT was equivalent across all treatments, but the wood and plant treatment had to increase the most from the test period to reach this level.

Table 29 Review of SCL findings

	Plant effect	Wood effect
Baseline	no	p<0.05, wood lower
Testing	no	no
Recovery	no	suggestive
Interactions	yes	
Hypothesis	Null accepted	Null rejected

This study gives *moderate* evidence to reject null hypothesis 1-1 and accept the alternate hypothesis.

1. Treatment effects were found only for wood, not plants.
2. Wood treatment effects were found only in the low or moderately stressful baseline and recovery periods.

Hypothesis 1-2: There is no difference in the frequency of non-specific skin conductance responses between built environments featuring natural materials and environments devoid of natural materials.

Strong wood treatment effects were found with respect to the frequency of non-specific skin conductance responses (Table 30). F-NS-SCRs are short-term spikes in skin conductance related to unprovoked stressful thoughts. The wood treatment yielded a lower F-NS-SCR than the non-wood treatment. As in 1-1 above, this leads to the conclusion that sympathetic activation, or stress, was lower in subjects exposed to wood visual surfaces. Again, this result does not apply to the plants for which no treatment effects were found. F-NS-SCR was lower in all test periods.

Table 30 Review of F-NS-SCR findings

	Plant effect	Wood effect
Baseline	no	$p<0.01$, wood lower
Testing	no	$p<0.05$ wood lower
Recovery	no	$p<0.01$, wood lower
Interactions	no	
Hypothesis	Null accepted	Null Rejected

This study gives *moderate to strong* evidence to reject null hypothesis 1-2 and accept the alternate hypothesis.

1. Treatment effects were found only for wood, not plants.
2. Wood treatment effects were significant at the $p<0.01$ and $p<0.05$.

Hypothesis 1-3: There is no difference in the amplitude of skin conductance responses between built environments featuring natural materials and environments devoid of natural materials.

There were no treatment effects found for plants or wood for the amplitude of skin conductance responses (Table 31). Null hypothesis 1-3 is accepted. Natural materials did have an effect on the amplitude of skin conductance responses.

Table 31 Review of A-NS-SCR findings

	Plant effect	Wood effect
Baseline	no	no
Testing	no	no
Recovery	no	no
Interactions	no	
Hypothesis	Null accepted	Null accepted

Overall, the data provide moderate evidence to reject null hypothesis 1 and accept the alternate hypothesis.

- A wood treatment effect exists for sympathetic activation.
- The strongest wood treatment effect was found in periods of low to moderate stress.

Hypothesis 2: There is no difference in interbeat interval between environments featuring natural materials and environments devoid of natural materials.

There were no wood or plant treatment effects found in any of the treatment periods (Table 32). Null hypothesis 2 is accepted. IBI was affected as expected by the PASAT stressor; however, no natural material treatment effects were found.

Table 32 Review of IBI findings

	Plant effect	Wood effect
Baseline	no	no
Testing	no	no
Recovery	no	mo
Interactions	no	
Hypothesis	Null accepted	Null accepted

Hypothesis 3: There is no difference in parasympathetic nervous system activation between built environments featuring natural materials and environments devoid of natural materials.

Hypothesis 3-1- There is no difference in high frequency power of the ECG signal between built environments featuring natural materials and environments devoid of natural materials.

No treatment effects for heart rate variability were found in this study (Table 33). HF n.u., the indicator of parasympathetic activation, revealed no differences across treatments, nor were there any differences based on study period. As the level of stress and relaxation differs among the study periods, one would expect to find at least period differences in HF n.u.

Results from this study lead to the acceptance of null hypothesis 3. However, it is not clear if the construct has been accurately captured by the study methodology. This is discussed below in limitations.

Table 33 Review of HF n.u. findings

	Plant effect	Wood effect
Baseline	no	no
Testing	no	no
Recovery	no	no
Interactions	no	
Hypothesis	Null accepted	Null accepted

Hypothesis 4: There is no difference in attention between built environments featuring natural materials and environments devoid of natural materials.

Hypothesis 4-1:There is no difference in PASAT test errors between built environments featuring natural materials and environments devoid of natural materials.

There is no evidence of treatment effects for attention as measured by the PASAT test. Therefore, the null hypothesis is accepted. The PASAT test was used in this study primarily as a stressor activity. The PASAT's ability to test for attention was secondary to the study.

The PASAT test has not been used in environmental psychology as an attention measure before. The conventional measures are the Necker cube (Tennessen and Cimpich, 1995; Kaplan, 1995) and the symbol digit modalities test (Tennessen and Cimpich, 1995). However, to implement these tests takes three minutes for each administration. The focus of this study is psychophysiology, and these repeated breaks would make the psychophysiology record unclear. These breaks have the potential to increase or decrease stress levels each time they are implemented. It was important in this study to have one primary stressor, the PASAT, and to make the psychophysiological record as clean as possible in order to detect the effect of the subtle environmental manipulation.

5.4 *On materials*

It is clear that there was a wood treatment effect found in this study. This supports the theory that wood, a non-living biological material, provides stress-reducing effects in line with the general "nature" effect discussed in environmental psychology/psychophysiology (Kaplan and Kaplan, 1989; Ulrich 1984). This result has major implications with respect to the fields of biophilic and evidence-based design.

Just as interesting is the lack of plant treatment effect found in the study. This study set out to replicate the plant effect found in past studies (Lohr *et al.*, 1996; Lohr and Pearon-Mimms, 2001) and to test for an analogous wood effect. This study failed to find a plant treatment effect, but did find a wood effect. Further discussion is required to address this apparent inconsistency.

This result could be due to the proximity and volume of wood and plants in the room. In this study, there were three plants in the room. There was one small plant on the desk at which the subject was sitting, one large plant in direct forward view at 8 feet, and a third medium-size plant 6 feet to the right of subjects in their peripheral view.

While Lohr *et al.* (1996) does not discuss the proximity of plants to subjects, photographs of the study setup were included in the article. The photograph shows three to four plants all within an arm's length of the subject and in direct view. This proximity may have provided a treatment effect as the plants make up a high proportion of the viewscape. The Lohr *et al.* (1996) plant treatment was much more visually apparent than the plant treatment in the current study.

The visual surface area of plants and wood in this study is estimated in Table 34. There were approximately 15 square feet of plants in view of subjects. Of the 15 feet, 13 square feet were in direct view and 2 feet were in the periphery. Further, only one small plant was within arm's reach of subjects with the largest plant being 8 feet away.

In contrast, there were 133 square feet of wood surface visible to subjects. This included 92.6 square feet in direct view and 40.4 square feet in peripheral view. The desk they sat at alone accounted for 14 square feet, all within arm's length. Further, the wood blinds that subjects faced made up 60 square feet of viewable wood surface.

In retrospect, the wood treatment was much more visibly present than the plant treatment, and this can be addressed in future research. One of the goals of this study was to make believable office settings. In this context, it is much easier to boost the wood content in a room than the plant content while still remaining within the common parameters of materials used in an office.

The proportion of "natural" is not a common subject in the literature. While not psychophysiology studies, Masuda and Yamamoto (1988) and Masuda and Nakamura (1990) report on the ideal percentage of visual wood surface area in a room. They found that 43% coverage by wood was rated as pleasing by respondents. They reported an inverted U-shaped preference relationship with wood coverage.

With regards to the room setup, we can calculate the percentage of wood and plant surface area viewable by subjects. Calculations are based on subjects sitting 10 feet from the front wall. Based on this assumption, approximately 29% of the viewable walls, floors, and ceiling were wood in the wood treatment. This is only 4% for plants. If the ceiling and walls above 9 feet, where subjects were very unlikely to look, are taken out of this calculation, wood accounted for 36% of viewable surfaces and plants 6%; this is a practical assumption, because the suspended lights were at this level.

Table 34 Visual surface area of plants and wood

	Height (feet)	Width (feet)	Area ($feet^2$)	Distance (feet)	View
Large plant	4	3	12	8	Direct
Table plant	1	1	1	2	Direct
Side plant	2	1	2	6	Periphery
		Direct	13		
		Periphery	2		
	Plant total		15		
Desk	2.66	5.25	14.0	2	Direct
Blinds	6.16	10	61.6	10	Direct
Small table	3.83	2.58	9.9	8	Direct
Chair (front)	4	1.8	7.2	8	Direct
Chair (side	4	1.8	7.2	6	Periphery
Bookshelf (large)	6.66	2.66	17.7	9	Periphery
Bookshelf (small)	3.5	2.66	9.3	6	Periphery
Bookshelf (side)	6.66	0.915	6.1	6	Periphery
		Wood Direct	92.6		
		Wood Periphery	40.4		
	Wood Total		133.0		

5.5 *On stress*

Although stress was found to be lower in the wood room for all periods with respect to the frequency of non-specific skin responses, the skin conductance evidence is subtler. Evidence of lower stress was strongest in the baseline period where both skin conductance level and the frequency of non-specific skin responses showed a wood effect. In the test and recovery periods, the frequency of non-specific skin responses was lower for wood, but there were not statistically significant differences in skin conductance levels among treatments. In the recovery period, skin conductance level, though not statistically lower, began to trend lower in the wood room than the non-wood room.

It would appear that the stress-reducing effect was stronger during times when no external stress was imparted on the subjects. The stress during these periods was a combination of subjects' baseline stress levels and any anxiety they experienced in relation to being in a study. During the test period, when a stressor was applied, skin conductance levels were not statistically or observably different.

There are two possible contributing factors to this finding. First, skin conductance reactions to the PASAT test were strong and introduced a great degree of variability into the data. The amplitude of responses and the individual variability in responses make any differences in mean response statistically non-significant. Simply put, intense and focused stress is stressful no matter what the surroundings.

The second possible explanation for the lack of wood effect during the PASAT test is the tendency for subjects to close their eyes or focus on one thing while concentrating. This means that some subjects were not taking in their surroundings. This may account for a weaker wood treatment effect in the test period.

Based on the results of this study, wood has a greater stress reduction potential in the indoor environment when stress levels are low to moderate. This may be a more realistic comparison to the ongoing low to moderate stress faced by those in office environments.

5.6 *On limitations*

A. HRV data

While it has been discussed in the literature for close to three decades (e.g. Askerod, 1981), heart rate variability analysis is relatively new and experimental. There are over 20 different types of HRV statistics reported in the literature (Task Force, 1996). Beyond statistical methods, experimental methodologies and results vary widely. For example, body position plays a large role in HRV. HRV is greater in subjects in a supine position in comparison to a sitting position such as the one assumed in this study (Task Force, 1996).

There were no treatment or stressor effects found for HRV in this study. There are two possible explanations for this result: either there were no real differences, or differences were not detected by the chosen methodologies.

If there were no real differences in HRV, there are several possible interpretations of this result.

- There are no parasympathetic effects with respect to exposure to nature.
- The baseline stress level associated with this study was sufficiently high that it did not allow for parasympathetic dominance in any period of the study.
- The time spent habituating to the environment was not enough to engage the parasympathetic system.
- Due to the sitting position of subjects, HRV was not present.

If there were HRV effects that were not detected due to the methodology of this study, there are a few possible reasons.

- Due to the sitting position of subjects, HRV was not detectable.
- The 2.5-minute epochs were not sufficient to capture HRV. A 5-minute epoch is suggested by the Task Force on Heart Rate Variability (1996), but 2.5 minutes is well within the minimums set out in the document.

There was also a quality issue with respect to the some of the ECG records from which HRV was calculated. As discussed in the methodology section, data was collected from electrodes on the wrists instead of the conventional torso placements. It was known ahead of time that this may impart more noise into the ECG signal. However, this was a calculated risk as it was believed that a torso placement of electrodes would be intrusive and would elevate stress levels prior to testing.

The spectral analysis of HRV was very sensitive to noise in this study. Tachograms were analyzed to identify noise and the records were cleaned. However, only 92 of 119 subject ECG records were used in the final analysis of HRV. These records were either clean or required minor cleanup or amplification of the R-spike. However, even using these very clean ECG records, there were no HRV differences found.

B. Stress

The PASAT was chosen as a source of stress for this study. This was an acute source of stress that produced moderate to strong stress results. It is questionable how well this characterizes the stress regularly faced in office environments. It is more likely that chronic stress at a low level plagues the occupants of indoor environments. The type of acute stress presented by the PASAT is not likely a common stress. The level of stress and the aural nature of the PASAT caused subjects to stop looking at their surroundings which was, unfortunately, counter to the goals of the study.

This study cannot make claims as to effect with respect to chronic stress. Wilken *et al.* (1999) prescreened subjects to identify those suffering chronic stress. This step could improve the study methodology in the future. However, results from baseline period do reflect the incoming stress of subjects plus any study anxiety or apprehension stress they have. It is perhaps the baseline period results that are most applicable to day-to-day stress responses.

C. Plant effect

No plant effect was found in this study. However, the limited plant surface area as discussed in section 5.4 precludes any conclusions on the effect of plants on stress.

D. Interpreting the wood effect

In this study, wood finished office furniture and blinds were compared to a control of white office furniture and blinds. One question that arose is whether we are witnessing a positive effect for the wood surfaces or a negative effect for "man-made" or artificial surfaces. Both sets of furniture had identical particleboard and medium density fibreboard cores. However, the "wood" furniture was veneered with a real birch surface, while the "non-wood" furniture had a white melamine foil laminate on it. There are two levels of concern related to the use of a white melamine foil surface. First, with recent food safely scares related to Chinese baby formula, melamine may have negative connotations. The second level of concern is that there may be a negative reaction to a non-natural surface.

In considering the issue of negative connotations of melamine, we must consider its prevalence in the market and the lack of reference to it as melamine in the consumer vocabulary. Melamine is a very common form of laminate currently used in furniture and countertops. It is rarely referred to as melamine, but most often by its various trade names. Given its ubiquitous nature in the marketplace, it is, therefore, unlikely that subjects in this study would have made the association between laminates and melamine, nor were they likely to have taken issue with the it.

The second level of concern over the exposure to a man-made versus natural surface is well grounded. We may have witnessed a lessening of sympathetic activation with exposure to wood in the room. Alternatively, we may have witnessed an increase in sympathetic activation when subjects were exposed to man-made materials. Based on our study design, we cannot definitively comment on the origin of our observations. However, from a practical standpoint this may be irrelevant. This is because with respect to office furniture the *de facto* standard is laminates for their cost and durability. Whether the laminates increased stress or wood lowered stress, we have established a relationship. In this study, we chose to state the relationship as a stress effect for wood. It could just as correctly be stated as a stress increasing effect for man-made laminate surfaces. However, as these man-made surfaces are the norm the move to wood surfaces would effectively reduce stress activation.

E. Attention measure

The PASAT is not a conventional measure of attention for environmental psychology. Weins *et al.* (1997) reports that mathematical ability is a confounding factor in PASAT results. This was observed based on the comments of subjects during the debriefing. In fact, science and engineering students outperformed other students on the test. Therefore, there is no degree of certainty that differences in PASAT scores could be attributed to treatments were they observed.

The PASAT test is commonly used to monitor cognitive function in multiple sclerosis patients. As a repeated measure on the same patient, the mathematical abilities issue is not a factor as patients are compared to their own baseline. For environmental psychology studies not involving repeated measures on the same subject, the PASAT attention test may not be appropriate. However, the PASAT was employed in this study primarily as a source of stress, for which it proved to be effective.

F. Confounds

A number of confounds that could be measured are discussed in 4.3.1. None of these possible confounds were found to have influenced results. However, there are other confounding factors that cannot be measured but must be acknowledged.

First, this was a single-blind experiment. Information about the goals of the research was withheld from subjects as to not influence the results. However, the experimenter, who was in contact with subjects, was aware of the goals of the study. While these goals were not relayed from the experimenter explicitly during testing there is the possibility of unintentional non-verbal cues of the experimenter influencing subjects.

Second, there was visible outside light that entered the room from between the blinds. Blinds were always in the fully closed position during testing. However, some outside light entered the room by reflecting between the blinds. As noted in Masuda (1992), wood absorbs ultraviolet light. This difference in ultraviolet light in the room was not controlled for by measurement.

Third, as all non-wood rooms were run first in this study, there is the potential for a history confound. The potential for this effect was reduced in the study design by scheduling the data collection early in the term before the stress of mid-term exams. Further, data was collected over just three-and-one-half weeks, reducing the potential for history effects. During the three week period there were no noted large historical events outside the university that would have affected the general disposition of the study population. Indeed, when the physiological measures were compared according to the week of study, there no serial or history effects found (see section 4.3.1).

One final possible confound is that the wood / non-wood effect could be a response to colour. Colour was not formally controlled in this study except to use white furniture as the non-wood treatment. However, the wood furniture used in this study was very light in colour and there was concern that it may be too subtle a manipulation. Although both sets of furniture were light in colour all wood inherently is slightly red and yellow in the L*a*b* colour space (Fell, 2004). As one of the goals in the execution of this research was to make the offices believable, commonly available white furniture was used. Future research into colour and reactions to artificial wood surfaces is needed to address this confound.

5.7 *On evidence-based design*

The field of evidence-based design is traditionally focused on healthcare facility design. This field was born of Ulrich's 1984 study on the effect of room views on patient outcomes. The main goal of evidence-based design is to provide outcome-based evidence to support the design of health facilities (Zimmerman, 2009). Today, evidence-based design is broadly discussed and accepted in healthcare for providing better outcomes for both patients and staff.

However, the key term is "evidence". In order to pursue evidence-based design, a body of evidence needs to exist and expand with increased knowledge. Ulrich (2008) notes that it is important that additional research be pursued to demonstrate that nature in hospitals is "medically beneficial and cost effective…

so that administrators are equipped to make well-informed decisions benefiting the patients, staff, and budgets." (p. 96).

Ulrich (2008) also notes that healthcare construction in the US in 2006 was $40 billion. It was $4.5 billion in Canada in the same year and grew to $5.5 billion in 2008 (Statistics Canada, 2010). Hospital construction and renovation is a large and high-priority market for biophilic design.

The evidence-based design tools used to add nature to hospitals are traditionally windows, natural light, water, and plants. Based on this study, wood may be considered as another tool to include nature in the design of healthcare facilities. It is easy to boost wood content; wood does not need watering or exposure to sunlight like plants. It does not require access to exterior walls in the way that windows do. Unlike water and plants, wood can also take a practical or utilitarian function in the structure of a building. Results from this study may support more wood application in hospitals or at least spur research into wood use in hospitals.

But what is happening outside of healthcare facility design? Of the 88% of our lives spent indoors, very little is spent by the average Canadian in healthcare facilities. Of our waking non-home time, we spend the most time in schools and offices. These environments also tend to be associated with stress. However, the concept of evidence-based design is relatively new to construction outside of healthcare (Zimmerman, 2009).

The call for more nature in buildings is a philosophical departure for the design field.   The focus of design in the 20th century was on man conquering nature and the elements (Salingaros and Masden, 2008). Architects aspired to increase the degree of separation a building provided from the world around it (Salingaros and Masden, 2008). This created buildings devoid of nature and connection to their surroundings. Although wood continued to be used as a building material in the

20th century, its use decreased significantly in non-residential buildings (O'Connor et al., 2004).

With better understanding of the connection between man and nature, designers are bringing nature back into offices and schools. While Salingaros and Masden (2008) acknowledge that plants help workers connect with nature in their office environments, they point out that this is only a partial solution. They argue that plants brought into a building of artificial materials allow humans to connect with the plant but not the building itself. The sharp contrast between building and nature "still triggers an underlying neurological disconnect on a basic level." (Salingaros and Masden, 2008 p. 64).

At the very least, wood may provide the same types of exposure to nature as plants in the built environment. Wood furniture, dividers, and flooring are examples of the superficial application of wood analogous to bringing plants into a room. This is the type of treatment applied in this study. However, wood has the additional potential to be integrated into a building structurally or visually. This integration of a biophilic material into a building allows users to connect with the structure and not just the material, creating true biophilic design (Salingaros and Masden, 2008).

5.8 *On future work*

This research has established initial evidence of a biophilic link between humans and wood on a psychophysiological level. There are several areas that would build upon this knowledge and lead to more evidence-based wood application in buildings.

One direction for future research would be to look for a wood effect without context. In this study, we showed a wood effect in the context of an office setting. Research with no context could provide a generalized understanding of wood effects on stress. Sakuragawa *et al.* (2005) exposed subjects to walls of wood or painted steel for short durations. They found that blood pressure decreased or stayed the same when exposed to wood. Blood pressure increased or stayed the same when exposed to painted steel. As blood pressure is moderated by both the sympathetic and parasympathetic nervous systems, it would be interesting repeat this study with skin conductivity and heart rate variability to observe these two systems separately. Further, the study by Sakuragawa *et al.* (2005) could be improved with a larger sample size and control of serial effects.

The second direction to expand upon this research would be to add different contexts to the knowledge base. A wood effect has been established for offices. Hospitals provide perhaps the highest priority environment to test for a wood effect on stress. Health and recovery are of utmost priority in hospitals. This is why the field of evidence-based designed originated and grew in healthcare. Schools are another environment where a contextual understanding of the wood effect is desirable. For schools, not only psychophysiological stress, but also the ability to focus attention and reduce aggression, are of interest.

It is of interest to identify the effect of combinations of wood and other biophilic materials. It was the intention of this study to explore the effect of the combination of wood and plants. Unfortunately, the plant treatment in this study was not large enough to provide a stress reduction effect. Therefore, the nature of wood and plant combinations could not be explored. A repeat of this study with a stronger plant treatment is suggested. Further, an exploration of the effects of wood and other natural or biophilic materials such as stone, water, and glass would be of interest to the design community that has all of these materials at their disposal.

After identifying what materials provide biophilic effects and understanding their interactions, the next step would be to refine the exposure levels and combinations of materials. For example, what percentage of wood, plants, or windows is ideal? What proportion of plants to wood area is ideal? This will further refine the use of these materials in evidence-based design.

Salingaros and Masden (2008) distinguish between the superficial application of biophilic materials to buildings and the incorporation of biophilic materials into a building based on their unique properties. In this study, we did the former with wood furniture in a painted concrete office. It would be interesting to study the effect of wood in a building when it is performing both a structural and visual function. An example of this would be exposed glulam beams in a structure. If Salingaros and Masden's (2008) hypothesis shows a further stress reduction effect for wood incorporated into a structure this information could provide momentum for the construction of more wood non-residential buildings.

It is of interest to research the applicability of these results to simulated wood and wood-coloured surfaces. Real wood surfaces were used in this study. However, we cannot comment on the applicability of the results to simulated wood surfaces. Masuda (2004) argues that wood is a preferable material for interior design as it reflects long wavelength light and absorbs short wavelengths. This is to say it reflects red and yellow and absorbs ultraviolet light. Masuda (2004) claims the red and yellow hue give the "warm" impression associated with wood. Further, the effect of absorbing ultraviolet could reduce fatigue in interior environments. This begs the question of whether a surface with the proper hue and ultraviolet absorbing properties can achieve the same stress-reducing effects found in the current study. A study of real wood, simulated wood, and painted surfaces of similar hues and ultraviolet absorption could address this question.

There are also areas outside of materials that warrant further consideration and research. In retrospect, the stressor used in this study is believed to have been too stressful to represent the type of stress encountered daily in an office. Future studies of this type should carefully consider the stressor used so that it is appropriate to the context. Perhaps no additional stressor is needed. If one were to prescreen for high and low stress individuals as in Wilken *et al.* (1999), the effect of environments on baseline stress levels could be fine-tuned. This is perhaps a more practical approach than the introduction of a novel stressor.

Testing without an introduced stressor could take the form of short duration or longer duration measurements. With short duration measures, the immediate effects on the sympathetic nervous system could be observed. Longer duration recordings over several hours or repeated measures over days or weeks may be more likely to show parasympathetic activity as subjects become acclimatized to being in an environment and being part of a study.

Future analysis of the existing dataset is also possible. This may include an analysis of recovery rates and a closer look at suggestive but not statistically significant results. This analysis will help in the design of future studies.

6 Conclusion

This aim of this study was to test for a stress-reducing effect of wood in the built environment. This question arises from the evolving field of environmental psychology and the more general field of biophilic design.

Environmental psychology considers the effect of environments on people, the effect of people on their environments, and the choice or preferences for environments. The field began with the examination of built environments and the effect of crowding in jails (Ittelson, 1960). However, the focus shifted almost entirely to the effects of natural outdoor environments when Kaplan *et al.* (1972) found a strong preference for nature in choice of environments. Balling and Falk (1982) discuss the origin of this preference for nature as innate and providing evolutionary advantage.

Ulrich (1984) altered the focus of environmental psychology from preference to effect when he found that hospital patients with a view to nature recovered faster than patients with a view to another building. This led to two parallel theories on the effect of nature on humans. Kaplan and Kaplan (1989) focused on stress effects on attention and the restorative effects of nature. Ulrich (1991) took a psychophysiological approach where nature reduces physiological indicators of stress. Throughout, the focus remained on comparing natural outdoor environments to outdoor urban environments (e.g., Stamp, 1996; Herzog *et al.*, 1997; Parsons *et al.*, 1998).

However, Canadians spend only 6% of their time outdoors (Leech, 1997). This leaves very little time for restoration from nature. Lohr *et al.* (1996) brought nature indoors by studying the effects of plants on stress and task performance in the built environment. Plants are now an established means of bringing the benefits of nature indoors (Lohr and Pearson-Mimms, 2001; Shibata and Suzuki, 2002). Plants are also a common element of evidence-based design. Evidence-based design is a movement in healthcare building design that puts an emphasis on scientifically defendable design for optimal outcomes for patients, staff, and other stakeholders (Zimmerman, 2009). Evidence-based design can also be applied to other types of buildings and users.

Recently, the term biophilic design has been used to describe design that acknowledges the human affinity for nature and natural systems (Kellert, 2008). With respect to biophilic design, plants are termed a biophilic material. In questioning the stress-reducing effects of wood in the built environment, we are looking to qualify it as a biophilic material or as a tool in the practice in evidence-based design.

In this study, we tested the stress effects of wood within the context of an office setting. Wood and non-wood offices were presented with and without plants to test for similarities and interactions with the already established plant effect. As stress responses are a function of the autonomic nervous system, we sought measures of the two branches of this system. Skin conductivity and inter beat interval were continually monitored during testing. Skin conductivity provided several measures of sympathetic nervous system activity. Inter beat interval was used to calculate heart rate variability, an indicator of parasympathetic nervous system activation.

A stress-reducing effect for wood was found in this study with respect to the sympathetic nervous system when compared to non-wood environments. Skin conductance level and the frequency of non-specific skin conductance responses indicate that subjects in the wood room were less stressed than subjects in the non-wood room. A similar plant effect was not found in this study, possibly due to a weak plant treatment. Further, there were no differences found with respect to parasympathetic nervous system activity for any treatment.

The results of this study provide evidence of stress reduction by the application of wood for practitioners of evidence-based design. Wood may also be classified as a biophilic material in discussions of biophilic design. From an extension perspective, this information must get into the hands of practitioners and policy-makers, and efforts will be made to disseminate these findings as widely as possible. This topic has a very interesting narrative that will likely be well received in the current climate of sustainable design.

Avenues for future research were outlined above. The key message is that this research gives initial evidence of wood as a stress-reducing or biophilic material. However, to affect change with respect to the design and marketing of wood, further research is required to fill in the details of this observed phenomenon.

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Appendix 1 Recruitment

Dr. Robert Kozak, *Principal Investigator*
The University of British Columbia
#4040 - 2424 Main Mall
Vancouver, British Columbia Canada V6T 1Z4

Co-Investigator:
David Fell, Ph.D Candidate

Call for Research Subjects:
Task Performance in Office Environments

Time requirement: 1 Hour
Honorarium: $25

We are currently seeking subjects for a research study of task performance in office environments. The goal of the study is to gain insight into healthy and productive built environments.

Total time commitment to participate in this study is one hour, 12-20 minutes of which you will be performing a mental task.

Eligibility
- Full time UBC undergraduate students
- Ages 18 – 30
- English fluency required

Disqualifying conditions
- Hypertension
- Heart conditions
- Prescription and non-prescription mood altering drugs
- Smoker
- Hearing impairment
- Sight impairment

Potential Risks: The physiological and psychological risks of this study are low as they do not exceed those risks associated with daily office work or studying conditions.
Confidentiality: Your identity will be kept strictly confidential in the study dataset and in any resulting publications.

To find out more or to register for this study please contact David Fell by email or telephone.

David Fell
TELEPHONE
EMAIL

Time requirement: 1 Hour
Honorarium: $25

Appendix 2 BREB ethics certificate

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL - FULL BOARD

PRINCIPAL INVESTIGATOR:	INSTITUTION / DEPARTMENT:	UBC BREB NUMBER:
Robert Kozak	UBC/Forestry/Wood Science	H07-02605

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
This study will take place in two generic offices on the UBC Point Grey Campus. We are currently in negotiations with building managers to find space.

CO-INVESTIGATOR(S):
Michael Meitner
David H. Cohen

SPONSORING AGENCIES:
International Environmental Institute - "Wood in the Human Environment"

PROJECT TITLE:
WOOD IN THE HUMAN ENVIRONMENT

REB MEETING DATE:	CERTIFICATE EXPIRY DATE:
December 13, 2007	**December 13, 2008**

DOCUMENTS INCLUDED IN THIS APPROVAL:

DATE APPROVED:
January 9, 2008

Document Name	Version	Date
Protocol:		
Wood In the Human Environment Proposal	N/A	November 27, 2007
Consent Forms:		
Wood in the Human Environment Data Consent	N/A	January 2, 2008
Wood in the Human Environment Consent	N/A	November 27, 2007
Advertisements:		
Wood in the Human Environment Ad	N/A	November 27, 2007
Other Documents:		
Wood in the Human Environment Deception	N/A	November 27, 2007

The application for ethical review and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board
and signed electronically by one of the following:

Dr. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Daniel Salhani, Associate Chair
Dr. Anita Ho, Associate Chair

Appendix 3 Study consent form

Dr. Robert Kozak
The University of British Columbia
#4040 - 2424 Main Mall
Vancouver, British Columbia Canada V6T 1Z4

Consent Form
Task Performance in Office Environments

Principal Investigator:
Dr. Robert Kozak, University of British Columbia

Co-Investigator(s):
David Fell, Ph.D Candidate
Dr. David Cohen, University of British Columbia
Dr. Michael Meitner, University of British Columbia
Dr. Russ Parsons, Northwest Environmental Psychology

This research is being performed as part of the requirements for a Ph.D dissertation. The resulting dissertation and related publications will be public documents.

Sponsor:
International Environmental Institute

Purpose:
This study looks at task performance in office environments.

Study Procedures:
In this study you will be asked to perform a 12-20 minute mental task. Your heart rate and skin conductivity will be monitored by two sets of electrodes on your skin. One set will be on the fingers of your non-dominant hand. The other set will be on your wrists.

There are several possible offices you could be assigned to. Assignment will be random and you will only see one office.

Potential Risks:
The physiological and psychological risks of this study are low as they do not exceed those risks associated with daily office work or studying conditions.

Potential Benefits:
By better understanding task performance and physiological responses to office environments healthier built environments can be designed and built. This research could be applied to residential, office, school, and hospital design.

Confidentiality:
Your identity will be kept strictly confidential in the study dataset and in any resulting publications. Any information that identifies you will be kept separate from the dataset and will only be available to the investigators identified in this document. Your personal information will be kept for the duration of the study in case follow-up contact is needed with you. Personal information will be destroyed/erased at the completion of the project.

Remuneration/Compensation:
In order to defray the costs of *inconvenience/transportation/loss of wages* each participant *will receive an honorarium* in the amount of $25.

Contact for information about the study:
If you have any questions or desire further information with respect to this study, you may contact Dr. Robert Kozak or one of his associates.

Contact for concerns about the rights of research subjects:
If you have any concerns about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at 604-822-8598 or if long distance e-mail to RSIL@ors.ubc.ca.

Consent:
Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without jeopardy to your honorarium.

Your signature below indicates that you have received a copy of this consent form for your own records.

Your signature indicates that you consent to participate in this study.

____
Subject Signature Date

____
Printed Name of the Subject

Appendix 4 Data consent form

Dr. Robert Kozak
College of Forestry
Department of Wood Science
The University of British Columbia
#4040 - 2424 Main Mall
Vancouver, British Columbia Canada V6T 1Z4
Phone: (604) 822-2402

Data Consent Form
Task Performance in Office Environments

Prior to your participation certain aspects of this study were not disclosed as they have the potential to influence the outcomes. These disclosures are made below.

1) Study Comparisons
In this study we compare task performance and physiological indicators of stress in different environments. We are interested in the effect of natural materials on the occupants of built environments such as offices. The study involves two comparisons. The first compared offices with plants to offices with no plants. The second compared offices with wood finishings to offices with conventional man-made finishings. You will have been exposed to only one combination of these two comparisons.

2) College and Department of Investigators
The principal investigator in this study resides in the College of Forestry, Department of Wood Science. This was not disclosed prior to your participation as this knowledge may have indicated that "wood" comparisons were being made. Three of the four co-investigators also reside in the College of Forestry, with the fourth being the principal in an environmental psychology consultancy. Names and affiliations appear on page 2 of this document.

Post Study Consent:
After reviewing these disclosures we ask for consent to use your data in this study. You may withdraw your results from this study by withholding your signature below. This will not effect the payment of your honorarium.

Your signature below indicates that you have received a copy of this data consent form for your own records.

Your signature indicates that you consent to your data being used in this study.

____
Subject Signature   Date

____
Printed Name of the Subject

Appendix 5 Survey

				#			Gender			Age		
	A			**B**			**C**			**D**		
Order	**#**	=	✓	**#**	=	✓	**#**	=	✓	**#**	=	✓
1	**9**			**2**			**4**			**3**		
2	**1**	*10*	☐	**4**	6	☐	**8**	12	☐	**2**	5	☐
3	**4**	*5*	☐	**5**	9	☐	**6**	14	☐	**6**	8	☐
4	**2**	*6*	☐	**4**	9	☐	**2**	8	☐	**5**	11	☐
5	**8**	*10*	☐	**3**	7	☐	**2**	4	☐	**4**	9	☐
6	**6**	*14*	☐	**1**	4	☐	**9**	11	☐	**3**	7	☐
7	**5**	*11*	☐	**8**	9	☐	**3**	12	☐	**1**	4	☐
8	**3**	*8*	☐	**6**	14	☐	**4**	7	☐	**6**	7	☐
9	**4**	*7*	☐	**9**	15	☐	**5**	9	☐	**5**	11	☐
10	**9**	*13*	☐	**2**	11	☐	**8**	13	☐	**9**	14	☐
11	**1**	*10*	☐	**9**	11	☐	**1**	9	☐	**8**	17	☐
12	**3**	*4*	☐	**8**	17	☐	**6**	7	☐	**4**	12	☐
13	**6**	*9*	☐	**6**	14	☐	**3**	9	☐	**2**	6	☐
14	**8**	*14*	☐	**1**	7	☐	**8**	11	☐	**1**	3	☐
15	**2**	*10*	☐	**3**	4	☐	**6**	14	☐	**2**	3	☐
16	**5**	*7*	☐	**4**	7	☐	**2**	8	☐	**4**	6	☐
17	**1**	*6*	☐	**5**	9	☐	**4**	6	☐	**9**	13	☐
18	**8**	*9*	☐	**2**	7	☐	**1**	5	☐	**3**	12	☐
19	**6**	*14*	☐	**1**	3	☐	**9**	10	☐	**6**	9	☐
20	**9**	*15*	☐	**9**	10	☐	**5**	14	☐	**8**	14	☐
21	**2**	*11*	☐	**4**	13	☐	**1**	6	☐	**5**	13	☐
22	**4**	*6*	☐	**5**	9	☐	**9**	10	☐	**4**	9	☐
23	**3**	*7*	☐	**6**	11	☐	**8**	17	☐	**3**	7	☐
24	**5**	*8*	☐	**2**	8	☐	**2**	10	☐	**8**	11	☐
25	**6**	*11*	☐	**3**	5	☐	**5**	7	☐	**2**	10	☐
26	**5**	*11*	☐	**8**	11	☐	**4**	9	☐	**5**	7	☐
27	**8**	*13*	☐	**4**	12	☐	**6**	10	☐	**1**	6	☐
28	**9**	*17*	☐	**2**	6	☐	**3**	9	☐	**6**	7	☐
29	**4**	*13*	☐	**1**	3	☐	**6**	9	☐	**9**	15	☐
30	**3**	*7*	☐	**9**	10	☐	**3**	9	☐	**4**	13	☐
31	**1**	*4*	☐	**8**	17	☐	**2**	5	☐	**8**	12	☐
32	**2**	*3*	☐	**3**	11	☐	**9**	11	☐	**5**	13	☐
33	**6**	*8*	☐	**5**	8	☐	**1**	10	☐	**9**	14	☐
34	**3**	*9*	☐	**6**	11	☐	**8**	9	☐	**2**	11	☐
35	**4**	*7*	☐	**9**	15	☐	**5**	13	☐	**6**	8	☐
36	**8**	*12*	☐	**8**	17	☐	**4**	9	☐	**1**	7	☐
37	**9**	*17*	☐	**4**	12	☐	**9**	13	☐	**3**	4	☐
38	**5**	*14*	☐	**3**	7	☐	**6**	15	☐	**4**	7	☐
39	**1**	*6*	☐	**2**	5	☐	**2**	8	☐	**2**	6	☐
40	**2**	*3*	☐	**5**	7	☐	**4**	6	☐	**3**	5	☐
41	**8**	*10*	☐	**1**	6	☐	**3**	7	☐	**9**	12	☐
42	**1**	*9*	☐	**6**	7	☐	**5**	8	☐	**5**	14	☐
43	**2**	*3*	☐	**1**	7	☐	**8**	13	☐	**6**	11	☐
44	**5**	*7*	☐	**8**	9	☐	**1**	9	☐	**8**	14	☐
45	**3**	*8*	☐	**5**	13	☐	**5**	6	☐	**1**	9	☐
46	**9**	*12*	☐	**6**	11	☐	**6**	11	☐	**6**	7	☐
47	**6**	*15*	☐	**3**	9	☐	**9**	15	☐	**4**	10	☐
48	**4**	*10*	☐	**2**	5	☐	**8**	17	☐	**9**	13	☐
49	**3**	*7*	☐	**9**	11	☐	**3**	11	☐	**2**	11	☐
50	**6**	*9*	☐	**4**	13	☐	**1**	4	☐	**3**	5	☐
		A			**B**			**C**			**D**	

Please rate how well the following attributes describe this room? Ratings are from 1 – does not describe at all, to 5 – describes very well.

	1 not at all 5 very well
Clean	①②③④⑤
Restful	①②③④⑤
Warm	①②③④⑤
Artificial	①②③④⑤
Modern	①②③④⑤
Natural	①②③④⑤
Productive	①②③④⑤
Healthy	①②③④⑤
Sustainable	①②③④⑤

Age ______
Gender ______
Faculty ______

Subject ______