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CRITERIA CONSIDERED FOR THE DETERMINATION OF HEALTH IN A RESIDENTIAL INTERIOR ENVIRONMENT

By

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ABSTRACT

CRITERIA CONSIDERED FOR THE DETERMINATION OF HEALTH IN A RESIDENTIAL INTERIOR ENVIRONMENT

By

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The focus of this study will be the evaluation of health of a residential interior environment related to five human perceptions: sound, touch, sight, taste, and smell. A survey was formulated and administered to twenty-four residential homes in the Southwest Michigan area to examine the relationships between these perceptions and the health of an interior residential environment.

Eight treatments were investigated along two factors: size and age of homes. The null hypothesis (*Ho*) resulted to be true, the observations collected and ranked according to the Friedman test will have no significant numerical differences as ranked from smallest to largest. If *Ho* is rejected, then at least one treatment is different than the others, where $p \leq 0.01$ (Daniel, 1978).

After the results of the survey were obtained and measured, analytical comparison determined the healthiest age of a home built over the last century was between the years of 1965 to 1985, and the healthiest size for a home was larger than 2,000 square feet determined $p \leq 0.01$. It was also established that the worst or unhealthiest home was between the ages of 1901 to 1930, and 1940 to 1965, both with the unhealthiest size as being less than 1200 square feet. The *Ho* was rejected with α 0.01 at 7 degrees of freedom.

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TABLE OF CONTENTS

LIST OF TABLES....vii
LIST OF FIGURES....viii

CHAPTER 1
INTRODUCTION....1
Organization of Thesis....4

CHAPTER 2
LITERATURE REVIEW....6
Assets to Healthy Environments....6
Sound....12
Physical Effects....15
Environmental Effects....17
Touch....20
Temperature and Humidity....20
Sight....22
Natural Environmental Influence....22
Natural Light....25
Illumination....30
Taste....32
Smell....34
Indoor Air Quality....34
Asthma....37
Multiple Chemical Sensitivity....38
Sick Building Syndrome....39
Toxins Related to Human Activity....40
Mold....42
Chemicals and Gases....44
Problem Statement....49
Study Purpose....51

CHAPTER 3
DATA COLLECTION AND ANALYSIS METHODOLOGY....52
Data Source and Experimental Design....52
Sense Classification and Data Organization....53
Analysis Methods....56
Chapter Summery....61

CHAPTER 4
RESULTS 62
Equipment Used...66
Accuracy Assessment with Ties...68

CHAPTER 5
CONCLUSION AND DISCUSSION...72
Conclusion...77
Limitations..79
Additional Research...82

REFERENCES CITED...87

APPENDIX A
A1. Five Sense Health Evaluations for Residential Spaces.....................101
A2. URCIHS...105

LIST OF TABLES

Table 1. Identification of Sound Levels..13

Table 2. Treatment Sound Data Ranked...62

Table 3. Treatment Touch Data Ranked...63

Table 4. Treatment Sight Data Ranked..64

Table 5. Treatment Smell Data Ranked..65

Table 6. Treatment Totals Ranked with Squared Totals.................................67

Table 7. Data Collection from Equations...68

Table 8. Treatment Data Ranked...69

Table 9. Treatment Ranked Totals...71

LIST OF FIGURES

FIGURE 1. Illustration of Friedman's Two-Way Analysis.................................58

CHAPTER 1

INTRODUCTION

"Architecture and urban design (space) may not determine human behavior, but bad design can numb the human spirit, and good design can have powerful, positive influences on human beings" (as cited from LeGates, 2003: 90).

Interior environments orchestrated by the knowledge, sensitivity, and expertise of a designer can affect a person's thoughts, feelings, and interactions within the function of the space (Pilatowicz, 1995). One of the most important goals of an interior designer in designing healing and restorative environments is to realize environmentally sustainable construction processes with the materials involved. This information can help to preserve and promote natural environments, as well as human health, within the interior space (McDonough & Braumgart, 2003). Such environments can help fulfill healthier physical, mental, spiritual, and emotional needs for every individuals from a variety of backgrounds and cultures (Schweitzer *et al.*, 2004).

As humans interact within their environment, evaluation of this interaction can be summarized by their senses of seeing, hearing, touch, smell, and taste (Guzowski, 2000). A person's senses can help define, and communicate, with that person's world. It can also assist in interpreting the influx of sensory information received. The health of a residential interior environment is relational to this interpretation, as well as to individual needs. When planning a residential environment, emphasis needs to be placed on all aspects of the occupant's life. A twentieth century planner, Patrick Geddes, mentioned that "healthy life is completeness of relation of organism, function and environment, and all at their best" (Bartuska & Young, 1994: 40).

In 1992, Bronson Hospital in Kalamazoo, Michigan, became a participant of the Pebble Project. Responding to evidence-based research, Bronson decided to invest funds into promoting healthy interior environments that made use of nature, art, music and light. Hospital administrators determined that such an environment reduced patient stay and decreased hospital based infections (nosocominal) by 11%, resulting in lowered hospital costs (Health Design, 2004).

In 1993, the United States Green Building Council (USGBC) formed a building rating system, Leadership in Energy and Environmental Design (LEED), to support and promote education about health and more cost effective building practices. In 1993, concerned individuals organized an international movement to define "sustainable construction" with an emphasis on ecologically sound practices for the construction environment (Kibert *et al.*, 2002).

Statistics from 2002 indicated that while the construction industry represented about 8% of the country's gross domestic product, it will utilized over 40% of materials for building and infrastructure construction (Levin, 1997). The total operational construction process can consume over 30% of natural energy (Kilber *et al.*, 2002; Bonda, 2003), produce 40% of atmospheric emissions, and instigate 25% of solid waste and water usage (Levin, 1997).

With the LEED rating system in place, more precise criteria have been expanded upon for development and use during the construction process. The goal is to encourage "reduce, recycle and reuse" of construction materials and to help eliminate wasted energy consumption. With such building materials as concrete, steel, wood and plastics (Gissen, 2002), LEED emphasized the removal of non-environmentally safe materials during the manufacturing process and construction installation (Kilber *et al.*, 2002). LEED also continued to emphasize sustainability with building design, construction and operation. Operational concerns, where related to the capability of energy conservation and cost, promotes higher efficiency in air quality, construction sites, water, and material resources (Bernheim, 2005).

The health of an interior environment may not only be impacted by the health of the exterior environment, but also can be affected by energy utilization as observed by the mechanical systems that supply light, air temperature control and other building functions that consume energy (Gissen, 2002). It has become evident that residential interior environments need to be more consciously evaluated as to the future influence construction and finish materials may have upon occupants' health in the future.

Organization of Thesis

This thesis has five chapters following the Abstract, Acknowledgements and Table of Contents. The information below provides a synopsis of each chapter.

Chapter 1, Introduction, reviews the history and value of sustainable environments. This information acknowledges the documented history sustainable construction and environments can have on individual health.

Chapter 2, Literature Review, examines previously documented information regarding the health in interior environments as it relates to the health of an individual. This documentation will include physical environmental elements as well as human emotional, social, and physical influences. In additions to a discussion of evidence consistent with residential environment, this chapter will also cover interior environments as they relate to health care facilities and office communities.

Chapter 3, Methodology, mentions the process of the statistical data collection used and the results of the data collected. Methods used to examine and compare the data are described. Accuracy assessment and viable criteria for the scientific data collected will be determined, using the Friedman's non-parametric two-way equation.

Chapter 4, Results, mentions equipment used, data presentation, the accuracy and determination for use. From the data collected, results were evaluated from eight ranked treatment groups determining the major findings.

Chapter 5, Conclusions and Discussion, mentions statistical reflection resulting from this research. Limitations discuss alterations to consider for continued research. Additional research manifests future considerations for a more accurate evaluation of healthy interior environments.

CHAPTER 2

LITERATURE REVIEW

"To think of the future is to break ahead from the past" (LeGates *et al.*, 2003, p. 170). This study emphasizes the need to look toward continual improvement for the future with consideration for a healthier environment. Sustainable environments can not happen without taking into account the interaction of human beings within the environment. The previous chapter introduced the purpose of sustainable construction, design, and the need for implementation into residential interiors. This chapter will introduce the influences interior environments have on human health as it relates to the five senses.

Assets to Healthy Environments

Design can have a large influence upon the quality of the environment by the uniqueness it gives to the space. This quality can also determine the effectiveness and appropriateness of achieving human health within the functional environment. Human fitness is defined by the optimal condition for individuals to adapt and integrate into their environments. Being fit means being able to adapt with balance to an environment which meet both the needs of the environment and those of the individual (Bartuska & Young, 1994). Evidence based data gathered in a recent survey by Commission for Architecture and the Built Environment (2004) specified an individual's perception of the healthiness of the space is critical to achieve a balance between the individual's physical health and holistic attitude (Sherman *et al.*, 2004).

The concept to define the meaning of health or wellness can be difficult. One author, Opatz (1986), has used a perspective to include a personal satisfaction involving six aspects of an individual's life with relation to significance: physical, spiritual, emotional, intellectual, social, and occupational (as cited by Savolaine & Granello, 2002). Other authors would define a healthy person as one having specific psychological, physical, and social images that can encourage that person to strive toward life's purpose and value (Hettler, 1986; Sweeney & Witmer, 1991; Zimpfer, 1992). Another study indicated that healthier life-style activities can encourage "health-enhancing" behaviors, which can lead to increased preservation of people's lives and goals (Savolaine & Granello, 2002).

Maslow's Hierarchy of Needs (1954) is a behavioral model that involves the study of human motivation, specifying different levels of needs an individual can progress through as life changes. Maslow identified behaviors based upon two opposite human needs: deficiency and growth (Huitt, 2004). Maslow specified that the deficient need had to be met before proceeding to the next growth level. At different times throughout a person's life, needs may change as the person adjusts and becomes a more self-fulfilled individual (Huitt, 2004; Bartuska & Young, 1994).

The significance of Maslow's behavioral model is evident with the realization each level has for growth and development in human life. Recognizing a person's needs and the level of those needs can help the designer plan better for a healthier environment. The first two need levels relate to physical needs; food, shelter, safety, and security. Acceptance and belonging, as observed in peer relationships, is the third (Huitt, 2004; Bartuska & Young, 1994). It has been observed that the emotional and social needs, found within the feelings of safety and belonging to a family system are basic to an individual's health. This family influence can encourage an individual's sense of health and belonging, encouraging self-confidence, which is the fourth need. Realizing self-actualization, a sense of fitting into society is the fifth (Guzowski, 2002). Self transcendence is the final stage of growth, when an individual wants to help others develop and reach their own potential. This is evident in behaviors of healthier individuals (Mack, 1994; Savolaine & Granello, 2002).

Studies have indicated that significant and emotional places create meaning in individual lives, for an individual "Home" is characterized by a sense of belonging, and balance, "one with the world" (Guzowski, 2000: 321). The term "home" can also produce an emotional familiarity among those who participate in allowing the individual to be who they are. This emotional belonging can motivate the individual's participation with recognitions of past and present people, experiences, and feelings (Manzo, 2005). This familiarity and sense of safety can help alleviate mental fatigue, allowing individuals to feel more accepted and free to be themselves (Staats *et al.*, 2004).

Feeling safe within an environment depends not only on the ability of the observer to acknowledge what is in that environment, but also their ability to interpret it. This interpretation is evidence of how the viewer organizes his thoughts from what he sees (Lynch, 1960) as well as from previous memories and experiences. As new images continually influence the viewer, the previous interpretations can change as new environments are considered.

Ongoing research continues to reveal the influence design aspects can have on the psychophysiological health and well being of occupants in a space. It has been documented that poor design in health care setting can have physiological consequences, such as hypertension, anxiety, delirium, and low pain tolerance. This can cause patients in healthcare settings to take more pain medications

(Wilson, 1972; Ulrich, 1984). Documented evidence has shown that visual influence of a person's environment, including architectural attributes, can modify the shape of their interpersonal behavior (Nascar *et al.*, 1999). Other studies have speculated on the effects of the relationship between residential interior environments and an individual whose level of stress can be observed (Evans & McCoy, 1998). Kennedy's study (1990) indicated that stress can prolong recovery from illness, as it decreases the immune system to fight infection (as cited by Ulrich, 1991).

A study done by Mehrabian & Russell (1974) specified that some interior environmental effects known to cause stress can be related to stimulations such as strong smells, loud noises, bright lights and colors, especially reds (as cited by Evans & McCoy, 1998). Other environmental conditions that can add to stress are evident in lighting, temperature, noise and privacy out of a patient's control increasing a feeling of helplessness (Ulrich, 1991), or ambiguous spaces inviting confusion, and spatial sensory depravation, as evident by lack of windows (Keep *et al.*, 1980; Ulrich, 1991).

Evidence based data from Taylor *et al.* (1997), indicated an awareness that healing environments can precipitate feelings of relaxation, calmness and motivation (as cited by Schweitzer *et al.*, 2004). Healthcare related studies have determined that certain environmental designs can encourage psychological support that allows for decreased stress. It also can synergize the healing effects of medications and foster recovery from other technological treatments (Ruga, 1989; Ulrich, 1991). Other scientific evidence has shown stress-reducing environments encourage individuals to increase social support, decrease distractions, and have a more direct contact with ingredients of nature (Altman, 1976; Ulrich, 1993; Evans & McCoy, 1998). Data indicated the most successful positive influences have been: happy, laughing and caring faces, animals, and elements in nature (Ulrich & Parsons, 1990).

A previous study by Kaplan & Kaplan (1989) recommended that restoration from mental fatigue can be seen at different levels and for different lengths of time. These characteristics can be evident with an increased attention capacity, cleared thought processes, and prioritized life issues with considered action (as cited by Berto, 2005). An example can be observed in one recent study about a coffee shop (Waxman, 2006). The principal comforts desired by the patrons included (in order) cleanliness, aroma, adequate lighting, comfortable furniture and view of outside landscape. Theses influences allowed the visitors to enjoy the space and feel comfortable whether socializing or by themselves. Part of the attraction grew from individual life experiences and existing circumstances (Waxman, 2006).

Another study speculated that recognition of controllable elements within the environment is needed for better understanding of their influence. Some elements for consideration are; light, sound, precision air quality, definition of water purity, consistent temperature and humidity control (Nascar& Presier, 1999). Other elements can be the position of furniture and floor layouts as they relate within the space and emphasize social interaction. Furniture flexibility can increase an individual's control, as well as facilitating rearrangement for privacy when needed (Ulrich, 1991).

With the knowledge that elements, and their placements within interior environments can promote health, increased acknowledgement and understanding is needed. Documentation regarding how humans, using their five senses, interaction with interior environments is further discussed.

Sound

When considering the subject of acoustics, two parameters must be understood. Frequency and wavelength are related to each other with the consideration of how sound travels through air reaching the cochlear. The human inner ear hair follicles transmit to audio-sensory nerves in the brain which determine the intensity of the stimulation from the original component (Bell *et al.*, 2001).

Frequency is the rate per second (units of cycles per second, or hertz) the sound travels through the median. The sinusoidal wave pattern repeats itself after a completed cycle, which is related to the distance between sections of the wave. This is known as wavelength (Cowan, 1994). Speed of sound can be affected by air temperature and density of the median the wavelength is traveling through. For example, at 70^{0} F, sound will travel through air at 1,128 ft/second while in seawater its speed is 4,920 ft/s (Cowen, 1994).

The human hearing range can be between 20 Hertz (low frequency wavelength that could be more than 50 ft and 20,000 Hz (high frequency wavelength is less than one inch), with the most sensitive range between 500 and 4000 Hz. As with a piano, the middle C key is at about 250 Hz, and changing an octave corresponds to either double or half that level (Cowan, 1994). Frequencies below 20 Hz display a resonance that sometimes can be felt more than be heard. A frequency above 20,000 Hz is sometimes used as an ultra sound when cleaning teeth (Cowan, 1994).

The basic level of sound is measured in decibels (dB), a term named after Alexander Graham Bell. Some levels of sound have been measured to be as follows:

Table 1. Cowan (1994) Identification of sound levels

Noise Source	Sound Level
Quiet	50 dB
Busy office	60 dB
Sidewalk by typical highway	80 dB
Damaging to ears after 8 hours	90 dB
Platform by passing subway train	100 dB
Maximum levels in audience at rock concert	110 dB
Aircraft carrier deck	140 dB (painfully loud)

Sources: Cowan (1994), Handbook of Environmental Acoustics. Van Norstand Reinhold, New York, p. 37. Not exact copy from book.
Bell *et al.* (2001), Environmental Psychology. Hartcourt College Publishers, Fort Worth, Texas, p. 143.

Two types of hearing loss that can cause permanent damage are seen as acoustic trauma with immediate damage, or a type of gradual damage that can occur over many years (Cowan, 1994). The immediate damage usually occurs with high-level noise exposure with the frequency between the ranges of 2000 to 4000 Hz, which can destroy hair cells in the inner ear and where hearing has the greatest sensitivity (Cowan, 1994). This noise-induced hearing can be obvious with a lesser sensitivity to consonant sounds and some difficulty understanding speech (Cowan, 1994).

Some stressors that are a continuous, low, recurrent part of everyday life can affect a human's mood, behavior, and health. These stressors, like noise, usually go unnoticed because they are universal and part of our everyday life. (Bell *et al.*, 2001). Ambient noise has been displayed as a buffer in office environments with consideration to increased job satisfaction and focus for organizational tasks (Leather & Sullivan, 2003). Ambient noise at 50 dB is at the best level for speech communication whether in doors or outdoors, while a noise level of 80 dB or greater will make speech communication impossible to hear (Cowan, 1994).

Evidence has indicated that individuals exposed to noise at levels over 80 dB during their years working may suffer long term hearing damage, no matter what industry they work in (Turney, 2005). Effects of noise on individuals can be first evident with a level of 75 dB or greater which can begin to cause hearing loss (Cowan, 1994). The EPA and Occupational Safety and Health Administration (OSHA) have indicated a lower limit of 85 dB and 70 dB respectively for auditory impairment criteria in occupational environments (Cowan, 1994).

Physical effects

Other evidence indicated that noise can increase pain perception, contribute to sleep deprivation, and possibly cause disorientation and confusion in the hospital setting, as specified by Grumet (1993). Such noise can also increase blood pressure, elevate the heart rate, and reduce patient satisfaction (as cited by Schweitzer, 2004). One study, Bronzaft *et al.* (1998), indicated frequent interaction with unexpected, loud noise could be with acute illnesses as well as altered sleep patterns (as cited by Bell *et al.*, 2001). The Environmental Protection Agency (EPA) in 1974 has recommended that hospital noise levels maintain 45dB during the day and 35dB at night because evidence indicates worsening health results at higher levels (Schweitzer *et al.*, 2004).

An individual's lack of ability to control noise could be related to feelings of lack of environmental control, helplessness, and possible depression as mentioned by Peterson *et al.*, (1993) and Bandura (1997) (as cited by Evans & Stecker, 2004). Unpredictable noise or unfamiliar music can also negatively influence an individual's ability to perform complex mental tasks, memorize, and recall new information (Bell *et al.*, 2001; Leather *et al.*, 2003). An example of this can be seen in a study from Persinger *et al.* (1999) that indicated students had more fatigue with less ability to concentrate during a lecture when fans were continuously running at 60 dB. The student's ability to concentrate greatly improved when the fans were turned off (as cited by Bell *et al.*, 2001). Another synonymous study by Crook & Langdon (1974) observed children who were less able to read or hear certain sounds, and who concentrated less, where living in environments with increased noise (as cited by Bell *et al.*, 2001).

Other research by Evans & Johnson (2000) studied the effects of noise in an open office. Their study suggested the effects of noise can add to physical stress, with indications of elevated levels of epinephrine, negative effects on cognitive behaviors, loss of motivational attempts, and higher risk for musculoskeletal disorder from lack of physical movement (as cited by Furnham & Strbac, 2002; Nascar & Preiser, 1999). These indications confirm the previous study of the students during a lecture, as well as another study that implied silence would be better than background noise or office noise when immediate recall performance was calculated (Furnham & Bradley, 1997). Poulton (1997) speculated the theory that an individual's inability to think or have "internal speech" can negatively affect the human performance (Poulton, 1997, p-158).

Studies using music as therapy have shown positive physical, mental, and emotional changes (Lau, 2000). In this random study from Barrera *et al.* (2002), it was observed that music had a positive impact on children with cancer as evidenced by reports of more comfort, better play, with positive communication and interaction, and reduced anxiety (Sherman *et al.*, 2005). Results from studies with Alzheimer patients indicated similar data were observed working with song recognition. Patients' melatonin levels increased precipitating a greater ability for relaxation and regular sleep (Lau, 2000). Song recognition also encouraged their communication and relationship skills with other individuals (Lau, 2000).

Environmental Effects

A level of sound change in the environment can be perceived by individuals as a nuisance, and thus have a negative impact on their perceived quality of life. For residential design, where private and public spaces are separate (Susanka, 2004), it is important for the private space to be quieter and have a more relaxed feeling.

The acoustical absorption coefficient is the ratio of the amount of noise absorbed between one sound wavelength and the material absorbing the sound. The higher the number, up to one, the greater the ability of the material to absorb sound (Madsen, 2006; Cowan, 1994). Sufficient sound absorption materials will have absorption coefficients greater than 0.4 while material's that will reflect sound will have coefficients less than 0.15. Noise Reduction Coefficient (NRC) is an industry rating for absorption coefficients over the human speech frequency range (Cowan, 1994). The NRC, defined by American Society for Testing and Materials (ASTM) Standard C423-90a, *Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method*, specifies the average of absorption coefficients to be 0.05 for frequencies banded at 250, 500, 1000 and 2000 Hz. This is only effective for absorption in relation to human speech or with sound frequencies mostly between 250 Hz and 2000 Hz (Cowan, 1994).

When sound interacts with the environment, it can do four things. First, sound can transmit through a substance such as porous carpet or thin wall. Second, it can be absorbed by the object off of which it reflects, such as upholstered furniture, or porous ceiling tiles (Cowan, 1994). Some of the quality of noise absorption of an object depends upon frequency and wavelength size. Lower frequencies are harder to absorb (below 250 Hz), and therefore the substance used to absorb noise must be effective. Absorption materials are needed to decrease echoes in spaces, which can precipitate wavelengths bouncing 40 to 50 ft. off the surface. Spaces with sound reverberation can increase noise levels up to 15 dB in an environment (Cowan, 1994).

The third and fourth interactions sound waves have with the environment are reflection and diffusion, which are usually evident with hard surfaces such as tile, wood, resin, drywall, etc. Reflection implies sound waves that rebound off a surface. Diffused sound waves are those reflected off uneven or convexed surfaces, allowing the evenly disbursement of sound (Cowan, 1994).

When planning interior residential finishes, the designer needs to consider the location of household appliances and the noise level they generate in the space used. For example, a kitchen food blender or a garbage disposal registers 76-81 dB at 3 ft., a microwave registers 56-58 dB at 3 ft., while a hair dryer in a bathroom measures 77-86 dB at 1 ft. (Cowan, 1994: 232). With this awareness, further consideration needs to be given to the finish materials and their absorption coefficient. An example would be the choice of finish selections that influence the reverberation of sound waves as they reflect off solid surfaces like brick, metal, concrete, and glass (Sheridan & Van Lengen, 2003). An individual's perception of noise also needs to be evaluated for sound nuance levels of their interior environment (Soneryd, 2004). Attention to interior noise levels can help with the application of construction materials, as well as finish selections and equipment locations.

Other sources of residential noise stem from the mechanics within the interior environment. For example, ventilation and air conditioning (HVAC) systems generate noise from within the machine, as well as from the production of the air circulating through the ducts (Cowan, 1994). Other residential noises may be evident in the plumbing system, including water going through pipes, and fans or electrical equipment as observed from TV's or computers (Cowan, 1994). Even though some construction processes do not specify increased insulation for interior walls and floors, it is recommended that if dwelling or mechanical noise generates more than 85 dB at 3 ft, it needs to be acoustically treated (Cowan, 1994).

Touch

Temperature and Humidity

Even though vision has a larger influence on our senses than touch, touch can help us perceive the environment in a three-dimensional perspective. Touch can establish weight, pressure, temperature, texture, and can help to complement the visual illumination from the external world around us (Guzowski, 2000). Touch of air on the skin not only can detect the humidity and temperature, but also the cleanliness of the air.

There is not much scientific based evidence regarding touch as a sense for environmental involvement. Environmental influences can be evident with texture, as it impacts the aesthetics of the space and has a psychological effect on human stimulation. For example, when sitting in a chair, a comfortable fabric touched can facilitate relaxation. Texture can be seen in fabrics, wood grains, carpet/ or area rugs, art and paintings. Other room finishes involving texture can also be evident on counter tops, window treatments, wall coverings, light fixtures, glass, and other interior accessories. Examples of architectural elements involving texture can be evident in kitchen cabinet and door styles, custom designed banisters, mantels, and metal hardware.

Temperature changes, perceived through touch, can affect individuals in industrial settings, evident by their physical symptoms of dehydration with loss of salt (sweating), muscle fatigue. High temperatures for over a period of eight hours or longer results in reduced performance as studied by Fraser (1989) and Sundstrom (1986) (as cited by Bell *et al.*, 2001). Also with the increased temperatures, at 95 degrees or better, individuals feel less in control of the environment that can cause more stress and deterioration in work performance (Bell et al., 2001). Other research indicated the most comfortable temperature requested by workers to be between 68-72 degrees Fahrenheit (Ireland, 2007).

In another experiment, Griffiths & McIntyre (1973) evaluated the effect of temperature variances of six degrees. Over a period of six hours the 32 subjects noticed that the smallest amount of temperature change (0.5 degrees), indicating that individuals find controlled temperature changes more favorable (as cited by Canter & Lee, 1974).

If indoor humidity is too low (less than 30%) it can cause individuals to feel they have the flu. The best interior relative humidity level is between 30% and 50% (US EPA). The sensitivity an individual realizes toward humidity was observed with Griffiths & McIntyre (1973) study involving the discrimination of relative humidity conditions in relation to air temperature. Six groups of 18 subjects each observed that humidity changes were most noticeable at higher temperatures. This confirmed the overall hypothesis that humidity can be directly perceived and can influence the effects of comfortable air temperature on environments (as cited by Canter & Lee, 1974). This experiment suggests that humidity control is also needed to provide healthy, optimal conditions (Canter & Lee, 1974).

Sight

Natural Environmental Influence

Visual perception is one of the strongest senses. Visual interpretation can be based on the stimuli placed upon the retina of the eye that sends neurological stimuli to the brain: then the visual and psychological response is translated by the brain to interpret the visual image (Bartuska & Young, 1994). Though visual images can be related to values and previous experiences, there are some basic principles for good design. Aesthetics, as defined by William Blair (1980), specifies that the science of philosophy is concerned with quality sensory experiences. This indicates the vision sensory as the primary mode on how individuals relate to their environment (Bartuska & Young, 1994).

The most informative visual influence a residence can display is a window.

Windows have been known to promote visual stimulation in the environment even when the window itself is not perceived (Stone & Irvine, 1994). The natural light from the window infusing the space can add illumination and reflection. When small, windows can create reflection off walls, floors, or other solid surfaces that induce shadows. When windows are at angles, they can evoke playfulness with reflections of varied shapes and sizes. When windows are large they can introduce the outside environment inside with visual acuity to climate, landscape and other aspects of nature (Guzowski, 2000). An individual can get a feeling of warmth and closeness with the outside environment as the natural light penetrates. Windows can provide protection from the elements, and from other dangers, yet at the same time administer a feeling of safety by the vantage point (Kaplan, 2001). The window can provide moments of fascination with its view of the exterior and thus reducing mental fatigue. No preparation is needed for viewing through the window; one just looks out (Kaplan, 2001).

The therapeutic value of windows was revealed in one study that indicated a scenic window can increase intentional gathering, and encourage a restoration of health (Stone & English, 1998; Stone, 2003). Windows can provide views that promote well being by allowing for visual variety and interest (Guzowski, 2000), as seen in the ephemeral landscape that changes as seasonal and climate conditions change (Bartuska & Young, 1994). Other documentation has indicated that viewing nature through a window had a healthy effect, promoting an individual's mental restoration and relaxation (Kaplan, 2001; Berto, 2005). The Vidar Clinic in Stockholm not only used window illumination for light, but even more to connect patients to the exterior environment in a therapeutic way (Guzowski, 2000). The 1984 research regarding environmental design from Roger S. Ulrich, suggested improved recovery time in the hospital setting for patients who had a view of nature from a nearby window, compared to those who had a view of a brick wall. This evidence proved a shorter recovery time, less administration of medications for pain, and fewer negative references to a lack of window from the patients when researching documented references (as cited by Looker & Stichler, 2003; Wilsonm, 2005). Outdoor views also reduced anxiety and pain, lowered blood pressure, reduced heart rates and improved moods of staff as well as patients (Ulrich & Gilpin, 2003).

The importance of the effect of natural light from windows has also been recognized in other European countries. In Germany, windows are a requirement for individuals in workstations and, daylighting is a legal requirement in workplaces in Finland and the Netherlands (Guwozski, 2000). Two other studies were consistent with the requirement for daylighting for occupants in a work environment. After spending six months with a window in their environment, workers claimed a greater job satisfaction with more enthusiasm, as well as better health and life satisfaction (Kaplan, 2001; Schweitzer *et al.*, 2004). More studies mentioned by Kaplan (2001) indicated a view from the window facilitated a feeling of well being and satisfaction from occupants of a residential environment. Another study reviewing those individuals' feelings found them to be more energetic, focused, and competent (Kaplan, 2001). These emotional characteristics can not only encourage the individual to enjoy the space more, but assist in coping with life's obstacles, as well as increasing basic health and well-being (Kaplan, 2001).

Other studies have observed increased learning capabilities. Tennesen and Cimprich (1995) indicated a study involving students with windows in a dormitory specified greater attention to performance (as cited by Kaplan, 2001). Evidence from the 1999 investigation by Heschong Mahone Group revealed that natural light improved the learning capacity for students in a school district by 20% to 26% (Wilson, 2005).

In January of 1970, the United States Congress passed the National Environmental Policy Act (NEPA) with the goal of encouraging harmony between people and their exterior environment in order to promote human health and well-being. This act encouraged views of the natural environment from windows and helped individuals to understand natural resources and ecological systems critical to a healthy environment (Bartuska & Young, 1994).

Natural Light

On average, Americans may spend up to 90% of their time indoors, according to the U.S. Environmental Protection Agency (Guzowski, 2000). Previous research has shown it is important for individuals to increase time spent in natural sunlight in order to maintain health. Some positive benefits are a visual acuity of objects within a space illuminated by daylight. Connection with natural daylight is important for individual acknowledgement of their environment (Guzowski, 2000). The location of the sun helps an individual realize time of day and seasonal changes. Sunlight or lack thereof can also reveal weather changes. Orientation with the exterior environment is needed so individuals may realize physical orientation, view distant objects from the windows, and experience exterior orientation of colors and objects such as clouds, morning and night. Without windows, none of these would be possible; therefore individuals need to acknowledge natural environment and better understand the ecological changes (Phillips, 2004; Guzowski, 2000).

Fritjof Capra (The Turing Point) has suggested that human health is related to our physical, spiritual, and psychological feeling, as it relates to balance with the elements in nature (Guzowski, 2000). Medical research regarding the physical and mental effects of essential environmental factors indicate daylight as being one of the most important. Some of information that research data have demonstrated that close association with natural light can improve our performance by increasing our ability to concentrate and focus, and magnifying our interest level and sense of well-being. Daylight can also affect an individual's mood, cardiac rhythms, or hormones (Guzowski, 2000) and can strengthen visual capabilities and decrease fatigue (Mahnke, 1993).

The lack of sunlight can precipitate some physiological conditions such as jaundice (overproduction of bilirubin caused by the increased breakdown of red blood cells), osteoporosis and rickets (resulting from lack of vitamin D) as well as Building Related Illnesses (BRI) and Sick Building Syndrome (SBS) (Guzowski, 2000). It was discovered in the early 1900's, that vitamin D from sunlight was needed to decrease some physical related illnesses. Evidence indicates that exposing hand and face to sunlight only fifteen minutes per day can provide sufficient amounts of vitamin D to prevent some of above mentioned illnesses (Guzowski, 2000).

Seasonal Affective Disorder (SAD) was first discovered by research done by Dr. Norman Rosenthal in 1984. It is recognized that SAD occur often during the seasons with less natural light, fall and winter, than those with longer sunlight, summer and spring (Guzowski, 2000; Bell *et al.*, 2001). Symptoms of SAD are evident in weight loss, fatigue, lack of energy, and carbohydrate craving, inducing weight gain (Guzowski, 2000; Mehnke, 1993). Norman Rosenthal found that full-spectrum light (which simulates sunlight), using 2500 lux (metric equivalent of footcandles) three hours longer in the evening and three hours earlier in the morning helped to decrease symptoms of depression (Mehnke 1993; Bower 1989). Other studies have indicated other physical conditions that respond well to phototherapy as: dementia, insomnia, depression, panic disorders, bulimia nervosa, and alcohol dependence (Guzowski, 2000).

Heschong (2003) noted other physical symptoms in his study regarding the association of reduced daylight with SAD. They are: cardiac rhythms, sleep disorders, melatonin production, biochemical and hormonal body rhythms (as cited by Schweitzer *et al.*, 2004). Feelings of balance, as regulated by the inner ear, and a sense of well-being can also be affected (Bell *et al.*, 2001). Not only are there physiological changes due to lack of natural sunlight, but lack of windows can increase loss of visual perception and cause disorientation when there is no evidence of a horizon (Bell *et al.*, 2001).

The effects of a setting sun called "sundown syndrome" has been known to cause detrimental behavioral problems in Alzheimer patients. The effects of memory loss, speech aberrancy, agitation, combativeness, and verbal outbursts were the typical disruptive behaviors displayed (La Garce, 2004). It has been researched that Alzheimer's patients have a deficiency in neurotransmitters in the brain. During this investigation, the elevation of neurotransmitters from the natural sunlight, at 5500 Kcal and 96 Color Rendering Index (CRI), was associated with unruly behaviors by 50%. Such influences can have positive effects on the interior environments of Alzheimer's units by increasing the quality of life for these patients. It decreases mechanical methods needed for control, and influences a standardized environmental design for Alzheimer's units and assisted care facilities (La Garce, 2004).

The difference between indoor artificial lighting and natural lighting are significant, in illumination levels, light diffusion, uniformity, time variation, color, and amount of ultraviolet radiation, as indicated by Zilber (1993) (cited by Schweitzer *et al.*, 2004). When Hollwich, Dieckhues, and Schrameyer (1977) studied the physiological effects of artificial lights on school children, they found that children behaved with more hyperactivity and stress, as indicated by their production of the stress hormone cortisol (as cited by Mahnke, 1993: 52).

USSR Academy of Medical Science reported physiological changes from natural light included evidence of strengthened immune system with reduction in disease, lowered pulse and blood pressure, increased reaction time and efficiency (as cited by Mahkne, 1993: 48). Studies by Dr. Campbell and colleagues at Cornell University indicated that exposure to bright lights could alter sleeping habits by decreasing sleep time by one hour, and improve sleep efficiently by 78% to 90% without changing the amount of time spend in bed (Guzowski, 2000).

The Policy and Planning Branch of Alberta Education in Canada found that students who were exposed to full spectrum lighting had higher attendance, better moods, less tooth decay and above average height growth. Another study by Nicklas & Baily (1996) of Innovative Design found that students in daylight environments out performed students without daylight by 5% to 14% (as cited by Guzowski, 2000). Two studies done by Cunningham (1979) regarding the affects of natural sunlight on behavior indicated increased positive attitudes from individuals, and another study indicated natural sunlight resulted in improved tips to waitresses. Cunningham perceived these results to signify natural sunlight encouraged individuals to be kinder toward others (as cited by Bell *et al.*, 2001).

Illumination

Lighting research has been used to focus on the condition needed for quality visual tasks. It has also furthered understanding of causes of visual discomfort. This information can also be used for a better indicator of health, safety and energy efficiency. Investigative evidence from Tobias & Cowan (1996) has confirmed that visual comfort can affect individuals' moods and thus affect their performance (Guzowski, 2000). The positive healthy influences from exterior lighting have demonstrated brighter lights to decrease crime stated by Painter & Farrington (2001), pedestrian fatalities claims, Sullivan & Flannagan (1999), and protection for convenience store clerks mentions Loomis *et al.* (2002) (as cited by Boyce, 2004).

Brightness is determined by the reflection of light from the illumination of the light source as well as the reflection of the surface. Another perception of brightness has to do with the amount of contrast the illuminated object has against the background (Bell *et al.*, 2001). The more the illumination, the easier it is for the object to be seen. Certain tasks require a certain amount of foot-candles for the task to be performed. Literature review speculates ambient light at 25-30 foot-candles, where task lighting is at a level of 70-100 foot-candles (Pilatowicz, 1995; Bell *et al.*, 2001). The average illumination from electrical lighting on a 30" high work surface has been recorded to be 130-510 lux according to the standards from Illumination Engineering Society (Chungloo *et al.*, 2001). Specialized tasks with very little contrast as in a small procedure as in an operating room would require between 1000 to 2000 Lux (Bell *et al.*, 2001).

Color Rendering Index (CRI) is used as an indicator on how well colors are represented with artificial light sources, as compared to natural light sources (Mahnke, 1993). The CRI for natural light is 100. The higher the CRI of artificial light, the "truer" is the represented color in the indoor environment (Mahnke, 1993). Therefore, engineers in Europe recommend a minimum of CRI 85 for visual improvement of workers (Mahnke, 1993). Faber Birren (1961) realized the same high CRI lamps of 750 lux provide enough illumination for desk tasks and visual clarity as 1076 lux of cool white illumination (as cited by Mahnke, 1993).

Lucidity of the interior environment would consider room height, window height and size as guides to the amount and distance light will penetrate a room (Guzowski, 2000). Placement of electrical lights can also depend upon the placement and width of the window in the space. Wider windows at higher placement locations can provide better daylight illumination than tall and narrow windows that provide a better view, but also more glare (Chungloo *et al.*, 2001). The 2.5H rule assumes that light will be emitted into a room 2.5 times the height of the window at a workstation height. Example is the distance of 5'-0" above 30", workstation height above finished floor (AFF) times 2.5 (Guzowski, 2000). The precise "light-to-reflection ratio" is 3:1 for furniture and walls (Mahnke, 1993, p-40). A suggested reflection off the floor is 20%, 25% to 40% for furniture and 60% for walls. Ceilings are the highest at 80% to 90% (Mahnke, 1993).

Taste

Lakes and rivers are becoming more polluted from industrial and agricultural runoff into the soil, and then into the water. Non-well water is usually disinfected with chemicals such as fluoride, and travels through potentially contaminated pipes made of copper, galvanized or plastic under the street. There is a potential for added chlorine in the water to react with dissolved organic material, causing a carcinogen compound called chloroform (Bower, 1989). Some individuals are very sensitive and vulnerable to the use of chlorine in their bathing water, let alone drinking it. Bathing with chemically treated water has been linked in one study to increased cancer mortality (Bower, 1989).

Contaminants routinely found in drinking water can be microscopic animal and plant particles such as bacteria, viruses, amoeba, molds, etc. Other contaminants can be organic chemicals that dissolve in water such as fluoride, pesticides, sulfates, and salts, or vaporized substances when interacting with water such as chlorine; or inorganic chemicals that can become carcinogenic such as heavy metals, nitrates or arsenic (Bower, 1989; Laporte *et al.*, 2001). In 1998, the EPA has required water treatment suppliers to inform their customers with annual quality reports indicate levels of contaminates found in the water as well as a phone number to call for further information (Laporte *et al.*, 2001).

Only 2,000 of the 82,000 plus contaminants found in potable water have been established by the U.S. Environmental Protection Act (Laporte *et al.*, 2001). Most municipal water treatment plants are set up for disinfection of water and not for purification, less than 1% of the treatment plants in the US can actually remove toxins, claims Friedman (Laporte *et al.*, 2001). The annual water treatment report from the author's area identified the pollutants found and how high those levels were. It also indicated range of detection. The highest range of detection was the same as the highest level the pollutants measured. A question comes to mind: could the contaminants levels be higher than the range of detection? (Holland BPW, 2005).

Pruss et al., (2002) concluded that access to water is important for human existence, yet it is also a great medium for illness and disease, mostly due to poverty and poor sanitation habits (as cited by Eyles *et al.*, 2004). World Health Organization (WHO) has determined that disease can result in 1.7 million deaths, 4% of the world's population. This can be related to poor water sanitation and waterborne diseases, specified Ezzati *et al.* (2002) (as cited by Eyles *et al.*, 2004). The most common recent disease has been Cryptosporidiosis, mentioned by Corso, *et al.* (2003), which is most commonly transmitted by animal to human by oral-fecal contamination found in swimming pools and other pools of water. This was recently seen in Milwaukee, Wisconsin in 1993 causing 400,000 individuals to be infected (as cited by Eyles *et al.*, 2004).

Smell

Causes of Poor Air Quality

It is evident that indoor air has about two to five times more condensed pollutants than outdoor air (Bernheim, 2005). People spend a majority of their time in indoor residential environments and are therefore subject to higher levels of air pollutants (Sherman, 2004). Concern regarding the effects of Indoor Air Quality (IAQ) on human health and safety is becoming more widespread. Environmental Protection Agency has recorded poor indoor environmental quality as the fourth largest environmental threat in the country (Stockbridge-Pratt, 1999). The causes of poor indoor air quality can be categorized into three separate areas. They are: indoor materials or products that promote emissions of hazardous compounds, human movement and activities, and chemicals emitted from building products (Pilatowicz, 1994). An environmentally sustainable approach for maintaining healthy air quality has to include non-toxic building design, incorporating adequate ventilation and maintenance of the mechanical system circulating the air (Pilatowicz, 1994).

Indoor Construction Pollutants

Stipulations regarding Indoor Air Quality (IAQ) for residential environments have considerably changed during the last century, as evident by State and Federal regulations for construction. The energy crisis of the 1970's encouraged homes to be built more energy efficient using tighter construction practices; less outdoor ventilation, thus promoted higher levels of indoor air pollutants. Not only the construction process, but also interior finishes and furnishings released gaseous pollutants. Asbestos was often found in ceiling, flooring tiles, and shingles in older homes. This fiber, used also for wall insulation before 1978 has been recognized as a lung carcinogenic (Pilatowicz, 1995).

Indoor air quality can be better controlled through elimination, separation and ventilation (Bower, 1989). Ventilation, the transfer of outdoor air into the indoor environment, can encourage the removal of interior hazardous chemicals as well as the mixing of non-hazardous outdoor air into the interior space (Pilatowicz, 1995). These requirements are expected to improve air purification with exhaust ventilation located in combustible, humid spaces, and by installing more efficient cleaners and filters within the HVAC systems (Heat, Ventilation, and Air Condition; Pilatowicz, 1995). The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) indicate the guide for ventilation is minimal air exchange of 0.35 air changes per hour (ACH), but not less than 15 cubic feet/ minute (cfm) per person in basic living spaces (ASHRAE 62-1999: 10).

Some examples of carcinogenic producing toxins used as building materials are fiberglass insulations, and Volatile Organic Compounds, claims USEPA (1995), California Air Resources Board (CARB, 2001), and Office of Environmental Health Hazard Assessment (OEHHA, 2001) (as cited by Sherman, 2004). Another example, formaldehyde, which can be found in composite wood products (particle board and medium density fiberboard (MDF), is the highest emitting source at a constant emission rate for up to 9 months, mentioned by Hodgson *et al.* (2000) (cited by Sherman, 2004).

The difficulty with having less indoor air pollutants is that toxins can get trapped into tight spaces where there is less air movement and ventilation (Bonda, 1998). National Institute for Occupational Safety and Health (NIOSH) estimates the causes of poor indoor air quality to be: 53% inadequate ventilation, 15% indoor contaminants, 19% outdoor contaminants, and 13% unknown (Bonda, 1998). Poor air quality has been shown in a study by Katsouyanni (2003) to be related to adverse physical effects such as asthma, lung cancer, cardiovascular disease, chronic pulmonary disease (COPD), diabetes, and stroke (cited by Eyles *et al.* (2004). A study by Schwarz (1994) claimed Building Related Illnesses (BRI) related to particulate matter in the environment has been linked to upper respiratory infections as well as suppression of the immune system (as cited by Eyles *et al.*, (2004). The World Health Organization (WHO) officials at the 2000 Air Quality and Health seminar in Geneva revealed three million deaths worldwide are caused by indoor air pollution (mentioned on CNN August 30, 1999, as cited by Eyles *et al.*, 2004).

Asthma

Asthma can be an acute or chronic pulmonary airway obstruction distinguished by the longer exhalation time taken during expiration (Merck, 1999). From 1982 to 1992, the death rate increased 40%. A combination of causes can precipitate spasms of smooth muscle airways causing contractions, and increased secretions (Merck, 1999). It can occur in adults and children (Merck, 1999).

Centers for Disease Control (CDC) have reported that asthma is the fastest growing, and leading cause of chronic illness among 0- years- old to 14- years- old children in the USA. Asthma increased 75% from 1980 to 1994 (Brugge *et al.*, 2003) and affected over 17 million children and adults. Potential causes are as a result of indoor pollutants such as radon, tobacco smoke, carbon monoxide, fungi, bacteria, viruses, mites, pollens, and animal dander (American Lung

Association, 2002; Eyles *et al.*, 2004). Other studies identified by Gomzi (1999), Rumch *et al.*, (2002), and Wamboldt *et al.*, (2002) have identified asthma affiliated risk factors in children with concentrations of formaldehyde, nitrous oxide, and particulate matter (as cited by Tavernier *et al.*, 2005). Rosenstreich *et al.* (1997), Nafstad *et al.* (1998), and Institute of Medicine (2000) specifically documented risk factors in the residential environment to include moisture, improper heating and ventilation, and high dust levels (as cited by Brugge *et al.*, 2003).

Multiple Chemical Sensitivity

Multiple Chemical Sensitivity (MCS) is defined as intolerance to many chemicals and other irritants at very low concentrations. Even though the number of individuals with MCS is rapidly increasing; further studies need to be conducted to determine the exact definition and causes of MCS (Bailer *et al.*, 2004). One study suggested that this disorder may be a somatic disorder without evidence of any medical cause (Bailer *et al.*, 2004). Individual related symptoms reflect hypersensitivity to chemicals, as well as psychological traits including anxiety. Poor Indoor Air Quality (IAQ) resulting from tighter construction may facilitate chronic low levels of environmental chemical toxins that could trigger MCS. Gist (1999) and Winterbauer (1997) have realized the lack of statistical data on the subject, as well as lack of diagnostic criteria and treatment methodology, has caused a controversy in the medical community regarding treatment (as cited by Nussbaumer, 2005).

Sick Building Syndrome

Air pollution can have the most significant effect on an interior environment, with evidence of concentrations of pollutants 100 times greater than found in open spaces (Pilatowicz, 1995). With Americans spending more than 90% of their time indoors, this can lead to a condition called "sick building syndrome" (SBS). First discovered in 1970, its symptoms are acute or on-site discomfort while in the building environment. Some investigations have suggested that microbial contaminations in buildings caused from construction materials, building age, and ventilation systems could be correlated with number of occupants and their physical activities (Raw, 2000).

Some of the physical characteristics resulting from sick-building syndrome, according to the World Health Organization, are: irritated sinuses, dry skin and mucous membranes, erythema, mental fatigue or headache, upper respiratory irritation including hoarse voice or wheezing, nausea, vertigo, and unclear hyperactivity (Bower, 1989; Pilatowicz, 1995). Other occupationally related physical symptoms are mental (somatic) conditions such as headache, nausea, sleepiness and fatigue; allergic reactions like runny nose and eyes; persons affected may remark about sensory changes, like taste, and odors (Bell *et al.*, 2001).

Toxins Related to Human Activity

Environmentally conscious space planning requires the assessment of the homeowner's activities when considering the avoidance of infiltrates from potentially toxic fumes. The increase in pollutants caused by human activities can include: gas particles from cooking, smoking, combustion, water use and physical activities, moisture in the bathrooms (EPA, 1994). Air filters and ventilation are used for better control of odor from human bioeffluents, as well as other air pollutants (Bower, 1989).

Carbon dioxide concentrations are meaningful in monitoring overall ventilation rates, as is the concentration of other pollutants indoors. Carbon dioxide rates indoors compared to outdoor spaces can indicate the quality of indoor ventilation (ASHRAE, 62-1999). Indoor carbon dioxide levels in the range of 1000 ppm or less are not related to any health issues concerning carbon dioxide itself, but with the perception of human odor. This concentration of carbon dioxide is equalivant to the constant ventilation rate of 15 cfm/person where the outdoor concentration is at about 350 ppm in a space engaged by sedentary adults

(ASHRAE, 62-1999). Studies have indicated that carbon dioxide concentrations of about 650 ppm above outdoor concentrations identify 80% satisfaction ventilation levels for human bioeffluents (ASHRAE, 62-1999). This difference would also depend upon the physical activity produced by the occupant level, which is indirectly responsible for the oxygen consumption, and food products prepared and eaten (ASHRAE, 62-1999).

Indoor activities from human behavior have been known to spawn a considerable amount of particulate substance. Recently, studies, one by Alvin *et al.*, (2000) have indicated that exposure to indoor airborne fine and ultra fine particles can affect human health (as cited by Afshari *et al.*, 2005). The activity that produced the largest concentration of these particles was the use of pure wax combustible candles with a size of particles being 241,000 particles/ cm^3. The weakest one was produced by a steam iron when ironing cotton, resulting in 550 particles/cm^3. (Afshari *et al.*, 2005).

Many pollutants in the air are 10 microns or larger and are very easy to remove with a standard furnace filter. Pollutants that are 0.1 to 1.0 microns, like house dust, are more difficult. Bacteria can be fastened to larger particles such as human skin flakes (exceeding one micron in size). Animal dander can be 0.5 to 1.0 microns, and mold spores around 1.0 micron (Bower, 1989). Viruses are commonly noticed in clusters and on other particles less than 0.1 micrometers in size. Lung-damaging particles contained in the lungs can be 0.2 to 5 micrometers (ASHRAE 62-1999). HEPA (high efficiency particulate accumulator) filters collect 99% of the particles at 0.3 microns or larger. They are often made more pleated in shape to increase the surface area, because they need to be denser for more air resistance to capture the smaller air pollutants (Bower, 1989).

Macher (2001) has specified that house dust is a consortium of materials originating from resources existing in interior environments deriving from pets, plants, construction materials and finishes, furnishings, occupants, and outdoor air (as cited by Rintala *et al.*, 2004). Viable fungi, claims Dales *et al.* (1997), have become evident in dust occurring in damp homes, which, Bornedhag *et al.* (2001) mentioned, has been proven to coincide with detrimental health effects (as cited by Rintala *et al.*, 2004).

Fungi, as the most common type mold, and mildew are small unchlorophylled plants that steal nourishment from other living animals and plants. They can also get nourishment from decaying materials, such as wood or paint, commonly used in the building process. Fungi can survive in environments with high relative humidity levels. Higher than 70% can generate mold, mildew and other fungal contamination (ASHRAE, 62- 1999), and has been known to cause severe allergic reactions (Bower, 1989).

Mold

Mold grows better with high air moisture, nutrients (cellulose) and protection from ultraviolet light such as sunlight. (Warsco, 2003). It cause allergic reactions when the seed spores used for reproduction of the mold are inhaled. Most of the seeds are very small, about one micron in size, easily airborne and very difficult to remove with common air filter (Bower, 1989).

Mold can be found inside the home environment under wet carpets, humidifiers, or locations of standing water (Bower, 1989), or on plants, foods, and other organic materials. It also exists in spaces with previous water damage like walls, and other porous surfaces (Green Home, 2004). Certain types of molds produce toxins, called mycotoxins, which can be found in living and dead organisms. Symptoms of common allergic responses to molds are: sneezing, runny nose, congestion in ears, lungs, and bronchus, with fatigue and weakness (Bower, 1989). Large quantities of airborne molds can cause physical health problems related to upper respiratory congestion, visual and skin irritation, central nervous system (CNS) problems related to memory, headaches and mood changes, aches, pains and possible fever (Green Home, 2004).

Four ways to increase a mold-free environment include: elimination of the source, separation of mold from the interior environment, filtration to eliminate pollutants in the air, and ventilation to reduce the contaminants in the environment (Warsco, 2003). Mold producing contaminants can come from human consumption (breathing and perspiration), interior construction surfaces, and airborne matter attached to interior materials (Warsco, 2003).

Control of indoor humidity, defined as the amount of water vapor suspended into the air (Richardson *et al*, 2005), can influence growth of other toxins that could lead to harm for occupants. These toxins may include: fungus, spores, bacteria, and house dust mites (Engvall, 2002). Mold and dust mites are not as proliferative with humidity levels below 70%. With varied residential humidity levels in different locations, relative humidity set at 40% will keep a home on the average around 70% humidity (Bower, 1989).

Chemicals/ Gases

The largest source of indoor air contaminants, among the more than 4,000 chemicals found in the air is from environmental tobacco smoke (ETS). The Environmental Protection Agency (EPA) has claimed environmental tobacco smoke (ETS) as human (Group A) carcinogen and estimates it causes 3,000 lung cancer related deaths per year among nonsmokers (Indoor Air Pollution, 1992; Warsco *et al*., 2003). Adult related physical symptoms of upper respiratory congestion include coughing and wheezing, headache, and conjunctival irritation, to name a few. Airborne particulate matter containing ETS has also been associated with impaired breathing, lung disease, exasperation of existing cardiac and lung complications, and lowering defense systems, as well as a change in immune systems (American Lung Association, 1992).

Luquette, Landiss and Merki (1970), as well as Russell *et al.* (1973), claimed that cigarette smoke has toxins like carbon monoxide, formaldehyde, and dichlorodiphenyltrichloroethane (DDT), which can result in physiological changes evident by, increased heart rate, blood pressure and breathing rate (as cited by Bell *et al.*, 2001). Higher concentrations of benzene have been evident indoors, which can be a byproduct of smoking (Rehwagen *et al.*, 2003). For many years, Hardoff *et al.* (1997) recognized that results from second hand cigarette smoke can project tar and nicotine on non-smokers who are in the same room at a rate of 30% (as cited by Bell *et al.*, 2001). Koop recognized that this can be more evident since the effects on young children have been demonstrated in an increase in upper respiratory complications (as cited by Bell *et al.*, 2001).

Carbon monoxide is the second major contaminant, which results from the end product of combustion. Non-functioning heating sources, such as improperly vented fireplaces can produce carbon monoxide, as well as nitrogen oxide, and sulfur dioxide. (American Lung Association, 1992). Attached garages can allow for infiltration of carbon monoxide from automobiles, as well as other chemicals stored in the garage (Bower, 1989). These asphyxiant gases replace the oxygen attachment to the hemoglobin in the human body, thus it decreases the amount of oxygen consumption by human tissues. Prolonged exposure can cause death.

Carbon monoxide is also a major pollutant related to automobile exhaust producing levels from 25 to 125 parts per million (ppm). Beard and Wertheim (1967) studied individuals with exposure over 90 minutes of carbon monoxide ranging from 50ppm to 250 ppm and found that exposure at 90 minutes of carbon monoxide at 50 ppm indicated significant alteration in judgment on time related tasks (as cited by Bell *et al.*, 2001).

Radon is the second principal cause of lung cancer after tobacco smoke. This odorless, tasteless gas is emitted from decaying uranium that is naturally occurring in the ground (American Lung Association, 1992). Radon can come into the house from the foundation with a lowered indoor air pressure (Bower, 1989). High concentrations of radon by the off-gassing of uranium, occurring naturally in the ground, can have the potential for lung cancer in individuals exposed over prolonged periods of time (Pilatowicz, 1995).

Volatile Organic Compounds (VOC's) are odorless gases associated with the construction process, and products used for indoor finish products which are emitted from most man-made materials at room temperature (Pilatowicz, 1995). Studies from Lechner (1991) have indicated that high humidity and temperatures have promoted microbial growth and accelerated the release of VOC's from indoor environments (as cited by Warsco *et al.*, 2003). Some of the chemicals emitted are: formaldehyde, benzene, and perchloroethylene (Pilatowicz, 1995). The most recognized sensitive chemical, formaldehyde, can be found in construction grade particleboard, or medium density fiberboard (MDF) commonly used as floor and wall boards in construction (Pilatowicz, 1995). VOC's can also be emitted by aerosols, household cleaning products, furnishings (urea-formaldehyde), and office materials like glues, copy paper, adhesives and corrective fluids (American Lung Association, 1992).

Other potential items that can produce toxins are: fragrances, paint fumes, cleaning products and disinfectants, and plastic sealants found on the backing of new carpet (Bower, 1989). Lead, another toxin, was used in paint products for homes before 1950 (Pilatowicz, 1995). Pesticides (semivolatile organic compounds), are another airborne household product that produces detrimental physiological effects in the interior environment (American Lung Association, 1992).

Biological agents are another high cause of interior air pollution. They can be caused by house dust mites, arthropods (i.e.-cockroaches), pets, molds, and other furnishings that contain protein. Common diseases caused from biological pollutants may invade the human body, resulting in an infection. Hypersensitivity to the toxic agent can cause autoimmune diseases and toxicosis, which occurs when the body produces a toxic chemical with a direct toxic effect on humans. (American Lung Association, 1992).

Chapter Conclusion

In 1972, hundreds of people in more than seventeen states reported upper respiratory problems associated with household chemicals used in their homes. The cause of most of these problems was due to the lack of ventilation, thus the use of toxic chemicals that progressed to toxic fumes. (Ruckart *et al.*, 2004). In 56% of these cases, human error was the cause, followed by equipment error in 12% of these cases. It was found that 20% (128 events) had to evacuate their homes. This amounted to more than 900 people. As many as 81% of the victims reported over two adverse physical effects, with the maximum number being five. Vertigo and Central Nervous System disorder were most frequently mentioned, (20%), followed by upper respiratory (19%). Fifty-six percent were treated at the hospital and released. Nine cases were fatal, with five deaths were related to carbon monoxide poisoning. The four top toxic chemicals reported in these incidents were: hydrochloric acid (general cleaning agent), sodium hypochlorite (Bleach), chlorine (Disinfectant), and sulfuric acid (toilet bowel cleaner). This report indicated the need for further education of the public about hazardous materials existing in the home (Ruckart *et al.*, 2004).

Increased awareness stemming from statistical data and other studies have produced clearer insight into human interaction with their interior environments. Although some physical conditions may be related to other environmental changes, such as diet (increased sugar) and more prepared foods with additives, polluted indoor air quality can be more detrimental, because of a person's prolonged contact with the environment. Those most at risk are the individuals who are already physically handicapped; those with cardiac or pulmonary complications, or immunosuppressed individuals, as well as children and the elderly (Bower, 1989).

In additional to the previous information, understanding the relationships between the products involved in interior environments and their effects on humans can help with the promotion of materials that have a positive influence on health. Education is needed to involve individuals in making these choices, helping them create environments that assist in mental and physical restoration, and promote individual health and well-being.

Problem Statement

Although most sustainable construction processes can help to decrease waste, energy and water consumption, there is little information about these techniques as they relate to the health of humans occupying interior residential environments. Some independent studies have specified the effects of sustainable materials and design for other interior environments, which may also assist with determining of healthy residential environments.

Research has involved the effects of natural light, mechanics of ventilation in relation to indoor air quality (IAQ), and relationship of furniture in space as it impacts work production and social interaction. There have also been studies of the effects of IAQ in residential environments and its relation to the increase in asthma and other pulmonary related illnesses in children, stemming from second hand smoke and other toxins (Brugge *et al.*, 2003).

The effects of IAQ in interior environments can be said to be similar in both commercial and residential environments. Because of the freedom of design for residential environments, choice of interior elements could be more controlled. Natural light, furniture placement and finish selections can be easily altered. Questions come to mind as how to best influence the planning, design, and construction elements in order to provide the healthiest environment. How does one determine the influences these different design elements can have on the occupant's well being? What design elements of the interior space can maintain the occupant's health with consideration to benefits from the exterior space? What part of residential construction can affect the health of the occupant? Could the age and size of a home impact the health of the interior environment?

Since there is little evidence regarding the significance interior residential elements can have on human health, I will provide information from a list of variables for evaluating residential environments. These results may be useful with further identification and recommendations for healthy residential environments.

Study Purpose

The purpose of the research is to evaluate the health of residential interior environments as it relates to occupants health.

This study, focusing on sensory evaluation of the environment, will address the following objectives:

- Sound- to measure noise levels within the residential interior environment; to consider the acoustic sensitivity of the finish surfaces (soft vs. hard) in fabric, walls, floors, etc.

- Touch- to determine texture of finishes as it relates to aesthetics and spatial function.
- Sight- to determine and observe the existence of natural landscape; the amount of natural light; application of finishes and visual space as it relates to function within the space.
- Smell- to measure interior residential air quality pollutants and discuss pollutants from construction, finishes, and furnishings; other contaminants existing within the environment; as well as other environmental consequences (i.e. - mold with increased moisture).

CHAPTER 3

DATA COLLECTION AND ANALYSIS METHODOLOGY

This research was coordinated with the equipment used from Michigan State University and approved for the use of variables by UCRIHS (Appendix A2) Details of data source, sense classification, and analysis method will be covered in this section.

Data Source and Experimental Design

This research was conducted with a list of variables involving the four senses that were employed for the implementation and evaluation of interior residential environments. This list was designed for one investigator to collect data on twenty-four residential interiors with consideration to two factors: age and size. The four separate age groups; 1900 to 1930, 1940 to 1965, 1965 to 1985, and 1989 to 2005, were examined and compared with two separate size groups. The two size groups were under 1200 sq. ft. and over 2000 sq. ft. Three homes were evaluated for each group developing eight groups evaluated in the Holland, Michigan area for a total of 24 treatments.

Five senses were used for health evaluation of the residential interior environments. The four senses used for the list of variables were sound, touch, sight and smell. For each sense, there was at least one question the investigator used to evaluate the space. The level of testing was done at an elementary level due to the experience of the investigator and time frame with which the equipment was used.

Sense Classification and Data Organization

Sound data was collected with a decibel reader borrowed from Michigan State University. The data collected was at different times of the day and in different locations of the home. The center of the main living space was used for this evaluation. The lower the sound measured, the better the score. The sound level determined for the outside was just outside the front entry. At certain opportunities, the investigator was able to ask the occupant what part of the day indicated the loudest amount of noise, and what the cause of that noise was.

Touch, as the second variable, was measured by the observation of the investigator to rate the effectiveness and relevancy of the transition of materials as they entered from one space to another. The measurement was determined by the relation of the finishes to the function of the space. The four most relevant spaces evaluated were; the living space, kitchen, master suite, and main bathroom. The five finish considerations were evaluated on surfaces; ceilings, floors, walls, countertops and fabrics on furniture. The scoring evaluation was determined as one point for the correct application, and zero points for poor application. When the finish was not present in the space being observed, "N/A" was used as the score. The best score for this evaluation was the highest score. The high score was then subtracted from 100 giving a low score. The best score needed to be the lowest number in all the categories evaluated.

Three variables were used for the evaluation of Sight. The first visual tool was with the use of a light meter to determine the amount of natural light as measured by foot-candles in the most common areas of the residence. The reading with the light meter was at 36 inches above the finished floor at a distance of one meter from the window. No artificial light was used, but only the light from windows. The four main spaces used for touch were also used for foot-candle evaluation. The data was averaged according to the foot-candle in each space divided by the four spaces evaluated. The time of the day was not regulated. The best score was the highest number, which was then subtracted from 100 giving the investigator the lowest and best number to evaluate.

The second evaluation of sight was with the consideration to the percentage of natural landscape vs. man-made scenery from a window at one meter from the window. The same four main spaces were evaluated for this view. The percentage of the natural landscape vs. the percentage of the man-made landscape per window as calculated by the investigator. The average percentage was determined by adding up the total natural landscape percentages calculated and dividing by the total number of windows viewed. The best percentage obtained was subtracted from 100 giving the lowest number for the best evaluation.

The last variable for sight was with consideration to the aesthetic observations of the furniture, cabinets, appliances, and equipment needed to function within that space. This was determined by the application as well as location of the materials involved for the function of the space. Example of this is with the placement of the furniture in the living space that invited social interaction. The rooms evaluated were the same four main spaces used. One point was given for adequate application and zero points for poor functional application. The data was averaged for the finished numerical indicator then using the highest score subtracted from 100 to indicate the lowest, best value.

The sense of smell represented the measurement of interior air quality. As before, the four most used rooms were evaluated. The DUSTTRAK instrument was used to determine respirable size particle concentration per mg/m^3. The respirable size rang is (Particulate Matter) PM 10 microns, PM 2.5 microns and PM 1.0 micron. This helps with the detection of airborne contaminants of a particular size, not weight, and does not to identify which particles were present (P. Weinstein, personal communication, July 26, 2005). The lowest concentration registered was the best score.

A photoionization detector, ppbRAE, is the most accurate detector of the measurement of VOC gases. The normal levels are 200-500 ppb. The range extends from one ppb to 2,000 ppm with the calibration of ten ppm isobutylene gas. TSI Q-Trak Indoor Air Quality Monitor was used to measure carbon dioxide, carbon monoxide, temperature and relative humidity. This can help with thermal comfort and investigate IAQ.

The highest score used as the best score in during the data collection was subtracted from 100 so that the lowest numbers indicated the best scores in all the blocks measured.

Analysis Methods

After compiling and organizing the data, Friedman's nonparametric statistical test (Daniel 1978) was implemented to determine if there was a difference amongst the treatments. Friedman's test required that data collected was from random samples and that nothing is known about the parameters of the variables of interest, such as mean or standard deviation. The variables for the 24 treatments were ranked by the lowest number indicating the healthiest and best results. Treatment groups were consolidated according to age (four groups of them) and size (two groups of them) for a total of eight grouped treatments.

Microsoft Excel spread sheet was used to sum the ranks for a treatment to detect differences between homogenous subjects labeled "blocks". The blocks, or evaluation of the interior spaces for this research, may indicate some of the same criterion with respect to each other and could be considered "experimental units". With the involvement of Friedmans's statistical data for evaluating a hypothesis, each treatment was ranked as observed by the sums of the columns. For each treatment a rank was assigned having one as the lowest score, two the second, etc. Only with a tied score was the mean number used as the ranking score. An example of this could be where two treatments ranked as four. The tie rank score would be 4.5 (ie. 4+5/2=4.5) as allocated to each tied scores.

For this experiment, the null hypothesis $H_0: \varnothing_1 = \varnothing_2 = \varnothing_3$, means no treatment is significantly different than another. To demonstrate the hypothesis false, at least two of the treatments, or sum of the ranks (k) would not be statistically equal.

H_1 : Not H_0 (1)

According to Friedman (Daniel 1978) let *b* denote blocks, *j* the treatment, and *k* the rank of the treatment. In the following equation, *R* will represent the sum of the ranks in each column. The rows symbolize the blocks and the columns are the treatments.

Figure 1. Illustration of Freidman's Two-Way Analysis

Blocks	Treatments 1	2	3	*j*	*k*
1	x	x	x	x1*j*	x*k*
2	x	x	x	x2*j*	x*k*
3	x	x	x	x3*j*	x*k*
b					R_{bk}

Note: Adopted from Daniel (1978).

According to Daniel (1978), let *Xij* denote the number of samples categorized, where *b* (*b*=1,2,3....*k*) is equivalent to the data collected in rows (block), category *j* (*j*=1,2,3...*k*) in reference to columns (treatments), and *k*(*k*=1,2,3...*k*) as reference to ranked data.

When *b* and *k* are numerically small, there needs to be a comparison or significance of Friedman's equation with use of Chi-square. The determination of rejection or acceptance of the H_0 can then be determined. The calculated value of X_r^2 must be equal to or exceed the tabulated values in the Chi-square table with a required level of significance. When considering the appropriate degrees of freedom, the tabled X_{99}^2 value (99th percentile on chi-square) and tabled X_{95}^2 value (95th percentile on chi-square) are valued as 0.01 and 0.05 critical values for determining an alternative hypothesis (Sheskin 2004).

The number of degrees of freedom is calculated by:

$$df = k - 1 \tag{2}$$

Friedman two-way analysis stipulates that the sum of the ranks are determined and then squared. Those squared ranked sums are then summed as equation:

$$\text{Let:} \quad \sum_{J=1}^{k} \langle \Sigma R_J \rangle^2 \tag{3}$$

If X_r^2 is greater or equal to tabulated Chi-square with k-1 degrees of freedom, Ho can be rejected at α level of significance. The test statistic can be concluded with:

$$X_r^2 = \frac{12}{bk(k+1)} \sum_{J=1}^{k} \langle \Sigma R_J \rangle^2 - 3b(k+1) \qquad (4)$$

(Daniel 1978)

X_r^2 will need to be adjusted if a tie occurs and will need to be adjusted by the average for the rank positions that the tie occurs. Ties within a given block are the ones that are of interest. Adjustment used with ties will be accommodated by dividing X_r^2 by the equation:

$$1 - \sum_{b=1}^{b} Tb/bk\,(k^2-1) = \qquad (5)$$

(Daniel 1978)

$$Tb = \sum t^3{}_b - \sum tb \qquad (6)$$

where tb equals the number of ties observed for a given rank.

To adjust for ties, we need to recalculate X_r^2 , the chi-square approximation with an equation is:

$$X_r^2 = \frac{12*R^2/\,(kb)\,(k+1) - 3b\,(k+1)}{1-\ \text{ties}/\,(kb)(b^3-1)} \qquad \text{(equation 4)} \qquad (7)$$

(Daniel 1978)

For calculation with Chi-square, where indication of b and/or k are not tabulated (Daniel 1978), one can then compare the X_r^2 for the significance of the tabulated Chi-square with k-1 degrees of freedom. If a significance difference exists between at least two experimental treatments evaluated, H_o can be rejected, H_1 : Not H_0 would be true indicating significant statistical difference between the treatments. Once the test indicates a statistical significance and error rate is α, a multiple comparison procedure is executed to determine which treatments are significantly different (Daniel 1978).

The significance difference between blocks can be determined as:

$$\left[Rj - Rj_1 \right] \geq z \sqrt{\ } kb(k+1)/6 \qquad (8)$$

$z = \alpha / k$ (k-1), which is found on the Table of Normal Distribution (Sheskin 2004). Rj and Rj_1 are treatment rank totals.

Chapter Summary

In summary, this chapter outlined the comparison of Friedman's Two-way non-parabolic equation using more than one treatment categorized and ranked. Equation for ties was included with a need to significant results for Chi-square. If Ho was rejected, multiple-comparison procedure needs to be used with the Friedman test to conclude which treatment ranked totals are different.

CHAPTER 4

RESULTS

For this study, there are basically two factors measured. The first factor size has been grouped into two treatments; less than 1200 ft², and more than 2000 ft². The second factor age, has been grouped into four treatments; 1900 to 1930, 1940 to 1965, 1965 to 1985, and 1989 to 2005. Each age group has been evaluated with the two sizes mentioned. Three homes were evaluated from 14 variables and averaged for each of the eight treatments.

Table 2. Treatment Sound Data Ranked

Space is less than 1200 ft²

	1901-1930 # 17, 20, 10		1940-1965 # 2,11,15		1965-1985 # 23,3,22		1989-2005 #18, 7,12	
Questions Evaluated	data	rank	data	rank	data	rank	data	rank
1a	39.5	8	37	7	33	4	34.6	5
1b	44.4	8	39	5	38	4	35.9	3

Space is greater than 2000 ft²

	1900-1930 # 14,16,6		1940-1965 # 19,4,8		1965-1985 # 9,24,21		1998-2005 # 13,1,5	
Questions Evaluated	data	rank	data	rank	data	rank	data	rank
1a	32.3	2	35.8	6	31.44	1	32.54	3
1b	35.88	2	40.7	7	31.57	1	39.44	6

1a- decibels inside residence
1b- decibels outside residence

This sound table references the grouping and ranking of the sound data collected. This data results indicate the lowest decibels registered was from homes aged 1965 to 1985 over 2000ft². Second lowest ranked was the larger oldest homes aged 1901 to 1930 over 2000ft². Third were the newest homes aged 1989 to 2005 irregardless of size.

Table 3. Treatment Touch Data Ranked

Space is less than 1200 ft²

	1901-1930 # 17, 20, 10		1940-1965 # 2,11,15		1965-1985 # 23,3,22		1989-2005 #18, 7,12	
Questions Evaluated	data	rank	data	rank	data	rank	data	rank
2	86.7	8	85	5	85	6	82	1.5

Space is greater than 2000 ft²

	1900-1930 # 14,16,6		1940-1965 # 19,4,8		1965-1985 # 9,24,21		1998-2005 # 13,1,5	
Questions Evaluated	data	rank	data	rank	data	rank	data	rank
2	84	4	85.67	7	82.34	3	82	1.5

2- total touch (max = 18)

Data collected for touch indicated the newest aged homes, 1989 to 2005, irregardless of size indicated the best results. Ranked third indicates the homes ages 1965 to 1985 over 2000ft².

Table 4. Treatment Sight Data Ranked

Space is less than 1200 ft^2

Questions Evaluated	1901-1930 # 17, 20, 10 data	rank	1940-1965 # 2,11,15 data	rank	1965-1985 # 23,3,22 data	rank	1989-2005 #18, 7,12 data	rank
3	92	3	96	8	93	4	51.2	1
3a	59.6	8	47	4	35	1	49.6	5
3b	98.7	8	98	5.5	97	4	97.2	3

Space is greater than 2000 ft^2

Questions Evaluated	1900-1930 #14,16,6 data	rank	1940-1965 #19,4,8 data	rank	1965-1985 #9,24,21 data	rank	1989-2005 #13,1,5 data	rank	Ties
3	95.67	6	96.09	7	66.08	2	93.58	5	
3a	53.34	6	57.5	7	38.34	2	43.75	3	
3b	98	7	97.67	5.5	96.67	2	96.34	1	2

3- average foot-candles
3a- average percentage of natural landscape from window
3b- sum of numbers (max. = 4)

The first and third best ranked homes are evident with the newest homes as the best irregardless of size. Second ranked are the homes aged 1965 to 1985 over 2000ft^2.

Table 5. Treatment Smell Data Ranked

Space is less than 1200 ft²

	1901-1930 # 17, 20, 10		1940-1965 # 2,11,15		1965-1985 # 23,3,22		1989-2005 #18, 7,12	
Questions Evaluated	data	rank	data	rank	data	rank	data	rank
5	0.06	7	0	4	0	8	0.04	5
5a1	0.11	7	0.1	1	0	8	0.1	6
5b	61.1	3	35	2	211	5	285	6
5c1	649	6	665	7	490	4	431	3
5d	10.4	7	15	8	4	1	6.29	3
5e	84.7	5	94	7	93	8	84	4
5f	11.3	6	12	7	9	4	18.1	8
5g	86.3	3	91	7	93	8	74.3	1

Space is greater than 2000 ft²

	1900-1930 # 14,16,6		1940-1965 # 19,4,8		1965-1985 # 9,24,21		1998-2005 # 13,1,5	
Questions Evaluated	data	rank	data	rank	data	rank	data	rank
5	0.039	2	0.039	2	0.039	2	0.0494	6
5a1	0.089	3.5	0.089	3.5	0.085	2	0.0914	5
5b	25.58	1	82.84	4	659.7	8	544.92	7
5c1	681.1	8	617.2	5	52.67	1	174.42	2
5d	9.07	4	9.62	6	5.11	2	9.19	5
5e	78.57	2	78.7	3	77.4	1	84.9	6
5f	5.61	2	10.1	5	6.58	3	3.94	1
5g	87.43	5	90.94	6	87.37	4	82.77	2

Indoor air quality was tested on different variables

5- TSI Dust Track- average inside
5a1- Difference between outside/inside
5b- ppbRAE- average inside
5c1- Difference between outside/inside
5d- Q-Trak: Humidity- average inside
5e- Q-Trak: Humidity- outside
5f- Q-Trak: Temperature- average inside
5g- Q-Trak: Temperature- outside

Results from smell, indoor air quality, ranked better in homes over the age of 1965 and over 2000ft².

IAQ Equipment Used

The best difference between the Dust Track results inside and outside was from the homes aged 1965 to 1985 over 2000ft^2. The difference was 75.5%, ranked second. The best data for the least amount of particles present inside indicated a tie for all home sizes over 2000ft^2, except the most recent age, 1998 to 2005.

The first rank was for homes smaller, 1940 to 1965, which could be due to the lack of occupants in the homes. Mostly, all the dust particles inside the homes were within .01 mg/m^3, except the smaller older homes. MIOSHA prefers the limit to non-toxic dust over an eight hour average to be 5mg/m^3 (P. Weinstein, personal communication, July 26, 2005). Though, none of the residents investigated were at this level, repeated measurement in the offices at MSU have indicated 0.050mg/m^3 dust as average. (P. Weinstein, personal communication, May 2, 2007).

The best data for the least amount of particles present inside registered by RAE was for the older homes. RAE Normal levels are between 200-500 ppb. Newer homes were higher; 1965 to 1985 over 2000ft^2 was 660 ppb, and 1998 to 2005 over 2000ft^2 was 545 ppb.

Measurement of relative humidity (RH) was determined, which is the percentage of water vapor in the air compared to the total amount of water vapor the same air could hold in any temperature (Richardson *et al.*, 2005). The most common limit recognized to prevent mold and dust mite proliferation is RH ≤ 45% (Munir *et al.*, 1995; Richardson *et al.*, 2005). Statistical results indicated the best homes aged 1965 to 1985 over 2000ft^2. The inside humidity measured 45.11 % RH with a difference from outside of 68 % RH. On the average the smaller homes had consistently higher rates.

Table 6. Treatment Totals Ranked with Squared Totals

Space is less than 1200 ft^2

	1901-1930 # 17, 20, 10		1940-1965 # 2,11,15		1965-1985 # 23,3,22		1989-2005 #18, 7,12	
	data	rank	data	rank	data	rank	data	rank
Ranked total	87	8	77.5	7	69	5	54.5	3.5
Squared total	7569		6006		4761		2970	

Space is greater than 2000 ft^2

	1900-1930 # 14,16,6		1940-1965 # 19,4,8		1965-1985 # 9,24,21		1998-2005 # 13,1,5	
	data	rank	data	rank	data	rank	data	rank
Ranked total	54.5	3.5	74	6	34	1	53.5	2
Squared total	2970		5476		1156		2862	

This table indicates the overall collection of data from treatment results. Homes between the ages of 1965 to1985 over 2000 ft^2 are evident as having the healthiest interior environments. The worse ranked home was smaller than 1200 ft^2 and between the ages of 1901 to 1930.

Accuracy Assessment with Ties

Table 7. Data Collection from equations

Sum of Squares	33771
Blocks	14
Treatments	8
Part1	402.036
Chi-Square	24.0357

To determine X_r^2. the equation with fourteen blocks, and eight treatments is:

$$X_r^2 = \frac{12}{bk(k+1)} \sum_{J=1}^{k} \langle \Sigma R_J \rangle^2 - 3b(k+1) \qquad (4)$$

$$= 12 * \langle \Sigma R_J \rangle^2 / (14*8) * (8+1)$$

$$= 402.036$$

(Daniel, 1978)

To get the results for Chi-square (X_r^2):

$$= 402.036 - (3 * (14 * (8+1))) = 24.036$$

Table 8. Treatment Data Ranked

Ties for 14 blocks

2	8	6
2	8	6
3	27	24

sum	42
total ties	4

The equation used below is the final adjustment for Chi-Square.

$$X_r^2 = 1- (42/(14 * 8)(14-1)) \tag{4}$$

$$= 0.97115$$

$$X_r^2 = 24.036/ 0.97115 = 24.7496$$

When considering the rejection of *Ho* where k -1 = 7 degrees of freedom, the reliability between the sum of the squares being as large as 24.7496 with $p \leq 0.01$ indicates that *Ho* can be rejected. Where α 0.05 at is 14.067 at (k-1) = 7 degrees of freedom, and α 0.01 at $df = 7$ is 18.475. This result indicates a significant difference in at least one of the treatments evaluated.

When rejecting the *Ho* from Friedman analysis, it is best to know where the difference occurred. Searching for the value of z helps to evaluate the comparison between all the treatment results.

$$z = \alpha / k(k\text{-}1) \quad 0.05/8*7 = 0.00089 \; = \; 0.001 \tag{5}$$

When using z as:

Where 0.001- 0.05= 0.499 illustrating $z = 3.08$

Now knowing the value of z, the number can be used to insert into the equation for multiple comparison to determine the least value needed for the differences between the treatment rank totals (Daniel, 1978).

$$z = \sqrt{} \, bk(k+1)/\, 6 = \sqrt{} \, 14*8*9/6 \tag{6}$$

$$= 3.08 \sqrt{} \, 168$$

$$= 39.921$$

The following table indicates the differences between the sums of the ranks.

Table 9. Treatment Ranked Totals

	Rank 1 minus other ranks					
Rank		Rank 2				
2	-19.5		Rank 3			
3.5	-20.5	-1		Rank 5		
3.5	-20.5	-1			Rank 6	
5	-35	-15.5	-14.5			Rank 7
6	-40	-20.5	-19.5	-5		
7	-43.5	-24	-23	-8.5	-3.5	
8	-53	-33.5	-32.5	-18	-13	-9.5

These testing results recognized rank one is the treatment aged 1965 to 1985 over 2000ft^2 as the best rank. This treatment is compared with the other seven treatments to determine the greatest significance. This difference is represented by the homes between the ages of 1901 to 1930 and 1940 to 1965 both under 1200ft^2.

CHAPTER 5

CONCLUSION AND DISCUSSION

The statistical data collected from this thesis clearly indicated that homes built from 1965 to 1985 with over 2000ft^2 were healthier. The results of this four-sense evaluation indicated, with significance $\alpha = 0.05$, the least healthy homes were those aged from 1903 to 1940, and 1940 to 1965 and smaller than 1200ft^2. Many considerations come to mind as to what would cause these differences.

It appears that during the years of 1965 to 1985 the American work ethic was strong. Most white collar individuals remained in their jobs for a lifetime. It was uncommon to switch jobs unless something was drastically wrong. Quality of workmanship was the prize of the laborer. Many products did not cost much, and most materials were constructed in the United States. The concept of "plenty" was prevalent. Petroleum for the automobiles seemed to be in endless supply. As for potential for global warming and air pollution- "What is that?"

This is also the time where the "the bigger, the better" concept grew. The wealthy wanted homes built to be the biggest and best and were able to afford larger "white elephant" homes. These homes did not consider size in relation to energy efficiency. Many homes had large rooms with many windows and high ceilings. Not only were construction projects and labor for installation more financially efficient, but also construction materials were more affordable. This could allow the homeowner to spend more money for extravagant details. More attention was devoted to having the best; and each room seemed to have one designated function. These attributes could be seen in the fabric and finishes that created a more extravagant environment while maintaining functionality of the space.

Since land was plentiful, homes stood on larger lots, therefore homeowner's did not have to look at their neighbors through windows. Residents were able to have more natural light with landscape views. Homes were closer to uninhabited habitats which could produce natural soothing noises, such as birds singing. With the homes set further away from the street, the impact of man-made noise could be limited. This image could also produce an image of privacy. Privacy can help with feelings of calmness and relaxation. These homes exhibited evidence of a healthier interior environment, even at a time when a consideration for a healthy environment was not recognized during the construction process.

This thesis data indicated evidence that even in the home with the best natural light, there was only enough illumination for ambient lighting. The best average was measured between 35-50 foot-candles in the homes between the ages of 1965 to 1985. The third ranked were residents aged 1985 to 2005 and over 2000ft^2.

It was not until 1984 that Ulrich discovered the positive influence windows had on the health of hospital patients, and Rosenthal realized the effects of full-spectrum light on SAD patients. Human need for natural daylight was not well understood before that time and was not taken into account in the construction process for home built before 1985. But after that date, and more recently, research on the effects of daylight helped persuade builders that larger, more influential homes should have taller windows that would let in more natural light.

Interior visual influences became stronger during these years not only with the promotion of decorating as an occupation, but as more impressive architects emerged with Post-Modernism. After the simplicity of Modernism, the Post-Modernism era tried to add detail using building construction as variety and communication to the public (Wikimedia.com). Ornamental woodworking influenced homes to have more vernacular, custom details including: balconies, porches, and other embellishments. More wood interest flourished, as evident in the interior designs of Frank Lloyd Wright and the Arts and Crafts movement. Wood concepts from other famous designers, Ray and Charles Eames and George Nelson, also influenced interior residential and furniture design.

The realization of affluent interior environments in relation to human size became obvious. An example of this is the location of the furniture in the public living environment. Furniture placement influenced the ease of social interactions as well as visual balance for comfort and relaxation. This impact could be seen with texture, color, scale, light, and space as it flowed from one room to another. The emphasis of the outside environment blending with the inside environment is evident with designs from Frank Lloyd Wright. More time and interest were spent on colors, shapes and furniture location interacting with interior architecture, as observed with Eliel Saarinen's home at Cranbrook Institute of Art, Bloomfield Hills, MI. His wife color-coordinated the book covers on the shelves to match the rugs on the floor, and upholstery fabric on the chairs. As these great design concepts proliferated, distinguished individuals desired to have more.

These data indicated the homes from 1985 to 2005 were best for aesthetic persuasion, and homes from 1965 to1985 over 2000ft^2 ranked 3rd. Increased production and awareness of finish selections, as well as construction and design processes could have persuaded homeowners to seek more knowledge and better choices after 1985.

Homes during 1965 to 1985 were larger, which may have required larger, and thus better, HVAC systems supporting improved circulation. The building process did not demand tighter construction that could have increased ventilation from the outside air. This would have reduced the interior air pollutants, as well as dust and moisture concentrations, thus adding to a healthier environment.

The idea mentioned above is not indicated in these treatment data. The largest, newest home was ranked sixth. One of the homes tested had carpet installed just the day before. The homeowner then indicated that the HVAC vents had not been cleaned since construction, when the heat was on most of the time. These coincidences remind the evaluator of different variables that were not considered during data collection. It would be interesting to continue this study with uninterrupted dust particle readings to indicate how long the particles last, when they would decrease, and at what rate that would happen.

In considering the sense of taste, the quality of interior water was used for this evaluation. Difficulty in determining additional criteria for the water before it entered the home caused recognition of inaccurate data. Variables that could influence water are: location and condition of water before it enters treatment plants, treatment plant's filtration system in the area, pipes used for water to travel to the home, pipes within the home, filtration system of water within the home. Another consideration was the age of the homes. Very few, if any, of these homes twenty years ago considered the need for filtration or purification system for the water entering the home. The concept of water being impure, or contaminated was not even considered, which is quite different from today. Because the homeowner has no control over water entering the home, healthier water by purification needs to be considered as water enters the home.

Conclusion

Evidence collected from this thesis has heightened awareness that further inquiry is needed to consider the health of different elements used in residential interior environments. This information could persuade design professionals to contemplate sustainable construction applications and products, drawing on their knowledge and development of design practice. Sustainable implementations existing in health care facilities and office environments already offer scientifically based evidence. These spaces were considered first by focusing on increased human production during work (office), as well as physical healing for quick release of patients from healthcare settings. It has been only in the last couple of years that more attention has been given the construction of homes, where individuals also spend much of their time.

The LEED-Homes, developed by USGBC, has just this year finished its pilot study. There are nine areas of focus used to gain points for certification. This study compliments LEED-Homes in areas of Energy and Atmospheric efficiency, Indoor Environmental Quality (IEQ), Materials and Resources, Sustainable Sites, Innovation and Design Process, and Public Education. Most of the points are gained by recognition of energy and waste conservation. IEQ promotes purer quality by stipulating decreased moisture and toxic gases with the instillation of efficient ventilation and insulation. Site location encourages effective landscaping for insulation as well as increased natural light. Sustainable design needs to start with the concept of the building style as it is recorded on paper. This can promote sustainable construction materials, processes and finishes. Unfortunately, at this present time, sustainable products and processes have a greater up-front cost to the homeowner. Increased education can promote a better understanding of the long-term savings, as well as encourage smoother transition for continued energy conservation. This study further verifies the necessity for healthier residential environments as a complement to sustainable construction.

Environments that positively influence emotions can also have a healthier impact. Holistically, psychological perceptions can alter physiological changes. For example, an individual in a high stress occupation is more prone to hypertension and heart attacks. Altering design to promote positively engaging interior environments can improve psychological and physical health. Promoting Maslow's level for social needs can be encouraged by considering to furniture placement to encourage social interaction; by providing a view of more natural light with privacy or a picturesque view, and by decreasing unwanted sounds. Environments designed to promote the uniqueness and giftedness of the occupant can further fulfill their need for self-actualization. Promotion of individual needs by interaction within the environment can encourage healthier psychological changes.

Truly environmentally healthy designs can be instituted where the designer creates an environment that promotes health for the occupant, depending upon their physical, psychological or social needs. With consideration to this thesis, and the five senses mentioned, design and construction could be formulated with evidence-based data to recognize healthy attributes for the encouragement and maintenance of healthy interior environments. For example, a design for an individual's home with SAD disease could specify a lot of tall windows, using mostly southern exposure, three sky-lights facing the south, and light bulbs that were at least 5500°K. These effects would increase the full spectrum amount of light in a room and decrease SAD symptoms during the fall/winter months when there is less natural light.

Limitations

Data collected from this study results from the homes located in and around Holland, Michigan. It could be said that this data significance can only be specific to a certain location. Further evaluation needs to be constructed for data collected from homes in another part of the country, or even another country, in order to have a more diverse perspective on the interior criteria and construction needed to promote healthy interior residential environments.

The only treatment considerations to the homes researched was with the diversity of age and size. There may be some other treatments not considered.

Some of the homes evaluated were not occupied and had been empty for months. It would be interesting to determine how the statistical data collected would be altered depending upon longevity and activity of occupants present. The literature review also mentioned a relation between human pollutants and the number of occupants in the home, as well as the activities within the home.

Sound changes under the influence of temperature, humidity, and the medium the sound wave travels through. Sound changes measured for this study were not as accurate without these considerations. This information was not considered, as inside and outside measurements took place at sporadic times of the day. This brings to mind the cause of the sound variation, whether it is due to the outside wall construction or the density of the medium the sound traveled through. There was also a lack of consideration as to whether a specific time of the day was noisier. In the vacant homes a true determination of the correct amount of indoor sound, could not be specified, considering medium, or lack thereof.

Because of the scope of the data collected with the resources available, it was not possible to establish controlled environment for a more accurate determination of natural light. Foot-candles measured were at non-specific times of the day. Other limiting factors not considered; window height, size, location in relation to the sun, time of the day, season, and amount of window reflection or tint.

Urban or rural locations of the homes were not observed for differences. This would influence the amount of natural landscaping viewed, as well as the amount of natural light. Exterior locations could also limit the residential size and height. The floor level of a urban home could alter window data. Smell could be more obvious in urban environments, and thus influence IAQ.

Room size with ceiling height was not considered for observation in relationship to visual aesthetics or window height. Differences in the amount of natural light and sound could be evident, depending upon the finishes specified. Aesthetic comfort could be altered by finish specification and relation of furniture in space. A smaller sized room may only have enough furniture for two people vs. larger space for social interaction with six to eight people.

Function of space evaluated was not indicated. Obvious spatial function was recognized, but consideration to multiple functions was not addressed. A room that has multiple purposes may have finishes that are indicated for more than one function. An example of this can be seen with a kitchen that is used for cooking as well as for adult socialization and interaction with children doing homework. The multiple functions of this space with design could indicate a large island with non-porous surfaces and seating, increased illumination, and more square footage for storage.

HVAC equipment within the homes was not considered as to age, size, filtration, quality and function. The variation of this equipment could alter the measurements of the IAQ. Consideration also needs to be given to humidity and temperature levels and regulation.

The Q-Trak measurements taken are a good indication of the amount of particles within the air, but not to the particles collected in materials and to their location within the homes. Perhaps the locations used the most would indicate the most particles within the atmosphere. Some determination has been with porous materials that harbor more airborne particles. Materials located in certain areas in the home and the use of those spaces was not considered with this study.

Additional Research

The evaluation from this study dictates further study in these areas to improve the accuracy and knowledge of health related design principles.

The additional research for the effects of sound from electronic equipment as evident with surround sound TV's, cell phones, computers, and other electronic devices. Consideration about how these devices influence human health either through noise or touch.

One concern that the author has realized being in a home using Energy Star was the increased interior level of noise. Though the non-porous, solid surfaces were used to decrease absorption of chemicals, toxins or other harmful materials, noise reverberated off these surfaces. Some area rugs on the center of the floor, and some fabrics on the furniture provided softer surfaces. The decreased absorption of sound could decrease feelings of relaxation and thus add more stress. This raises the question of the definition of sustainable and environmental protection from noise pollution. Study the evidence of noise as it relates to interior sustainable finishes and considers an investigation that needs to recognize the significance of an individual's perception of the noise with consideration for sustainable planning (Soneryd, 2004).

A study is needed that relates to the design significance of walls, custom storage, private and public spaces as they interact with finishes, sound and light. It would be interesting to understand how important separation of space feels in relation to function, and what differences there need to be in relation to function of the space toward sound and light.

More research about the conservation of energy with consideration to the design criteria when specifying window placement, water and heat usage, placement of private vs. public spaces, or location of other functioning spaces. An example of this can be the conscious placement of windows higher and mostly on the southern exposure for increased natural light. More natural light is healthier in spaces where more daytime activity takes place.

A study to understand the relationship of the size of furniture as it relates to size of the space and humans. Questions come to mind: Could there be a health effect related to the placement of furniture in a room? Could the size of the room in relationship to the size of the occupant promote health? Is big really better?

The psychological impact of a healthy environment needs better research. Questions not considered in this thesis arise. If Maslow's Hierarchy of Needs speculates that different levels of needs are indicative of different ages, does the perception of a healthy environment change with the age of the individual? What would those changes be and are they related to physical or mental health? How would home design change relative to the individual's level of health? Could this be the same for every individual regardless of culture and race?

Not enough studies have indicated whether a view of natural environments is a source of pleasure to all individuals regardless of ethnic diversity. Individuals could consider exterior environments differently, depending upon the environment they were raised in. Design plans would need to consider views, as well as natural elements impacting the interior space. Frank Lloyd Wright's use of rocks and water close to the home may not be enjoyable for every individual. More research to determine the best energy efficient, cost conscious source of home heating. This data collected could be used to educated builders and homeowners about HVAC systems that are sustainable and more efficient. This education would also better acknowledge a need for better ventilation, as well as outdoor/indoor air exchange, quality systems with filters that decrease dust particles, gases, and regulate temperature and humidity.

More research about the effect of alterations in temperature and humidity can have on individual health related issues: viruses, flu like symptoms, etc. It would be beneficial to know what the healthiest temperate and humidity is for health.

It would be important to have better understanding about the interactive factors involved within interior environments. This could be with materials and/or construction processes. As one recent study indicates, significance of the absorption rate of materials specified can alter apparent air quality and possibly decrease ventilation rates (Sakr *et al.*, 2006). An example of this can be how plants can help to purify the air and increase absorption of toxins.

Most research about water seems to indicate a potential for increased contaminants. There could be more research about the other factors that come in contact with water that could influence the purity. This brings to mind other uncontrollable variables that could influence water health. What if the water was from a well instead of city water? What if individuals had water filters or softeners that indicated a lower amount of contaminant? What if the pipes constructed from the water source to the home indicated more contaminants and the home owner was not aware of the differences?

Much research has been done regarding the influence of color on individual emotions. Because color is a wavelength interpreted by the sensors in the cones of the eyes, which is then transmitted to the brain for clarification, subjective information is given. Still, research regarding the psychological influence of color as it relates to the functions within residential environments needs more consideration for better design and influence on individual health.

More research is needed on the ability of the interior environment to provide an emotional engaging awareness. The interior factors that could determine certain emotional experiences from an individual are not clearly understood. Music and smell might influence certain emotions. Maybe there are emotional impressions that certain visual finishes can evoke.

This research considered the interior residential environments with evaluation tools relating to the five senses. There could be research about the consideration of a healthy interior environment when an individual lacked one of their senses. Some considerations could be: what can be done to better communicate healthier environments? This then precipitates the question, what other ways are there to determine the safety of residential interiors?

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APPENDIX

Appendix A

Table A1. Five Sense Health Evaluations
For Residential Spaces

1-Sound-

Measure the decimals of the loudest sound outside the home at the present time. Also, measure the decibels of the same sound inside the house in the center of the main living area.

Decibels Inside______________________________________

Decibels Outside____________________________________

This measurement will help to determine the "sound nuance" inside the house to outside the house.

Ask the participant:

Time of day of loudest noise___________________________

Type of noise heard__________________________________

2-Touch-

Using surfaces of the environment (ceiling, floor, fabric, walls and countertops), walk through the main living area, kitchen, and master bedroom and bathroom in the home to determine the transition of the surfaces mentioned above and how they flow from one space to the other. Determine if the surfaces used in the environment were the right application for the space once in the space and consider the function of the space. Give one point for each space if the application was correct and felt good, and the transition was acceptable with adjacent spaces. Give zero points if not comfortable.

Main Living Area
Ceiling______Floor______Fabric______Walls______Countertop_____
Kitchen
Ceiling______Floor______Fabric______Walls______Countertop_____
Master Suite
Ceiling______Floor______Fabric______Walls______Countertop_____
Bathroom
Ceiling______Floor______Fabric______Walls______Countertop_____

Table A1. (con't)

3-Sight/Light-

Using a light meter, measure the foot-candles of light from the center of the main living area, kitchen, master bedroom and bathroom at waist height (36" high) using no electricity. Add up the number of foot-candles and divide by the number of rooms evaluated to determine an average. A system will be developed to be sure that the measurement of the light meter in each space will be at the same height.

Main Living Area ________________Kitchen____________________
Master Suite ____________________Bathroom__________________

3a-Sight/Scenery-

From certain windows in the home, stand back one meter (three feet), and determine the percentage of the view to be natural and the percentage of the view to be man made. Find the average for the spaces by adding up the total percentages and divide by the number of windows viewed. Rooms used will be: main living area, kitchen and master bedroom and bath. All rooms in each space will be viewed and evaluated.

Main Living Area- ____

____

Kitchen-____

____

Master Suite-____

____

Bathroom____

____

Table A1. (con't)

3b-Sight/Anthropometrics

This evaluation concerns the movement of the human body to perform a task with efficiency and comfort in the space intended. Each space will be evaluated by the listed criteria below. One point will be given for an effective application and zero points for not.

Main Living Area- Seating area that allows for social interaction as well as individual tasks, centered around at least one focal point.

____

____

Kitchen- A basic triangle is visualized between the stove, refrigerator and sink for the best effective use of space.

____

____

Master Suite- The scale and placement of the bed with respect to the master bathroom and closet placement.

____

____

Bathroom- Flexibility and available space that allows for movement with consideration to placement of the sink, shower and toilet.

____

____

4-Taste-

Check the amount of total dissolved solids in the water in the house by sampling the water from the kitchen sink. The water collected will be tested fro concentration of particles. This will help to determine purity of water in the home. Type of pipes in the house will also be a consideration.

Sample collected in a new, clean container____________________

Type of pipes in the house______________________________

Attached evaluation of water collected______________________

Table A1. (con't)

5-Smell-

Determine the air quality by standing in the center of the main living area, kitchen and master bedroom and bath. The use of held hand meters will help to determine the purity of the inside air. The Qtrak can measure Co2, CO, temperature and humidity. The TSI Dust Track and RAE will measure PPB (particles per billion). This will help to determine the concentration of foreign particles in the air. Each device will be held in the center of the space to determine a reading.

Main Living Area-
Qtrak____
TSI Dust Track_______________________RAE________________

Kitchen-
Qtrak____
TSI Dust Track_______________________RAE________________

Master Suite-
Qtrak____
TSI Dust Track_______________________RAE________________

Bathroom-
Qtrak____
TSI Dust Track_______________________RAE________________

Outside air-
Qtrak____
TSI Dust Track_______________________RAE________________

Information about the home to be evaluated:

City home is located in____
Year home was built_______________ Square feet____________________
Number of people living in the home_______________________________
Number of pets living in home_____________________________________

Evaluated by______________________________Date_________________

Table A2. Consent Form For Research Survey
Five Sense Health Evaluations

I am a graduate student at MSU. I am conducting a survey specific to my thesis. I have a four-page research survey that I would like to use on this house. I am going to use some hand held equipment for measuring sound and particles in the indoor air, temperature and humidity. A light meter will be used to determine the amount of natural light in interior spaces. I would like to obtain a sample of water from the kitchen sink to determine the amount of particles in the water.

The data collected will be confidential and used only for the purpose of this thesis. No addresses for the participants will be documented or given out. Therefore, there will be no information regarding the location of the home, or value of the home be publicly released. No one will be notified of any information that will effect the property value of the home. There will be nothing left behind, and no tool collected will touch the homeowner, or the interior environment, except the floor. Therefore, there are no risks or benefits to the homeowner. The purpose of this research survey is to collect and measure real data for my thesis.

This participation on your part is totally voluntary. You may choose not to participate at all, or you may refuse to participate in certain procedures or answer certain questions or discontinue your participation at any time without penalty or loss of benefits. One copy of this consent form will go to you.

If there is anything found that is to be harmful to your health, you, the homeowner, will be made aware of the concerns noticed. Because the researcher is not an expert, the homeowner could be advised to seek expert advise if a concern for public safety arises. This research survey is solely for the purpose of a thesis. Broad, general results may be published.

If you have any questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this research study, you may contact- anonymously, if you wish:

Peter Vasilenko, PhD. Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: 517-355-2180, Fax: 517-432-4503, email: ucrihs@msu.edu or regular mail: 202 Olds Hall, East Lansing, MI 48824.

Investigator: Dr. Jon Burley, PhD
College of Planning, Design and Construction
MSU, E. Lansing, MI 48824
517-353-7880 email: burleyj@msu.edu

Researcher: Morna Hallsaxton, MSU Graduate student

I voluntarily agree to participate in this research study.

Participant______________________________ Date__________