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Printer:  PrintPartners Ipskamp B.V. Enschede

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Beyond Comfort in Built Environments

Proefschrift

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus, prof. ir. K.C.A.M. Luyben,
voorzitter van het College voor Promoties,
in het openbaar te verdedigen op
donderdag 24 september om 12.30 uur

door

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Samenstelling promotiecommissie:
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Onafhankelijke leden:
Prof. dr. H. Bubb, 
Prof. dr. ir. D.J. van Eijk, 
Prof. dr. ir. D.V. Keyson, 
Prof. dr. C. Katzeff, 
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Technische Universiteit Munchen, 
Technische Universiteit Delft, 
Technische Universiteit Delft, 
Interactive Institute, Swedish ICT, 
Liberty Mutual Research Institute for Safety, USA 
Technische Universiteit Delft, reservelid 

ISBN: 978-0-979496308-7
NUR-code: 964
Table of Contents

Table of Contents v

1 Introduction Beyond Comfort in Built Interior Environments 1

2a Patterns of Discomfort 35

2b Influence of Expectations and Pre-experiences on Comfort at Work 55

3 Changing the View of Workspace from Inside to Outside 67

4 Possibilities to Improve Aircraft Interior Comfort Experience 83

5a Retro to New-Retro: Challenges to Planning & Designing Nine Control Room Layouts 99

5b Expectation Changes and Team Characteristics in a Participatory Design Process 111

6 Interior Effects on Comfort in Healthcare Waiting Areas 129

7 Environmental Comfort Design Considerations for Future Control Room Interiors 161

8 Reflections and Conclusions 183

Acknowledgements 207

Curriculum Vitae 209

Publications 210
CHAPTER 1
INTRODUCTION
1 Introduction
Beyond Comfort in Built Interior Environments

Today every person on the planet lives a significant portion of his or her life in a built indoor environment. In the early Paleolithic period, the indoor environment was a cave. A built environment is not a cave but rather a natural ideal environment for protection from the outside elements, an early prototype for future indoor built environments. Some environmental designers believe the beginning of environmental design traces back to the paintings on the walls of these caves, as it is the human hand, which influences the interior. The paintings represent a connection to nature and events occurring outside the cave (Figure 1). The paintings may be the beginning of communicating visual narratives to a larger audience through sensory communication (The Maude Group, 2013). “Buildings do not merely provide physical shelter and protection; they also mediate between the world and the human consciousness” (Pallasmaa, 2013). Current environmental design is much more complex than the protection of a cave from outside elements and paintings connecting the inside to the outside world.

![Figure 1. An image of a horse from the Lascaux caves in France (Lascaux2, 2007).](image)

It could be said that the interaction between humans and their environment or ‘human factors’ began when early humans fashioned simple tools and utensils. Tools such as those used to paint the horse on
the cave wall in Figure 1, although the modern evolution of ergonomics and human factors as a technology started in the late 1880s (Hawkins, 1987). Human factors focus on human beings and their interaction with the environment and items used for work and everyday living (Norman, 1988). The benefits of including good ergonomics and human factor principles in a system that involves human interaction, far outweigh the costs (Hendrick, 1996).

This PhD thesis addresses two specific areas within human factors: the environmental design and macroergonomic areas. According to the Environmental Design Technical Group (EDTG) of the Human Factors and Ergonomics Society (HFES, 2014), “Environmental design is the discipline concerned with the relationship between human behavior and the designed environment” (EDTG-HFES, 2014). For this PhD thesis the term ‘designed environments’ is replaced with ‘built environments’ to make clear the distinction does not wholly concern sustainability. Additionally, “built environment” generally refers to the interior of a built environment. The majority of the following Chapters and studies discuss research and findings in the ‘built interior environment’. Several of the following Chapters research the aspects of participation and teamwork and move into the realm of the macroergonomic area of human factors. Macroergonomics is defined as, “the study of productivity and quality of work life improvements by an integration of psychosocial, cultural, and technological factors with human-machine performance interface factors in the design of jobs, workstations, organizations, and related management systems” (METG-HFES, 2014).

The research for this PhD thesis introduces and describes various aspects of environmental comfort: environmental design, the research of comfort, comfort and holistic design models, the research question and three elements to consider when designing for built environments, and an outline of the contents of the additional chapters. It considers improvements for the built interior design process and focuses on three elements, from a multitude of possible elements, which exist in a comfortable built interior. Additionally, this PhD thesis encourages those involved in the design process i.e., architects’, engineers, and designers, to consider a holistic design process for a comfortable built interior environment.

ENVIRONMENTAL COMFORT

Ong (2013) coined the term, environmental comfort, although the topic itself is older and taught at all architecture schools. Traditionally, the
comfort criteria in the design of the built environment include light, sound, heat and air quality (Ong, 2013). All of these influence physical comfort.

Light in this context, is defined in terms of adequate brightness, lack of glare, neutrality of color. The noticing of actual daylight or a sense of outdoor light may help with the sense of time. There are lighting comfort standards and visual comfort standards (e.g. ISO 8995-1:2002, Lighting of work places), but there are many unknowns about the effect of light (Bakker, 2014).

Sound influences comfort as well. It is more true to the standard measurements than are temperature and light. An example of the influence of sound on other people is the study by Hongisto (2005). Hongisto (2005) showed that distracting noise can reduce productivity by 7% in performing complex tasks and can cause stress.

Although important for comfort, heat or thermal temperature is not considered one of the five senses (de Dear & Brager, 1998, & de Dear & Brager, 2002). For instance, Kosonen & Tan (2004) concluded, based on questionnaires, that reducing the temperature from $27^\circ$ to $21^\circ$ C increases worker productivity by 30%. Temperature is the number one complaint by workplace occupants and affects both productivity and health (Vink, 2005).

Air quality is a growing issue in buildings, as well as outdoors, especially in large cities (Ong, 2013). Circulating fresh outside air is best according to Ong (2013), but not always practical depending on the building location, outside temperature, noise or pollutants.

These physical characteristics are often associated with Environmental Design. The International Society for Environmental Ergonomics mentions the focus areas on their website: Climate (temperature, humidity, and heat radiation), Noise, Vibration, Lighting, and Pressure. Additionally, there are many studies found in the annual Human Factors and Ergonomics Society (HFES) conference proceedings. The HFES, Environmental Design Technical Group (EDTG) focuses on specific parts of the environment such as seating, computer settings and interior design. For instance, the HFES EDTG meeting in 2014 consisted of papers about vehicle interiors, classroom interiors, computer devices, open plan offices and hospital interiors (Proceedings of HFES 2014, 2014).

The above-mentioned studies usually observed a part in the environment (e.g. a seat (Franz, 2011) or the use of a computer device (Albin et al., 2014). Additionally, mono-disciplinary studies were conducted regarding temperature (de Dear & Brager, 1997), light (Ariens & Zonneveldt, 2005), noise (Hongisto, 2005) and air quality (World Health Organization, 2010).

Chappells & Shove (2005) discussed thermal comfort as two constructs, a universal physiological construct or a negotiable socio-cultural construct.
Comfort from a universal physiological construct views properties offered by the surroundings, not as an experience of the person. The thermal model, the predicted mean vote (PMV) model considered people as more or less passive receptors of the environment (Roelofsen, 2013). An alternative way of looking at comfort is as a 'highly negotiable socio-cultural construct', according to Chappells & Shove, (2005), and observes comfort as 'an achievement, rather than an attribute'. A consequence of this recognition was that 'comfortable' means an environment in which people could make themselves comfortable; i.e., an environment that offers sufficient possibilities or opportunities for adjustment and adaptation to achieve comfort (Chappells & Shove, 2005; Shove et al., 2008). Opportunities to achieve comfort are relevant for all to interact with their environments, modify their behaviors and gradually adapt their expectations to match their surroundings. In today's world, research on crowd control has many more possibilities (Li, 2013). In Wang’s (2014) first experiments, all occupants gave preferences for the indoor temperature and automated heating and cooling systems, which calculated an average. From a built surroundings standpoint, this meant occupants might possibly control opening and closing the windows, manipulating thermostats, using crowd temperature determination, and putting up sunscreens.

Another recurring issue with this view on comfort as a fixed condition is the dismissal of variety. Critiques of the PMV model state that ‘psychological factors’ are not taken into account. For example, Rohles et al., (1980) in their ‘psychologist look at comfort’ adjusted the interior design of a room, (e.g., add carpets, wood panels, and comfortable furniture) but did not change the thermal parameters for the room; however the occupants perceived the room warmer than it actually was. In fact, by announcing to people that the room temperature was higher than it actually was had the same effect. Scholars in the thermal model field recognize that psychological aspects are ‘important factors’ in the experience of thermal comfort (Veen & Vink, 2014). However, psychological aspects tend to be dismissed as difficult to quantify or 'very hard to deal with' (Höppe, 2002).

Additionally, the laboratory models are often not accurate for predicting actual experiences of comfort. When researchers go out into the field to test their predictions, they are sometimes surprised by contradictions of their models. Apparently, people feel comfortable within a much wider range of climatic conditions than the models predict (Goldsmith, 1960; Höppe & Seidl, 1991; Nicol et al., 1999).

At present, the research literature available focuses primarily on physical comfort in environmental design. However, more research and studies are emerging to include the psychological and socio-cultural aspects. The study of aircraft interior comfort (Vink & Brauer, 2011) shows that contact
with the crew can increase or reduce comfort. In this study, the average score of eight was for the flights with positive crew comments, compared with 3.9 in the case of a complaint. Despite, the research conducted in various areas there are still many examples of inappropriately built environments. The aircraft interior is an example of the term known as ‘not connected’ to the human condition (Vink et al., 2012). The ‘comfort’ in waiting rooms and offices also shows room for improvement (Bazley et al., 2010). The technological developments and performance requirements in control rooms ask for new design considerations for comfortable interiors (Bazley et al., 2014). Although a number of studies conducted in these areas are published, in practice there is room for improvement, because good reasoning and clear standards and guidelines are missing.

**COMFORT AND COMFORT MODELS**

In most comfort models, the physiological aspects receive the most attention, while the psychological and socio-cultural, although important, are less often mentioned. An example of a physiological model is the discomfort pyramid (Bubb, 2008) demonstrating that if the environment is unpleasant, the physical conditions will ultimately overrule all other factors if not addressed. This model contains the elements for physiological environmental design of heat, light, sound, air towards the bottom of the pyramid and the added ergonomics or human body physical comfortable fit (anthropometry) at the top of the pyramid (Figure 2).

![Figure 2. Bubb Discomfort Pyramid model (2008).](image-url)
The De Looze et al., (2003) comfort model shows only one block of psychological comfort, emotions and expectations (Figure 3).

These theoretical statements are proven partly for pressure between seat and human, temperature, but also pertain to color, e.g., lighting. However, this theoretical concept conflicts with current models and standards and not applied in many designs.

Vink & Hallbeck (2012) also present a comfort model (Figure 4) inspired by the model of Moes (2005) and De Looze et al., (2003).
This model simplifies the steps that influence the comfort/discomfort experience. The interaction (I) between a product (P) and a person (P) starts in an environment where the person is doing a specific activity (U=Usage). This interaction (I) can result in internal human body effects (H), such as changes in the human sensors, tactile sensations, body posture change, blood flow changes and muscle activation. The perceived effects (P) are influenced by the human body responses, and by expectations (E). As previously mentioned, expectations influence perception and therefore the comfort or discomfort score. The outcome is feeling comfortable (C) or (N) nothing or feelings of discomfort (D). The comfort experience and to what extreme the comfort or discomfort is different for each person. The (M) indicates extreme discomfort and possible musculoskeletal issues. The circled (E) and (C) indicate that expectation is often linked to comfort. A feedback loop shows that a person may change or alter the discomfort (Vink & Hallbeck, 2012).

Participatory ergonomics focuses on how to involve people in decisions, which directly affect their comfort and well-being. The aim is to match the technological developments and requirements of a business, or in this case a built environment, to the human needs of the proposed activity (Koro & Amada, 1991; Wilson & Haines, 1997).

Ideally, a user centered design process places the user (human) at the center of the design process of a system, product or building design accommodates to the needs of the user. Visccher (2008) proposed a ‘user center theory’ for the built environment of offices by utilizing the participatory design process to link the macro perspective of producing and delivering a built environment and micro user experience to provide environmental support for peoples activities. In this PhD thesis, Chapter 3, Chapter 5b and Chapter 7, discuss the use of participatory design and user centered design processes.

Konieczny (2001) concluded that the changing environment of comfort in service is dependent on the pre-experience and attitude of a person. He considered three main elements to access pre-experiences and attitudes for flight travel: Hardware (e.g. airport signs, walking distance, and toilets), Software (waiting and boarding times) and Lifeware (staff competencies and personal support). He concluded that pre-experiences and attitude toward flight correlated with the flight outcome. Bazley et al. (2010) modified the Konieczny model (Table 1) and exchanged hardware for physical comfort, and separated psychological into two categories, intellectual and emotional. Intellectual comfort replaced Software and emotional comfort replaced Lifeware.

The word psychological is used throughout this book but sometimes it is referred as intellectual. Although technically and emotional is included in the realm of psychological, for the purpose of discussing several of the case
studies in this book, psychological will be shown as psychological (intellectual) and emotional. The reasoning behind this distinction is that for several of the case studies a clear distinction between what a person thought and what a person felt was important. The separation of the word psychological into intellectual and emotional was necessary.

Table 1. A modified version of Konieczny's (2001) table of pre-experiences for flight shows an example of elements for pre-comfort experiences where pre-experience for work elements may occupy more than one comfort type (Bazley et al., 2010).

<table>
<thead>
<tr>
<th>Comfort Type</th>
<th>Pre-Experiences (Elements)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>Buildings</td>
</tr>
<tr>
<td></td>
<td>Roadway</td>
</tr>
<tr>
<td></td>
<td>People</td>
</tr>
<tr>
<td></td>
<td>Sunrise</td>
</tr>
<tr>
<td>Intellectual</td>
<td>Looking forward to work</td>
</tr>
<tr>
<td></td>
<td>Talking</td>
</tr>
<tr>
<td></td>
<td>Singing</td>
</tr>
<tr>
<td>Emotional</td>
<td>Colors</td>
</tr>
<tr>
<td></td>
<td>Upset</td>
</tr>
<tr>
<td></td>
<td>Excited</td>
</tr>
</tbody>
</table>

Bazley et al., (2010) found the most significant pre-comfort experience variable was the visual images seen along the way to an appointment and the second most significant variable was the audio experience. A statistically significant relationship between physical and intellectual comfort levels suggested that the pre-comfort experience variables had a positive effect on the physical and intellectual comfort levels. Previous office visits or attitudes about the office, visits, and experiences, which happened earlier in the day demonstrated an effect on comfort levels throughout the day.

Additionally, people were an influence on comfort in the office environment. People can change a physical environment from comfortable to uncomfortable or uncomfortable to comfortable. Group dynamics can be comfortable or uncomfortable and are somewhat dependent upon
personalities, past experiences, expectations and frames of references (Whedon, 2000).

**HOLISTIC MODELS**

Holistic design is an approach to design which considers the system being designed as an interconnected ‘whole’, which is also part of something larger. A holistic design should include the physical, emotional and social conditions together as a prerequisite for good health (Stokols, 1992). Holistic models of comfort and the inclusion of socio-cultural and sensory communication provide environmental designers with a deeper understanding of a perceived comfortable design beyond the physical requirements and standards.

There are holistic comfort and healing environment models in the healthcare industry. Kolcaba (1994) presented a theory of comfort that utilized a holistic intra-actionable perspective. It is a framework within which comfort relates to (a) interventions that enhance the state of comfort and (b) desirable subsequent outcomes of nursing care. Researchers in the healthcare industry confirmed the importance of a ‘holistic’ approach, which included the psychological, psychosocial, emotional and spiritual aspects for the healing of patients, as well as, the buildings and surroundings in a healing environment (Samueli Institute, 2008).

Admahpour et al., (2014) described an interesting model (Figure 5) in a paper studying the effect of the interior environment on comfort. The model describes airline passenger comfort as an experience generated by interior features. Admahpour et al., (2014) found that comfort is depicted as a complex construct derived from human perceptions beyond the psychological (i.e. peace of mind) and physical (i.e. physical wellbeing) aspects and includes perceptual (e.g. proxemics) and semantic (e.g. association) aspects. Based on the analysis of 857 comments on aircraft interiors, they discovered eight themes describing the relationship between the interior and human comfort: “The theme ‘peace of mind’ mainly represents a person’s psychological state while ‘physical wellbeing’ embodies the person’s physical state; therefore people are placed in the center of the model”.

9
Figure 5. This model demonstrates eight themes describing the relationship between the interior and human comfort and the relation to the environmental space (Admahpour et al., 2014).

‘Proxemics’ refers to human’s perception of control and privacy located immediately around the person and space around one’s personal space as shared with others or in other words, this is the ‘social’ space. The other four themes elicit by stimuli at virtually any given distance from the passenger, shown by arrows: Pleasure: this theme underscores the pleasantness, delight and enjoyment experienced. Satisfaction: is associated with effectiveness, efficiency, usability and goal achievement. Association: referred to the interpretation of the environment in terms of its meaning and personal significance. Aesthetics: defined as the experiential pleasure or displeasure related to neatness and style (Admahpour et al., 2014).

Another model is Bronfenbrenner’s Bio-Ecological Systems theory (Bronfenbrenner, 1994; Bronfenbrenner, 1995). According to Bronfenbrenner & Morris (2006) the model which illustrated that “a person is the complex and dynamic relationship between his or her biological makeup, immediate surroundings, the relationship between those immediate surroundings, other settings he/she does not occupy but which affect him/her and the cultural expectations of others “like” him/her. The relationships cut multiple ways and morph over time.”
This bio-ecological model or Process-Person-Context-Time model (PPCT) also proposes that the most scientifically rich studies include more than one distinct but theoretically related proximal process in the same design (Bronfenbrenner & Morris, 2006). According to Tudge et al., (2009) “studies based upon bio-ecological theory should include elements of process, person, context, and time, and should include explicit explanation and acknowledgement if one of the elements is lacking.” This PhD thesis explores not only the knowledge from western researchers like Ong (2013), Vink & Hallbeck (2012), Helander & Zhang (1997) and De Looze et al., (2003) but it also considers the eastern design tradition of Feng Shui in Chapter 6 and Chapter 8. Feng Shui is an environmental design process about which architects from the west are gaining knowledge and applying to the built environment (Mak & Ge, 2012; Mak & So, 2011; Mak & Ng, 2005; Too, 1997; & Chuen, L.K., 1995).

It is challenging to link Feng Shui with western scientific literature and culture and it is difficult describe in scientific terms because Feng Shui is not generally accepted as science in some of western academia. This lack of acceptance by academia may be more prevalent in the United States than in other parts of the western world. The blending of art and science is slowing reviving in the western world but the intuitive, holistic and invisible nature of Feng Shui lends itself to skepticism by pragmatic researchers. However, some researchers have attempted to study Feng Shui from a scientifically from a western perspective. Mak (2009) developed a structured framework and a prototype model using a ‘knowledge based expert systems (KBES) approach’ to Feng Shui. The model is a research tool to demonstrate the capturing, structuring and representing of Feng Shui knowledge for preliminary design; it is not a full expert system application. It is linear and a challenge from the standpoint that Feng Shui is considered a more 'holistic' process and the KBES model may be comparable to the human factors engineering top-level analysis tool (functional requirements and allocation) used in the preliminary design process (Stanton et al., 2005). There are a number of papers on game theory and virtual reality, commercial, residential, and landscape architecture demonstrating the value of including Feng Shui principles in the design process for comfortable built environments (Joye, 2007; Mak & Ng, 2004; Heim, 2001; Chuen, 1995; Yu, 1994; Shaw, 1989; & Sobin, 1963).

Explaining Feng Shui in simple terms is difficult, but the following is an attempt. Feng Shui is an ancient system of geomancy developed over 3,000 years ago in China. It is a complex body of beliefs, some aspects are rational and some are superstition (Chuen, 1995). Feng Shui literally translates as, ‘wind and water’ and is pronounced ‘Fung Shway’. Wind and water symbolize the flow of ‘qi’ or ‘Chi’ pronounced ‘Chee’. A translation of Chi is "vital energy flow" or “breath of nature”, because Chi can be gathered by water and flowing energy (Xu, 2003). Field (1998) referred to
it as a type of environmental policy of "hinder the wind and hoarding the waters." Feng Shui recommends situating the human built environment in locations in space and time where qi or Chi is balanced. This balancing of the energies of the environment assures the health and good fortune of those inhabiting the given space (Tchi, 2009). Feng Shui emphasizes harmony with nature and surroundings, cycles of time, with the goal of creating and maintaining positive chi, flow or energy. Today Feng Shui still influences Chinese architecture and built environmental design (Mak, 2009). The Feng Shui principles and model presented in Figure 6 exemplify a ‘holistic’ model. The Feng Shui bagua model, used by Feng Shui practitioners, helps assess and design or redesign a built environment.

The term “bagua” (or “ba gua”) derives from the book of the I-Ching, a sacred text used to tell the future (The Spiritual Feng Shui, 2010). The ‘Feng Shui Bagua’ model and is one of the basic and fundamental tools of Feng Shui. The term “bagua” means “eight areas” (“ba”=eight, “gua”=area) and the Feng Shui bagua is a blueprint or grid map that relates to five elements (fire, water, wood, metal and earth), a number, various aspects of a person’s life, body parts, colors, and compass directions, to the eight sections of built environmental space. The model shows eight main sections of a space known as the “guas” of the bagua. The bagua model has

**Figure 6.** The Feng Shui Bagua model is one of the main tools used in the practice of Form School Feng Shui (The Spiritual Feng Shui, 2010).
a ninth center section (balance) corresponding to the eight major
corresponding life areas. A Feng Shui practitioner places the bagua map
over a floor plan of the purposed designed or redesigned space (The
Spiritual Feng Shui, 2010).

A Feng Shui assessment considers cycles of time very important as life is
not static and change is constant and inevitable. Feng Shui studies the
connection and change of the human, heaven and earth through cycles of
time. Energy or ‘qi’ changes with time. Therefore, the time dimension is
important when assessing or studying the energy of a space based on
direction, shape and landscape, such as in Feng Shui practice.

This is a very simplified definition and model example of Feng Shui.
However, it is not possible to describe all of the Feng Shui principles and
schools of thought in this PhD thesis introduction. An example of the Feng
Shui process for design assessment is shown in Chapter 6.

FLOW

As mentioned before, Feng Shui embraces the concept of “flow” or ‘Chi’,
movement of energy throughout a space over time. An alternative to
improving the physical environment first for comfort may be to design for
flow first, flow with intention. Feng Shui establishes intention and
identifies the positive “flow/energy” or “chi” of an environment.

Another source of flow is social interaction, resulting from optimal
interaction, with a persons or people. People and their energy are
constantly changing the visible and invisible flow of the physical
environment. Flow may also refer to intuitive movement, or wayfinding,
through a defined space (Salvendy, 2012). According to Heim (2001), flow
is a smooth, unimpeded movement through space-time. It is an aesthetic
quality of spatial movement and occurs throughout the physical world.
Csikszentmihalyi (1997) defined flow as, “the simultaneous state of
concentration and enjoyment we enter when we ‘lose ourselves’
completely in an activity.”

PLACENESS

Intention is a large part of a comfortable built environment because in
essence, it implies the purpose and the quality of the energy the space
extends into the world. Placeness is another concept that embraces
intention. The spatial features of a built environment support the
formation of places and facilitate significant occupant experience/
qualities. Koskinen & Norros (2010) created a “Placeness profile” that
supports designers to creating a control room space in a control room place when used by the operators is discussed in more detail in Chapter 7. A “Placeness profile” is a design tool, which draws attention to the spatial characteristics of control room systems that are important for the appropriate functioning of the control room in its future usage. The intention is to inform the designers of such spatial features that have psychological, social and cultural implications and instead of focusing on spaces and their physical characteristics only, the design should be targeted to facilitating places in which people act (Koskinen & Norros, 2010).

THREE ELEMENTS

Naddeo et al., (2015) reviewed 300 papers on comfort, and found that most conducted research is in the field of physical, emotional, cognitive and postural comfort, while in the field of organizational-environmental comfort, the number of empirical studies is limited. This is one of the motivations to write this PhD thesis.

This topic, ‘effects of built environments on comfort for people and interaction between people’ has also been a personal interest. This interest stems from an introduction to Feng Shui shortly after receiving a degree in applied psychology, specializing in human factors. The apparent east/west connection between the two disciplines inspired the impetus of melding the two design processes. Whilst working as a control room human factors engineer and designer, the need for a holistic design process and more research and emphasis on the psychological and socio-cultural aspects for comfortable, sustainable design was apparent.

As past chair of the Human Factors and Ergonomics Society Technical Group of Environmental Design, the focus for continued research and studies on comfort elements in the built environment was encouraged. There are many elements in a comfortable environment and the selection of three elements is based on personal observations of interiors in different settings.

For these reasons, the three elements chosen from the many possible elements that exist in a comfortable built environment and addressed in this PhD thesis are, ‘being in control’, ‘stimulating people interaction’ and ‘sensory variability’, because they are understudied in the area of research about comfort.
BEING IN CONTROL OF THE ENVIRONMENT

The importance of ‘being in control’ is well known from literature on work stress. The Karasek Job Demand-Control Model has dominated research on occupational stress for the past twenty years (van der Doef, & Maes, 1999). ‘Being in control’ reduces the formation of stress. However, everyone’s reaction to stress is different and some stress is necessary to reach an optimal level of ‘eustress’ so skills increase and a person becomes comfortable with a new level of anxiety, i.e., an expanded “comfort zone”. Ideally, people adapt to the feeling of ‘productive discomfort’ and are not afraid to try new things in the future. For comfort, the same principle seems to apply. For instance, Leather et al., (1998) found that more control of the interior climate increases comfort. Having control of the inner climate of an interior environment increases the feeling of comfort (Ong, 2013; ASID, 1998).

People prefer to be in control of their environment. People want to control and adapt the temperature to their own situation (Ong, 2013). Vink (2005) showed that job satisfaction is higher when people are in control of their working environment or working situation. Additional studies show that environments, which provide the possibility for occupants to open the windows, are more appreciated (Leather et al., 1998). Being in control of the environment implies choice. If a person, given options, e.g. opening or closing a window, the person feels in control, may experience feel less stress and be more comfortable.

Kastelein (2013) states, “People respond favorably when they enjoy greater control over their workplace environment and they feel more valuable when their input is solicited in formulating these systems.” However, world cultures differ in their cognition of the environment and control.

Li et al., (2000) ascertained the East Asian view of the environment is “holistic” and seen as a whole, whereas western cognition tends to be object-focused and control-oriented. It is important to note that different cultures respond differently to ‘being in control’; both reflect important aspects in cultural realities and adaptation to different social environments. Therefore, it is important to consider the socio-cultural aspects of ‘being in control’ when designing the built environment.

STIMULATING PEOPLE INTERACTION

Relationships are humanity’s greatest source of happiness, joy and belonging; and the greatest source of pain (Yukon Wellness, 2014). The happiness index also shows that interaction amongst people is important (Gross Happy Planet Index, 2015). Interactive relationships are a source of
information, advice, and ideas; practical assistance and support; encouragement and motivation; companionship; introductions to new people and opportunities; and personal feedback. Interiors stimulating positive human relationships are therefore preferable. Kastelein (2013) evaluated the interior layout at Google and discovered that the coffee corners stimulated people interaction and communication, thereby increasing creativity. Riratanaphong (2014) showed relationships with colleagues were an important factor for achieving satisfied workers. Herzberg et al., (1959) showed that the completion of tasks increased job satisfaction. Kaye & Jordan-Evans, (2008) stressed the importance of having exciting and challenging work as the primary reason to stay in the job. Kastelein (2013) concluded after a literature review that office workers were uncomfortable in open plan configurations and preferred private enclosed workspaces, which may work better for individual tasks but were less successful for teamwork. In open plan situations, the environment, which forced people to sit together, was not supportive when people have different activities or goals. The open plan situation worked best when people were working as a team with similar goals.

SENSORY VARIBILITY

The human sensory system welcomes variety, some degree of randomness referred to as contrast pattern recognition, or sensory variability (Heerwagen et al., 1993). Post et al., (2013) had subjects observe pictures of car interiors. Results revealed that both unity and variety positively predicted the aesthetic appreciation of car interior designs.

It appears good appreciation equates with proper balance of unity and variety. Buildings perceived as pleasing have mimic patterns that are found in nature (fractal patterns), and may indeed extend to the immune system and have a dynamic interaction with people (Boyden, 1971; & Heerwagen, 1998). Humans tend to gravitate towards natural scenery due to a hypothesized instinctual preference for savannahs and other living, green environments (Frumkin, 2001).

This interest in nature allows people to absorb the features without much effort, allowing for recuperation of the mind and body (Kaplan 1995). Environmental psychologists note that observing nature scenery resulted in improved cognitive task performance and may have offset mental fatigue and stress (Kaplan, 1995).

There is a strong connection between the characteristics of Feng Shui influenced buildings and the influence of nature. These natural elements influence human comfort and wellbeing. An explanation for the appreciation of nature is that people prefer moderate levels of patterned
complexity and sensory variability in the environment (Heerwagen, 1998; Cooper, 1968). Apart from appreciation, an environment missing sensory stimulation and variability can lead to boredom and passivity (Heerwagen, 1998; Schooler, 1984).

The spatial features of a built environment support the formation of ‘places’ and facilitate significant occupant experience/qualities (Seamon & Sowers, 2008). In a complex working environment ‘sensory variability’ may be described as an integration of the senses with the environmental elements and includes the physiological, psychological and emotional well-being of occupants. It supports socio-cultural, communication, and situation awareness. The variability creates comfort, self-fulfillment, safety, security, and has character of ‘place’.

The three previously mentioned elements are promising for further study regarding environmental comfort in built surroundings: having control of the environment, an environment supporting social interaction and an environment with moderate levels of patterned complexity and sensory variability.

**SUMMARY OF THE LITERATURE IN A MODEL**

The aforementioned themes and models show that a holistic approach consisting could be useful for creating a comfortable built environment. It also shows that expectation, time, control, and contact with people influence the experienced comfort. This PhD thesis studies these elements further.

A summary of the findings in the referenced literature is shown in the Comfortable Built Environment model (Figure 7), summarizing the findings in the literature and based on the concepts of the aforementioned comfort and holistic models, particularly the models of Bubb (2008), Konieczny (2001), Admahpour et al., (2014), and the Feng Shui Bagua (2010).
The comfortable built interior environment model shows the overlapping space between a built interior environment and the human. This overlap is where the comfort elements reside. Some prominent characteristics of the built interior environment are temperature, air quality, light, and sound which influence the “balance” between the human and interior environment. During an interaction with a built interior expectations and pre-experiences accompany the physical, psychological (intellectual and emotional) and socio-cultural of the human and influences some of the perceived comfort or discomfort in the interior.

Ideally, the characteristics of the built environment and the human experience are “in balance” and contain elements indicating the interior environment as a “comfortable built environment” space. The concept of time and change, shown in the outer ring, indicate that interior environments and people change through time. For example, an interior considered comfortable e.g., a bedroom, kitchen, during childhood may or may not be comfortable as an adult. Everything changes and evolves through the cycles of time. Built interiors perceived as comfortable have certain elements that provide comfort through cycles of time. Therefore, time is an important factor to consider in the design process, particularly when designing for comfort.
The environment surrounding the built environment, e.g. topography and landforms, is important and has a direct affect on the built interior environment. There are many aspects and elements to consider for the design of a built environment. The external factors that surround the built environment influence comfort for humans i.e. Bio-climactic Design: air temperature, solar radiation, air movement, and relative humidity; Ecological Design: analysis of climate, geology, hydrology, and vegetation; and Environmental Psychology: noise, shapes and natural environment. (Wei, 2006). Many external factors i.e. light and sound are found in the built interior they often exhibit a different nuance i.e. natural light or sound outside, versus indoor natural light or sound. Psychological or socio-cultural comfort elements may include refuge, mystery, simplicity, complexity and order to (Terrapin Bright Green, 2012). However, the focus of this PhD thesis is on the built interior environment and therefore the exterior environment and the effects it has on a built environment, deemed important, will not be included in much detail in this book.

THE RESEARCH QUESTION

The focus of this research is to discover how influential these three elements are in designing built interiors for comfort.

The research questions are:

1. **How influential are the three indicated areas (being in control, stimulating people interaction and sensory variability) for comfort?**

2. **How may the three elements be included in holistic design for a built interior environment?**

The theoretical hypothesis is that by designing built interior environments, beyond the physiological realm, with attention to one or more of the three elements (being in control, stimulating people interaction, and sensory variability) will increase the probability of creating and providing a comfortable environment.
OUTLINE OF CHAPTERS

This PhD thesis gathers new information on traditional physical comfort issues, and psychological (intellectual and emotional), and socio-cultural comfort in built interior environments. Additionally, the following studies take pre-comfort experiences and expectations into account and the importance of studying comfort over time. For this reason, it may be preferable to study the effects of environments in natural settings. The studies were conducted in natural settings. A disadvantage of choosing a natural setting is that selection of the cases was guided by whether the participants were willing to collaborate and the conditions were not fully controlled. However, the relevance will be greater and the translation into practice easier. The selection of the three elements is apart from the fact that these are theoretical promising fields to study. Influencing the selection was the availability of environments that could be researched and are compared for relevancy in the design of built interior environments that are experienced as comfortable. These studies also focused on holistic design.

The objective of this PhD thesis is to gain more knowledge about the psychological (intellectual and emotional) and socio-cultural aspects and elements for comfort in built interiors and to purpose a holistic process of designing built environments. To substantiate this, the case studies in this book are located in different interior environments. The environments include a dance studio, professional offices, airplane, control rooms, and healthcare waiting areas. Table 2 indicates the focus on one or more of the three aforementioned elements in Chapters 2-7.
**Table 2.** Outline of Chapters 2-7. The gray boxes indicate the presence of one or more of the three elements in a built interior environment.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Topic</th>
<th>Being in Control</th>
<th>Stimulating People Interaction</th>
<th>Sensory Variability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>Patterns in Discomfort</td>
<td>Discomfort Comparison, During the Workweek and Throughout the Day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2b</td>
<td>Influence of Expectations and Pre-experiences on Comfort at Work</td>
<td>Comfort in the Office Over Time, Pre-Experiences and Expectations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Changing the View of Work-space from Inside to Outside</td>
<td>Windows Windowless (1) Office Remodel Study (2) Dance Studio Study</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Possibilities to improve aircraft interior comfort experience</td>
<td>Comfort Assessment for Aircraft Interior and the Journey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5a</td>
<td>Retro to New-Retro: Challenges to Planning &amp; Designing Nine Control Room Layouts</td>
<td>Traditional Control Room Design Assessment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5b</td>
<td>Expectation Changes and Team Characteristic in a Participatory Design Process</td>
<td>Participatory Design Process With a Team of Designers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Interior Effects on Comfort in Healthcare Waiting Areas</td>
<td>Non Traditional Comparison Study and Assessment of Interior and Comfort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Environmental Comfort Design: Considerations for Future Control Room Interiors</td>
<td>Control Room Considerations: Collaborative, Human Centric, Automation, Multi-Cultural</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In chapter, 2a patterns in discomfort were studied throughout the workweek and during the day in three different countries for three different occupations. The researchers compared discomfort, and discomfort accumulation and fluctuations over the course of the day and the workweek. The element ‘sensory variability’ concerns variation in the environment sensed by the human body upon waking, traveling to work, and being at work, as well as discomfort accumulation and fluctuation over the course of the day and the workweek. Job variation in tasks during the workweek may prevent repetitive task muscular skeletal disorders (MSDs) and offset boredom and possible safety risks for both sedentary and skilled labor work (Vink, 2005; Hewitt, 2004). Humans live through their senses and need changing patterns of stimuli to activate them (Humphery, 1980; Platt, 1961; Cooper, 1968; Schooler, 1984; Cabanac, 2005). The element of ‘people interaction’ was present in the two sedentary occupation studies because “people” made the participants most comfortable and uncomfortable in the workplace. A study by Riratanaphong (2014) showed the relationship with colleagues as an important factor for achieving satisfied workers. However, Herzberg et al. (1959) found that finishing the task, positively influenced comfort and showed that the completion of tasks increased job satisfaction.

Chapter 2b is a further analysis of one of the studies mentioned in Chapter 2a regarding physical, intellectual (psychological) and emotional comfort levels throughout the day and workweek. The element ‘sensory variability’ in the environment was reported by the participants upon waking, traveling to work, and being at work, as well as discomfort accumulation and fluctuation over the course of the day and the workweek. Unchanging environments are boring. Humans experience physiological and emotional daily cycles (Humphery, 1980; Platt, 1961; Cooper, 1968; Schooler 1984; Cabanac 2005). The element of ‘people interaction’ was present in this study because “people” made the participants most comfortable and uncomfortable in the working environment. Kaye & Jordan-Evans, (2008) stress the importance of having exciting and challenging work as the top reason to stay in the job. The interaction with people is an important factor in creating comfort.

Chapter 3 comprised of two studies about built environments with and without windows. The first study (project one) discusses an office layout for two US government entities sharing one large space. The study followed a participatory process and suggested design guidelines to divide the larger space into two smaller spaces. The new design provided the employees with an outside view in the new office.

The second study (project two) considered the effect of windows on creativity and comfort in a dance studio. Subjects gave their opinion (through a self-assessment survey) regarding physical comfort and creativity in a room with windows or without windows. The elements,
‘being in control’ of the environment and ‘stimulating people interaction’ were present in the office remodel (project one), in the sense that the participants were also the occupants of the new space and involved in the design process. They controlled opening and closing the office windows. Veitch & Gifford (1996) study found that perceived control of the physical environment had a negative effect on creativity; however, project two (dance studio) indicated creativity was present in the room with windows and the room without windows. The element of ‘sensory variability’ was found in the dance studio (project two), by the variation of light or no natural light due to the windows or no windows and in the office (project one) by seeing the outside view.

**Chapter 4** investigated aircraft interiors and studied the influencing factors of comfort. Assessment of comfort used key words from the trip reports of 10,032 passengers, as well as a scale for the overall comfort of the flight duration. The participants recorded and gave their opinion about the attitude of the crew and airline staff communication thereby indicating ‘people interaction’. The lack of legroom was the factor influencing comfort the most, but service by flight attendants, ‘people interaction’ was important and also had a large effect on the comfort experienced by passengers. ‘Sensory variability’ also plays a role in this study. For example, the lack of food or bad food, not enough information or, extremely loud information on the intercom or a message that one strained to hear stimulated the senses, albeit negatively. The types of sound and sound level are very important to comfort. Mellert et al., (2008) showed passengers did not mention a noisy interior, but often complained more about neck pain and were more aware of swollen feet during a plane ride. The noisy interior had an ancillary effect and intensified body areas already experiencing pain.

**Chapter 5a** represented the human factors engineering challenges of replicating an older French control room design of the 90s for a new facility in the USA. Challenges included changes in technology, cultural differences, new codes, regulations and standards. An ideal control room provides control room operators safety, ergonomic design and control of systems. A human factors top-down approach was suggested to provide an optimal design and implementation assessment, thereby suggesting the element of ‘being in control’ by the human factors team.

Ideally, a human centered design (HCD) was chosen to optimize the interior to meet safety and needs of the control room operators rather than forcing the control room operators to change how they work to accommodate the system (Noyes & Bransby, 2001). Although the HCD provided guidance, it was not a requirement for this real world project. The safety standards, regulations, and budget constraints presented challenges to designing control rooms with special attention to comfort and well-being. This is not unique; Larson et al., (2014) showed the friction
that exists between ideal human factors design and company budgets and regulations.

Chapter 5b discussed a participatory design process applied to nine control rooms and the element of ‘being in control’ of the design of the built environment was the focus here as well. A human factors specialist researched the expectations of a culturally and professionally diverse design team throughout a yearlong participatory design process. This participatory design process resulted in active participation as team members influenced and somewhat controlled the design process to provide a comfortable optimal working environment for control room operators, but the team struggled with space, cost constraints, and management to meet this goal. This study aligns with Larson et al., (2014).

Wilson (1995) stated, “It is the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals.”

Chapter 6 studied the element of ‘sensory variability’ in three health care waiting areas. Participants self assessed their physical, intellectual and emotional comfort levels by what they saw and heard on the way to an appointment, in the waiting area and after the appointment. A Feng Shui expert, using Feng Shui principles designed one waiting area. A doctor, using some Feng Shui principles and some western design principles designed the second waiting area. The third waiting area used only western design principles. The researcher conducted a Feng Shui assessment of each waiting area and compared the locations with the comfort levels recorded at each location. There is a close relationship between Feng Shui and ‘sensory variability’, especially visual and auditory, as the complementary of opposites (yin and yang) or patterns found in nature are an important part in the Feng Shui design approach. Buildings and interiors perceived as pleasing, mimic patterns found in nature (fractal patterns), and may indeed extend to the immune system and encourage a dynamic interaction with people (Boyden, 1971; Heerwagen, 1998).

However, this still needs empirical verification. The element of ‘sensory variability’ was most often present in the interior designed by the Feng Shui expert and registered the highest comfort level for the participants.

Chapter 7 is a theoretical treatise on designing future control rooms using all three elements; ‘being in control’ of the environment, ‘stimulating people interaction’ and ‘sensory variability’ in the ‘holistic design’ guideline process. The design process includes innovative solutions for heating, lighting, and other physical, psychological, and socio-cultural environmental design aspects as well as, advancement in technology, automation and robotics, a multi-disciplined, multicultural, and human
centric collaborative workforce. The interior is a character of “place” that supports situational awareness, sense of control and sense of presence when occupied (Koskinen & Norros, 2010). Additionally, functional affordance connects the environmental features to the intention of the user in an activity context (Bradner, 2001; Hartson, 2003).

REFERENCES


Xu, Jun. (2003), A framework for site analysis with emphasis on feng shui and contemporary environmental design principles. University Libraries, Virginia Polytechnic Institute and State University, Blacksburg, VA.


Yukon Wellness. (retrieved 2015) http://www.yukonwellness.ca/holistic.php#.VLTnBHs6-tM.
CHAPTER 2
2a Patterns of Discomfort

Conne Bazley, Rachel Nugent, & Peter Vink
Published in the Journal of Ergonomics, 2015
Volume 5, Issue 1, Pages 1-7

ABSTRACT

A review of literature on comfort and discomfort indicates an increase in physical discomfort during the workday. In this paper, three different types of occupations were studied to identify whether a similar discomfort pattern exists in these occupations while participants perform work throughout the workday and work week. Results are that sedentary and labor-intensive occupations show an increase in physical discomfort throughout the workday. In addition, during the workweek, each occupation had a peak discomfort day and all occupations experienced a reduction of discomfort at the end of the last day of the workweek. Acknowledging and understanding why, when, and where discomfort peaks occur could assist in varying task scheduling to improve job performance. Future research should include emotional and psychological discomfort assessments, investigation of effects of age, time of year, and location in the world.

Keywords: patterns, discomfort, comfort, MSD, workweek, task, performance
INTRODUCTION

The term Musculoskeletal Disorder (MSD) applies to a broad range of disorders and injuries (e.g., sprain, strain) of the musculoskeletal system. These occur when the demands of an activity exceed the capacity or limitations of the musculoskeletal components (Hildebrandt, 1995). Symptoms of MSDs include numbness, tingling, aches, pain, localized inflammation, weakness, and/or difficulty in moving joints, which can significantly reduce the ability to do work or carry out daily activities (Larson, 2013). MSDs can occur suddenly due to a single incident (e.g., handling a heavy load) (Hildebrandt, 1995) or due to a sudden movement (e.g., slip/trip/fall) (Costa & da Vieira, 2010). Alternatively, they develop gradually over long periods of time and are frequently referred to as Cumulative Trauma Disorders (CTDs) (Staal, de Bie; Hendriks, 2007) or Repetitive Strain Injury (RSI) (e.g., tendonitis, bursitis and carpal tunnel syndrome) IJmker et al., (2007). As the disorder progresses, individuals experience symptoms on a more frequent basis IJmker et al., (2007). Symptom severity increases in intensity, becomes chronic and symptoms are experienced for longer durations. In severe cases, symptoms are experienced constantly and the individual becomes permanently disabled IJmker et al., (2007).

The brain interprets situations where physiological limitations have been exceeded, perceiving varying intensities of sensations that correspond with the magnitude in which limits have been exceeded. These sensations signal that internal homeostasis is disrupted and recovery steps are required. Physical sensations include mild to severe aches, pains and discomfort, and perceived sensations of fatigue and tiredness. This is consistent with studies by Öztürk & Esin (2011), da Costa & Vieira (2010), Boocock et al., (2009), and Buckle & Devereux (2002).

Many studies use discomfort recordings that mostly check the effect of an intervention. This is consistent with studies by Bosch, de Looze, & van Dieën (2007), Groenesteijn et al., (2009) and Schoenmarklin & Marras (1989). For instance, Groenesteijn et al., (2009) used questionnaires on local postural discomfort to determine the difference in experience between two chairs. Reducing discomfort is not a luxury.

Helander & Zhang (1997) showed discomfort related to feelings of pain, numbness, and tiredness. Hamberg et al., (2008) showed that discomfort was a predictor of complaints in the back and neck and should be reduced for that reason. Discomfort is also related to human productivity. In order to stay ahead of business competitors, reducing employee discomfort during work hours is beneficial (Vink, 2005). Hewitt Associates (2004) states, “Companies with higher growth in profitability have engagement
levels that are more than 20% higher than those of their counterparts and provide more growth and development opportunities."

However, discomfort research is not only related to musculoskeletal problems and productivity. A previous literature study of the MEDLINE database showed that between April 1993 and April 2003, 109 papers list discomfort in the title (Vink, 2005). Discomfort is a main topic of study and most of the 109 papers concern patient pain studies (43 out of 109) and aspects of physical discomfort (35 out of 109). Thirty-five studies discuss the effects of posture or assembly tasks on musculoskeletal discomfort and pressure during seating. A Science Direct review of discomfort related literature resulted in 318 papers submitted between 2003 and July 31, 2013. The majority of studies over the past 10 years (52.2%) are patient pain studies as displayed in Table 1.

**Table 1. Topics studied in 318 papers between 2003 and 2013 with discomfort in the title.**

<table>
<thead>
<tr>
<th>Topics related to discomfort (n=318)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient discomfort (e.g. Music in treatment, give injections)</td>
<td>52.5%</td>
</tr>
<tr>
<td>Behavior and discomfort (e.g. Discomfort intolerance and behavior problems)</td>
<td>7.9%</td>
</tr>
<tr>
<td>Visual discomfort (e.g. Glare)</td>
<td>6.6%</td>
</tr>
<tr>
<td>Work organization and workplace (e.g. Effects of rest breaks)</td>
<td>4.7%</td>
</tr>
<tr>
<td>Musculoskeletal (e.g. Joint motion, seat/wheel chair)</td>
<td>4.7%</td>
</tr>
<tr>
<td>Eye discomfort (e.g. Effect of lenses)</td>
<td>3.5%</td>
</tr>
<tr>
<td>Thermal (e.g. Effect of ventilation)</td>
<td>3.1%</td>
</tr>
<tr>
<td>Driver discomfort (e.g. Noise)</td>
<td>2.8%</td>
</tr>
<tr>
<td>Vibration (e.g. Lateral vibration in trains)</td>
<td>1.9%</td>
</tr>
<tr>
<td>Hand tool/grip (e.g. Effects of handle design)</td>
<td>1.9%</td>
</tr>
<tr>
<td>Animal discomfort (e.g. Types of stables)</td>
<td>1.6%</td>
</tr>
<tr>
<td>Others (&lt;1% per topic)</td>
<td>9.1%</td>
</tr>
</tbody>
</table>

By combining the categories of musculoskeletal, driver discomfort, vibration, and hand tool, 11.3% of the papers are in the physical category. The titles often did not mention emotional and psychological issues. Helander & Zhang (1997) distinguished the difference between comfort and discomfort in their article, *Field studies of comfort and discomfort in sitting*. Based on questionnaires by Zhang et al. (1996) and Helander &
Zhang (1997), discomfort related to physical characteristics of the environment, such as posture, stiffness, and fatigue. When discomfort is absent, nothing is experienced. Because comfort relates to luxury, relaxation, or feeling refreshed, experiencing more of these aspects is necessary in order to notice comfort. This division is affirmed by the fact that the comfort scales did not appear to be useful for high physical load (>65% MVC) (Kong et al., 2012).

Publications are emerging on the importance of including emotional and psychological aspects of comfort in the area of environmental design (Ong, 2013). Most of these studies do not mention the specific time of day for the data collection. However, Bosch, et al., (2007) showed that discomfort increases during a day of assembly work. In theory, a difference in discomfort found in several of the 318 studies (e.g., Groenesteijn et al., (2009) and Schoenmarklin & Marras (1989) may be attributed to the way the measurement of discomfort was performed. For instance, the possibility is that a "new situation" recorded in the morning is the "old situation" recorded in the afternoon. Perhaps during the week, patterns that have the same effects are found and disturb discomfort findings. The purpose of this study is to identify if discomfort patterns are present during the workday and throughout the workweek. If a pattern exists across all work occupations it may be useful information for future discomfort experiments to gain theoretical knowledge on how and when these patterns evolve and occur during the workday and workweek. Additionally, knowledge of discomfort patterns and peaks may assist in job design of work tasks and task scheduling to offset days lost due to health issues for employees thereby creating a more productive, cost saving work environment (Vink, 2005; Hewitt Associates, 2004).

This research attempts to address whether there is a common pattern in the physical discomfort experience for different working professions during the workday and work week. The scope of this research encompasses evaluation of three studies related to discomfort in three occupational settings. The majority of workplace studies are in offices and most often include sedentary work. Therefore, this study includes two sedentary occupations, which differ in content: an administrative job and a knowledge intensive job. The third occupation is a physical demanding job and chosen to show possible differences or similarities to the sedentary occupations regarding a pattern in discomfort.

In each of the three studies, discomfort was recorded three or four times throughout the day as well as throughout a workweek. Each study used a different method for recording discomfort. Only one study recorded emotional and psychological discomfort levels. The purpose of this study is to examine whether there is a common pattern of physical discomfort despite the different collection methods used in three different countries, and three different occupations.
METHODS

Participants

Three professions were selected to compare patterns of discomfort for this study: engineering professionals located in the USA (Bazley et al., 2012); administrative personnel located in the Netherlands (Vink et al., 2009), and physical plasterers located in Ireland (Nugent, 2012). All three studies commenced in the spring of the year. The three authors granted consent to compare the results of their studies: Bazley et al., (2012), Vink, et al. (2009), & Nugent, (2012). Authors from each study obtained permission from all participants using signed consent forms.

Materials and Procedures

Engineering professionals: A four-day self-assessment survey on comfort was administered to sixteen engineering professionals performing deskwork consisting of control-system engineering activities designing, and developing, electrical, and instrumentation systems. The work involved intensive decision-making and problem solving, interacting with mainframe computers specialized software programs and developing constructive relationships with department chiefs, business unit leaders, contractors, and external vendors. Eleven males and five females were surveyed and the age of the participants ranged between the ages of 22-60. The survey encompassed one workweek. A typical workweek began on Monday and ended Thursday. Each workday was ten to eleven hours long. The participants received a package of four surveys to begin the survey the following day.

The method used to measure participant responses to physical, psychological and emotional comfort assessment or symptom severity throughout the day was based on a Likert rating scale. Numbers were assigned to a person’s estimation of his/her symptoms and were meaningful. It allowed for a standardization of a variable, ‘symptom severity’, which can be highly subjective. This created uniform levels that were effectively used for statistical analysis. For this type of study, Likert responses were easier to administer and interpret and were a preferable method of measurement, (Trochim, 2006; Uebersax, 2006).

The first set of survey questions for a Likert scale rating, 1-5 (1, excellent to 5, very bad), asked about physical, psychological, and emotional comfort in the morning upon waking. In addition, participants were asked to circle a word best describing the level of comfort. The next set of questions asked for information about comfort levels after arriving at work (physical, psychological and emotional, each level rated 1-5).
The last part of the survey was completed at the end of workday and participants were asked to rate their comfort level (physical, psychological, and emotional, each rated 1-5). In addition, participants were to circle a word that best described what made them most comfortable and most uncomfortable in the office setting. A one sided Wilcoxon signed rank, using SPSS Statistics for Windows, Version 20.0, was applied for the difference between the beginning and the end of the workday. It is hypothesized, based on the work of Bosch, et al., (2007), that discomfort is higher at the end of the day and physical comfort is lowest at the end of the day (p<.05). A polynomial regression line was calculated for the pattern in discomfort during the week to describe the pattern. For the difference between the pre-work (to compare with the other two studies possible) and the highest point in the curve in the week, a one side Wilcoxon signed rank test was also applied (p<.05).

**Administrative personnel:** Ten participants (six male and four female) were studied performing deskwork which included, arranging meetings by phone and email, making layout or reports, making letters, answering phone and emails for the staff, preparing forms, for 8 hours a day. The age of the participants ranged between ages 20-60. Local Postural Discomfort (LPD) recordings were made during a five-day workweek, each day for two weeks for half an hour after starting work, half an hour before lunch, and half an hour before end of workday. The LPD method was used and consisted of a map with twelve body regions (van der Grinten, 1992).

A ten point-Borg scale was used to assess discomfort (ranging from ‘No Discomfort’ at 0 and ‘Extreme Discomfort’ at 10) per region (Borg, 1990). At the end of each day, a general questionnaire of what made people feel both comfortable and uncomfortable was completed. The average pattern of LPD during the day was recorded for two weeks. As in the previous study, the beginning and end of the workday were tested with Wilcoxon, a polynomial regression line was calculated, and the peak in the week line was tested against the beginning of the week value.

**Physical Plasterers:** Eighteen male plasterers (physical laborers) were surveyed as they carried out their usual physical activities of, applying coats of plaster to interior walls, ceilings, and partitions of buildings, to produce finished surface, according to blueprints, architect’s drawings, or oral instructions, using hand tools and portable power tools and mixing plaster and erecting scaffolds, during their work week. Participants declined to complete the demographic portion of the survey.

A Body Part Discomfort Survey (BPDS) was used in the study. It consisted of a body map sectioned by color and labeled to indicate ten body parts of interest, ten questionnaires, and twenty batches of ten Visual Analogue Discomfort Scales (VADS), one batch for each time event, (Belling, 2010), Cameron,1996; Huskisson, 1983). The body parts of interest in this study
were the neck, upper back, shoulders, mid back, elbows, low back, wrists/hands, buttocks/hips/thighs, knees, and ankles/feet. Individual VADS represented a single body part for each time event. The 100 millimeters (mm)-vertical lines were labeled ‘No Discomfort’ at 0mm and ‘Extreme Discomfort’ at 100mm. At each corresponding time event, plasterers marked a point along a VADS line to indicate their level of perceived discomfort for each corresponding body part. Twice a day, plasterers completed a questionnaire to indicate the activities they carried out in the previous work session and to detail their work times and break times. The participants were required to indicate the intensity level of their perceived discomfort in ten body parts at twenty different time events: four times a day (BW-before work, BL-before lunch, AL-after lunch, EW-end of work) for five consecutive workdays.

The average discomfort intensity for the ten body parts was calculated for each time event. Comparative analysis was carried out between the average discomfort intensity for all ten body parts and days of the week, and between average discomfort and the twenty time events.

As in the previous studies, the beginning and end of the workday were tested with a one sided Wilcoxon signed rank, using SPSS Statistics for Windows, Version 20.0 The data presented in the figures represents the average discomfort value for all subjects. A polynomial regression line was calculated to describe the patterns and the peak values at the end of the week was tested against the value at the beginning of the week. Standard deviation is not shown in the figures of this study because the figures show the sum of all subjects, which is only one value.
RESULTS

Engineering professionals: The physical discomfort was low at waking and increased during the workday averaged over the four days (Figure 1). Psychological discomfort was higher at waking, lower on arrival to work and increased by the end of the workday. Emotional discomfort was higher at waking and decreased towards the end of the workday. There were no significant effects on physical or emotional levels for a two-way repeated measures ANOVA test with DAYS and Time of Day (TOD) as factors. A marginally significant F: (p=0.051) DAYXTOD interaction was observed for the psychological comfort level suggesting that levels improved slightly. The results of the Wilcoxon test indicated that the difference between the beginning and end of the workday for physical discomfort was not significant for all types of comfort.

![Figure 1. Physical, Psychological and Emotional Comfort Level over workweek averaged over all Engineering Professionals (n=16) (rating 1-5; one, being excellent - five, being very bad). The solid columns indicate the corresponding values for Physical Comfort during the day, dotted columns correspond to Psychological Comfort and gray columns correspond to Emotional Comfort (Bazley et al, 2012).](image)

Regarding the engineering professionals workweek study, the pattern that correlates highest was a fourth degree polynomial regression ($R^2$ physical =0.4386, $R^2$ emotional =0.7586, and $R^2$ psychological = 0.6057 (Figure 2). The peak physical discomfort at the end of Monday was significantly different from the pre-work value (p =0.054, t=1.704).
Figure 2. Comfort Level Trendlines over Workweek based on a four-day workweek of all Engineering Professionals (n=16). W - Waking, A - Arrive at Work and E = End of Work. The solid (-) line indicate the corresponding values Correlation Coefficient (R²) for Pattern lines Regression Analysis using 4th Degree Polynomial for Physical. The dashed line (- -) corresponds to Psychological and the dash dot (- .-) line corresponds to Emotional (Bazley et al., 2012).
Administrative personnel: The physical discomfort was low at the beginning of the workday and increased during the workday as averaged over the ten-day period (Figure 3). The end of the workday discomfort was significantly different from the discomfort after half an hour of work (p = 0; Z-value= -6.8715).

Figure 3. The Local Postural Discomfort summed over all admin participants (n=10) over 10 Days at beginning halfway and end of the day (rating 0-10; 0 no discomfort to 10 extreme discomfort). Half an hour (HW) after the start of work; half an hour before lunch (HBL), and -half an hour before end of the workday (HEW) (Vink, 2009).

In the workweek study, the pattern that correlates highest was a fourth-degree polynomial regression line (R²= 0.39) (Figure 4). The peak was shown to occur on Wednesday and was significantly different from data received on Monday (p= 0.00391; Z-value= -2.6552).
Physical plasterers: Overall, the pattern for perceived discomfort intensity increased over a workday and throughout the workweek. A decline in intensity levels was observed after a period of rest (i.e., lunch and overnight) with the greatest decline occurring after an overnight break (Figure 5).
The workweek pattern that correlates highest was a 4th degree polynomial regression line ($R^2 = 0.88$) (Figure 6). The difference between the beginning and end of day is significant ($p = 0$; $Z$-value = -6.154) and the difference between the peak on Thursday is significant from the beginning of the workweek ($p = 0.00226$; $Z$-value = -2.8362).

**Figure 6.** Local Postural Discomfort summed up over all body regions and averaged over physical plasterers ($n=18$) and at the end of different days in the week as recorded on 100mm VADS scales (0 – ‘No Discomfort’, 100- - ‘Extreme Discomfort’). From left to right symbols denote the following: Before Work (●), Before Lunch (■), After Lunch (▲) and End of Work (X) (Nugent, 2012).

**DISCUSSION**

The results confirm time of day relationships for the administrative personnel workers and for the physical plasterers. Two of the three studies, the administrative personnel workers and physical plasterers show an increase in physical discomfort during the day. The increase during the day is in line with the findings of Bosch et al., (2007). Feeling tired and having lower comfort levels at the end of a workday is consistent with findings by Vink et al., (2009). However, the engineering professionals study shows no significant increase for physical discomfort during the day although there was a marginal significance for the psychological discomfort level during the day.
Murata et al., (2005) stated that anticipation about cognitive work completion causes a decline in comfort due to anxiety and the nature of cerebral work. The intensity threshold for physical discomfort was lower than that of the psychological discomfort and it is possible that the job tasks were intense enough to override the physical discomfort as described by Vink (2005). The study for the engineering professionals was only over four days as opposed to the administrative personnel office study that spanned over two weeks, of five days for each week. It is possible that after assessing discomfort for a longer period of time that the administrative personnel had a greater awareness of discomfort. Additionally, similarities and differences in chair and workstation design, office layout, were not compared in the two sedentary studies and the differences may attribute to the absence of physical discomfort in the engineering study and the presence of physical discomfort at the end of the workday.

All three studies showed a peak discomfort at the latter part of the week, which was significantly different from the beginning of the week. For the overall workweek, all three studies indicated a low physical discomfort at the beginning of the workweek, a rise in discomfort mid-week, and by the end of the week, the physical discomfort was low again. The peak of discomfort occurred on different days for all three occupations. The end of the first workday, Monday, was the peak for the engineering professionals.

The difference between relaxed activities on the weekend and returning to sedentary intensive knowledge work related activities was significant enough that physical discomfort was noticed the end of the first day of the workweek. The administrative personnel noticed the peak of discomfort on Wednesday. The Wednesday peak may have occurred because the beginning of the week is often very busy. There may be no time to register the discomfort until midweek when there is a break in the routine. Another explanation is similar to that of the engineering professionals that participants are away the work activities on the weekends and for the administrative personnel it took several days after returning to the work activities to register the discomfort. Ryan et al., (2010) found that much of the weekend effects would account for the work versus non-work contrast, given that work activities expect to be associated with a lower sense of autonomy and relatedness than non-work activities.

In the physical plasterers study, it is possible that discomfort levels peaked on Thursday, rather than the last day of work (Friday) because of the type of physical activities performed. Plasterer working environments and task demands vary on a daily basis. Generally, the initial activities in the earlier part of the week or the finishing activities on-site usually require more preparatory work can be more physically demanding. These activities include plastering ceilings and upper/lower wall surfaces. When the job
nears completion or later in the week in preparation for the weekend work activities may be less physically demanding.

All three studies showed a lowering in physical discomfort level by the end of the day for the last day of the workweek. This is consistent with studies by Sonnentag et al., (2008) in which participants are ready for the weekend and exhibit excitement and positive expectations for upcoming days off, or the weekend. The plasterers were asked to complete additional questions on comfort and they declined. However, the other two studies did ask additional comfort questions. The engineers and administrative participants indicated what made them most comfortable and uncomfortable in the office. Participants in both of the office studies found that “people” made them most comfortable, however, “people” also made them most uncomfortable. “People”, made employees feel more or less comfortable during the workweek in conjunctions with variations in personal duties, interactions, and biorhythms. “People” also influenced the mood and responsibilities for each day.

Participants in both of the office studies also found that “task” made them most comfortable. According to Kaye & Jordan-Evans (2010), exciting and challenging work, opportunities for career growth, learning and development, high-quality co-workers, fair pay, and supportive management are the six top reasons employees stay with a particular company. Herzberg (1959) describes that motivators create satisfaction by fulfilling individuals’ needs for meaning and personal growth. The issues such as the work or “task” itself and advancement relate to satisfaction. These studies align with the finding in this study that finishing the task is an important factor for comfort at work.

An important component of physical discomfort for the office studies was office temperature and inner climate. Participants indicated that “temperature” and “inner climate” made then most uncomfortable. Other studies found the relationship between discomfort and “temperature” (e.g., ANSI/ASHRAE, 2010 and Valancius & Andrius, 2013).

The natural environment affects not only the physical health but also the psychological health of human beings (Sundstrom et al., 1996). The engineering office had forced air conditioning and not well regulated throughout the building. Additionally, the windows did not open and the engineers had no control over the temperature. On the other hand, the administrative personnel office subjects were able to open windows and somewhat regulate temperature. There are many studies in environmental psychology research related to the effect of natural elements in the “inner climate”. For example, window size, sunlight penetration and the presence of plants influences workers’ moods (Sundstrom et al., 1996). Bakker & Voordt (2010) and Stokols (1992) state that, “physical, emotional and social conditions together are a requisite for good health.”
LIMITATIONS

Ideally, a case study analysis should have multiples of cases included. However, it is not common to find numerous field studies researching discomfort throughout the day and throughout the week for different occupations in different countries. For this study three different occupations in different countries, using different comfort questionnaires found an increase in physical discomfort throughout the workday and work week. The data collected were only from natural settings. This meant that selection effects were possible regarding gender, age, nationality, and time of year as well as type of occupation (two sedentary, one physical labor). Males and females participated in the two sedentary studies. However, there were only male participants in the physical labor study. There are varying discomfort and comfort tolerances for different age groups and genders. These variations provide difficulty for determining degrees of discomfort levels. Although quantitative results can be reported, many variables exist in real life studies and generally require qualitative reported results. Non-laboratory work study results often conflict with laboratory models, Heschong (1979) and Schiller et al., (1998). According to studies by Vink (2005), physical conditions are an important comfort factor. The discomfort pyramid of Bubb (2008) demonstrates that if the environment is unpleasant the physical conditions will ultimately overrule all other factors if not addressed (Bubb, 2008; Vink, 2011) (Bubb, 2008; Vink, 2011). However, the emotional and psychological connections, although defined by Höppe (2002) as, “difficult to deal with” may be more important for the sustainability of comfort (Ong, 2013 and Green & Jordan, 2003).

CONCLUSION

The purpose of this study is to identify whether discomfort patterns are present during the workday and throughout the workweek. Common physical discomfort patterns were found during the workday and throughout the workweek. One sedentary and the physical labor study work showed an increase in physical discomfort during the day. During the workweek, all three occupations had a peak discomfort day. All three studies showed a lower discomfort at the end of the of the workweek day. This sample size indicated a pattern across varied work occupations.
Future studies on how, when, and why these patterns evolve and occur during the workday and workweek should incorporate this comfort component in the experimental set up. Acknowledging and understanding why, when, and where discomfort peaks occur during the workweek could assist with changes in task scheduling and task performance particularly on days identified as peak discomfort days. Implementation of variation in work tasks in all occupations throughout the week and particularly on the identified peak discomfort day could possibly deter the on-set of MSDs, emotion and mental fatigue. Studies on discomfort and patterns of discomfort should consider the inclusion of many different occupations from around the world. The benefits of a holistic approach to discomfort should include emotional and psychological discomfort assessments and confirm whether effects e.g. age, gender, race, time of year, temperature, lighting, humidity, expectations, experience, and geographic location influence physical discomfort and peak discomfort days.

REFERENCES


Herzberg, F., The motivation to work. 1959: Wiley.


Ong, B.L., Beyond Environmental Comfort. 2013: Taylor & Francis.


CHAPTER 2b
2b Influence of Expectations and Pre-experiences on Comfort at Work

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Published in Advances in Social and Organizational Factors, 2012

ABSTRACT

Comfort research often includes a variety of factors e.g., environmental conditions, physiological, psychological, emotional levels, pre-experiences, expectations, and sustainability. This paper examines the effects pre-experiences and expectations may have on comfort levels over-time. Sixteen participants from a professional office completed a daily survey on their comfort levels throughout the workday for a four-day workweek. The survey measured comfort levels upon waking and the effects pre-experiences and expectations have on, before arriving to work, and throughout the workday. The results confirm the time of day relationships between pre-office experiences and intellectual (psychological) comfort levels. Participants showed high expectations levels for work performance from co-workers, managers, and themselves. Additionally, the majority of participants said that “people” made them feel comfortable and uncomfortable.

Keywords: comfort; workplace; expectations; pre-experiences
INTRODUCTION

A “holistic” approach in workspace and workplace design includes health, wellness and comfort. Optimal internal and external environmental conditions include good quality air, water, and climate, physical comfort and health, adequate space, smooth flow of work, general safety and safe working conditions. Other factors to consider beyond the physical environment are the mental and emotional health. These factors help promote growth, flexibility, creativity, and well-being in the workplace (INQA-Buero, 2005).

Comfort is a term that is often associated with a physical state or an environmental factor. Richards (1980), stresses that comfort involves the sense of subjective well-being. That is the reaction a person has to an environment or situation. According to Looze, Kuijt-Evers & Dieën (2003) some issues are generally accepted in comfort literature are; (1) comfort is a construct of a subjectively defined personal nature; (2) comfort is affected by factors of various nature (physical, physiological, psychological); and (3) comfort is a reaction to the environment. Comfort has other meanings as well. For example, “This room is comfortable” or “Being with you makes me comfortable”. Comfort relates to ease, which relates to satisfaction, contentment and finally to pleasure, for example, “The pleasure of your company”, has a warm feeling to it, although it rarely has to do with the physical temperature. Frequent interaction leads to the feeling of familiarity, which breeds fondness (Bornstein, 1989; &Bornstein, 1999). By combining comfort with pleasure, we encounter balance and sustainability. The aspects of pleasure and comfort are in product and game design (Green & Jordan, 2002).

A cognitive process is required in answer to “Are you comfortable?” It is necessary to think about who, what or why something is comfortable or not. Emotions are quick to overwhelm cognition particularly in the case of pleasure. Sensibility and a healthy balance of all comfort levels is the intended optimum result (Green & Jordan, 2002). Slater (1985) defines comfort as a pleasant state of physiological, psychological and physical harmony between a human being and his environment.

On the other hand, Helander & Zhang, (1997) note that discomfort due to sitting is related to more physical aspects like pressure points and stiffness, while comfort relates more to luxury and refreshment. Jordan (1997) discusses how environmental sustainability interrelates between comfort, pleasure and the usability of products.

Today, there is a significant amount of research projects focusing on human health and the connection between the environments and human psychological responses. The fundamental hypothesis of this body of research is, ‘since the earliest evolutionary phases of human life, we have
had a visceral, survivalist need to be sensitive and responsive to our surroundings” (Bilchik, 2002, p.10).

The surveys used in this paper investigate pre-comfort experiences along with incremental comfort level assessments for a group of professionals throughout the workday and a workweek. The survey for this study was modeled after Konieczny (2001), who considered three main elements to access pre-experiences and attitudes for flight travel; Hardware (airport signs, walking distance, toilets...), Software (waiting and boarding times) and Life ware (staff competencies and personal support).

Taking into account the many definitions for comfort, this paper combines environmental elements and intellectual (psychological) and emotional factors, measured over time to establish changes in comfort levels.

The three questions asked:

1. Do pre-experiences have an effect on comfort levels throughout the day?
2. Do comfort levels decline overall throughout the day?
3. Are physical conditions the most important factor influencing comfort?

METHOD

In response to the three hypotheses, a Four-Day survey on comfort was administered to a group of 16 people. The survey was given to 16 professionals working four, ten-hour days a week. The workweek begins on a Monday and ends on Thursday. Eleven males and five females were surveyed, twelve Engineers, two Designers and one Manager, and one Administrative Assistant. The age of the participants ranged was between age 22-60 and 13 of the participants were between the ages of 40-60.

The participants working at a professional office received a packet of four surveys and began the survey the following day. The workweek for this office is four, ten-hour days.

The first set of survey questions asked for a rating 1-5, (1, being excellent – 5, being very bad), on each waking comfort level (physical, intellectual and emotional). In addition, participants were asked to circle a word best describing the level of comfort upon waking. They were also asked to circle a color that best described their present comfort level. A “yes” or “no” question was included in this set of questions asking if the participant was looking forward to going to work for the day.

The next set of questions again asked for comfort levels (physical, intellectual and emotional, each rated 1-5), a word and a color to best
describe comfort levels. Additionally, they were asked to circle the word that best described the most significant thing they saw on the way to work and another question asked for the most significant thing they heard before arriving to work.

The last part of the survey was completed at the end of workday and participants were again asked to rate their comfort level (physical, intellectual and emotional, each rated 1-5) and circle a word that best described their comfort level at that time and another question to circle a color to describe the comfort level. In addition, they were to circle a word that best described what made them most comfortable in the office setting and an additional question asked them to circle a word that best described what was most uncomfortable in the office setting.

The survey began on a Wednesday and ended the following Tuesday. A two-factor repeated measures ANOVA with DAYS and TOD as factors was performed. Results were marginally significant for the intellectual comfort level.

RESULTS

The results were marginally significant for the intellectual comfort level. On average for the four days, the most significant visual that participants saw was, “nature”, followed by “roadway”. This is consistent with the route taken to the worksite.

The most significant thing that was heard was “singing”, followed by “talking”. Most participants listened to music, the news, or had conversations with carpool members on the way to work.

The “temperature” of the office was circled as most uncomfortable in the workplace was either too hot or too cold, followed by “people” at the office that made them uncomfortable. On the other hand, the “people” in the office also made them the most comfortable, followed by the “tasks” or nature of the job.

The physical, intellectual and emotional comfort levels declined comfort throughout the day, with the exception of Thursday, when all comfort levels improved (Figure 1).
Figure 1. Four-Day Survey for physical, intellectual and emotional comfort levels throughout the workweek.

There were no significant effects for physical or emotional levels for a two-way repeated measures ANOVA test with DAYS and TOD as factors, only a marginally significant F(p 0.051) DAYXTOD interaction was observed for the intellectual comfort level suggesting that levels slightly improved.

DISCUSSION

Pre-experiences and the effect on comfort levels

A modified version for pre-experience or pre-comfort experiences for comfort studies is possible (Table 1) by exchanging hardware for physical comfort, software for intellectual comfort and life ware for emotional comfort. Adding pre-comfort experiences to the study of comfort deepens the understanding and formation of personal comfort realities.
Table 1. A modified version of Konieczny’s (2001) table of pre-experiences for flight shows an example of elements for pre-comfort experiences where pre-experience for work elements may occupy more than one comfort type.

<table>
<thead>
<tr>
<th>Comfort Type</th>
<th>Pre- Experiences (Elements)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>Buildings, Roadway, People, Sunrise</td>
</tr>
<tr>
<td>Intellectual</td>
<td>Looking forward to work, Talking, Singing</td>
</tr>
<tr>
<td>Emotional</td>
<td>Colors, Upset, Excited</td>
</tr>
</tbody>
</table>

Comfort levels decline during the day

The participants physical comfort level was consistent with studies and declined throughout the working day (Vink, 2005). Declining physical comfort levels are observed throughout the day in offices where people have sedentary jobs, often sitting for up to 10 hours a day (Figure 1). Physical discomfort is often reported from sitting in an improperly fitted chair, as well feeling too hot or too cold from poor regulation of room temperature. Fatigue from eyestrain can occur from inadequate lighting, screen glare or and lighting. Temperature was the most uncomfortable element in the office for participants in both studies. Studies show that fluctuations in temperature, too hot, too cold have a negative effect on health, well-being and productivity (Haynes, 2008, ASHRAE, 2004).

The intellectual comfort level improved from the beginning of the day to the middle of the day, and then declined at the end of the day to about the same level as the beginning of the day. Anticipation about cognitive work
completed can cause a decline in comfort due to anxiety and the nature of cerebral work (Murata, Uetake & Takasawa, 2005). This may attribute to the marginally significance ANOVA result in intellectual comfort level. Emotional comfort levels were consistent with studies by Vink et al., (2009) throughout the day and work week. Although, Thursday showed a marked improvement in all comfort levels by the end of the day and the last workday. This is consistent with studies that participants are ready for the weekend and exhibit excitement and positive expectations for the upcoming days off (Integrated Media Measurement, 2009, Sonnentag et al., 2008).

On average throughout the week, intellectual comfort levels improved from beginning to mid-day and declined again at the end of day. Interestingly 48% said the tasks of the office made them most comfortable. The physical comfort levels declined throughout the day and the emotional comfort levels remained consistent or improved by the end of the day. The words “relaxed” and “calm” were circled to represent the waking comfort level, and “tired” was circled describing the end of the day comfort level, though technically the end of day comfort levels were similar to those upon waking.

Physical conditions are the most important factor in influencing comfort

Interestingly, the number one factor that made the participants most comfortable was the “people” in the office. People have an influence on the office environment and can change a seemingly physical environment comfortable or uncomfortable. Comfort and discomfort includes the interaction with co-workers or clients as well as factors and experiences outside of work, such as family, friends, health and personal business matters.

The survey found that people made them most comfortable and the office temperature the most uncomfortable. This was dependent on the mood and responsibilities for each day. A workweek has variations in personal duties, interactions, and biorhythms. According to Trump, (2009) working with people you like makes a difference in comfort at work. Oftentimes we try to improve the physical conditions and then measure comfort (Vink, 2005). Introducing people into an environment has influences on all three comfort levels.

The natural environment affects not only the physical health but also the psychological health of human beings (Sundstrom, Bell, Busby & Asmus, 1996). There are many studies in environmental psychology research related to the effect of natural elements. For example, moreover; in offices, the window size and sunlight penetration influences the worker’s mood (Sundstrom, Bell, Busby & Asmus, 1996).
In this study, the physical “temperature” was the most uncomfortable factor (ASHRAE, 2004). However, “people” were found to be the second most uncomfortable factor.

Physical conditions are an important comfort factor according to studies by Vink (2005). The discomfort pyramid (Bubb, 2008) demonstrates that if the environment is unpleasant the physical conditions will ultimately overrule all other factors if not addressed (Figure 2). However, having said that, the emotional connections may be more important for sustainability of comfort.

![Discomfort Pyramid](image)

**Figure 2. The discomfort pyramid of Bubb (2008).**

**CONCLUSION**

The results confirm the time of day relationships between pre-office experiences and comfort levels and 12 out of 16 participants said they were looking forward to work for the day. A positive attitude towards work is beneficial for the health of the company as well as the worker (Trump, 2009). The word circled by most participants to describe physical waking comfort was “relaxed”, the word for mid-day comfort was “calm”, and the word for end of day comfort was “tired”. Feeling tired and having lower comfort levels at the end of a working day is consistent with findings by Vink et al., (2009).

The intellectual comfort level improved from the beginning of the day to the middle of the day, and then declined at the end of the day to about the
same level as the beginning of the day. Anticipation about cognitive work completed can cause a decline in comfort due to anxiety and the nature of cerebral work (Murata, Uetake & Takasawa, 2005). This may attribute to the marginally significance ANOVA result in intellectual comfort level.

Emotional comfort levels were consistent with studies by Vink et al., (2009) throughout the day and work week. Although, Thursday showed a marked improvement in all comfort levels by the end of the day and the last workday. This is consistent with studies by Sonnentag, Mojza, Binnewies, & Scholl (2008) that participants are ready for the weekend and exhibit excitement and positive expectations for the upcoming days off.

By providing optimal internal and external conditions, the concept of “comfort in an office” equates to health and wellness in and out of the workspace and workplace to improve overall productivity and well-being. Often we try to improve the physical conditions and then measure comfort (Vink, 2005). However, this study shows the importance of the pre office experience and expectations and the fluctuations in the day of the week.

ACKNOWLEDGMENTS

This study would not have been possible without the survey participants. Thank you for your time and support.

REFERENCES


CHAPTER 3
3 Changing the View of Workspace from Inside to Outside

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Published in Advances in Social and Organizational Factors, 2008

ABSTRACT

Studies show that windows promote well-being, creativity and job satisfaction. In this paper, experiences putting this concept into practice are discussed. Project one, is an office layout for two United States government entities sharing one large space. An approach to a layout with windowed offices, similar to European workspaces, was used. Optimum environmental design results were achieved. Project two shows results from a questionnaire distributed to 33 participants at a dance studio. Their responses to physical comfort and creativity in two dance rooms, one with windows and one without were significant, (Z = -4.798, p=0.000) suggesting respondents felt more creative in the room with windows.

Keywords: environmental design; office layout; creativity; windows
INTRODUCTION

Implementing ergonomic principles into practice is not always an easy job. There is evidence that windows can improve the working conditions of employees (Nicol, 2006). However, it is not always found in reality. Therefore, in this paper more information is gathered about the barriers in convincing office interior architects of the positive aspects of a window. In addition, a study was done on whether a window does make a difference in physical comfort and creativity in dance studio rooms.

The first project was a redesign of an office layout. Due to over-crowding, and perception of job and department overlapping issues a new layout was proposed. The office plan layout was the result of a physical division between two government entities who performed similar tasks, but worked under slightly different code and regulation requirements. The redesigning of the departments took into account the location of employees and meeting rooms, specifically that of the windows.

The second workspace project studies two dance rooms in a dance studio to assess if there is a difference in physical comfort and creativity in a dance room with windows as compared to a dance room with no windows. A questionnaire given to students, instructors and parents provided the data for the study.

The goal of human factors strives to improve productivity and people’s health, safety and comfort (Hendrick, 2002). The International Ergonomics Association states Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people (2000).

The physical layout or spatial structure for any room has an effect on the occupants. Intention is required for a space designed or redesigned. Who will occupy the space? What will occupy the space and how will it be used (Sanders & McCormick, 1993)?

Studies by McCoy & Evans (2002) and Nicol (2006) on window or windowless workspaces/places suggests that the physical environment and a room with a view affect the overall well-being of the occupants of these spaces. Well-being promotes a holistic concept of wellness for individuals to include physical, mental and psychological well-being (INQA-BUERO, 2005).
What is meant by a “room with a view”? Ideally, a room with a view has a window to an outside environment, thereby providing a framed space or connection, with what is beyond the room itself. This view may be of the outside natural environment or of another space inside the same building. A recent study among 785 office workers showed that productivity was higher for those subjects having a window with a view on nature (Nicol, 2006). In 1999, the Herschong Mahone Group conducted a study on student learning confirming that natural light had a positive effect on students scoring higher on standardized tests (Hedge, 2000). In contrast, Brand, (2006) found no significant differences in daylight only luminance nor exterior view was related to workspace quality, although the study did not predict performance or productivity of workers. There are psychological implications for creativity and productivity in spaces that do not have a window Radikovic, (2004). According to the Gensler Survey, (2006), the number one complaint among workers is workplace temperature regulation. Windows that open and close should be considered in new office buildings although a study by Veitch & Gifford (1996) showed that employees who had more control over their environment, in this case light, were not necessarily productive. Although workers reported that they felt a well-designed workplace/workspace improved their performance, encouraged creativity and job satisfaction. Senior executives thought that comfort in the workplace had a positive effect on the company’s bottom line. In the UK, 84% of workers said comfort in the workplace was of primary importance to their job satisfaction and well-being (Gensler Survey, 2006). Rising healthcare costs for businesses and workers has forced the trend towards the well-being of the workplace and the occupants (INQA-Buero, 2005).

However, having said that positive effects have been shown does not mean that the implementation is easy. Therefore, in this study the first research question is was, what are barriers in convincing office interior architects of the positive aspects of a window?

The affect of windows on productivity and better working conditions have been shown. It is also interesting to find out whether windows are of importance in more creative activities like dancing studios. Therefore, the second research question of this study is do windows make a difference in mood or creativity in dance studio rooms?
CASE 1: WORKSPACE PROJECT

DESCRIPTION

This project is an office layout re-design and restructuring of two different government departments sharing one large space. The two departments, one City and the other County perform similar tasks but with different guidelines and code regulations for building and planning. By the year 2001, the departments had grown to maximum capacity and space and overlapping of departments was an issue. A physical division of departments was the decided alternative. Neither department could move to another building so a decision was made to re-design the floor plan to accommodate as many people as possible and still maintain well-being in the office. In the United States, many office layouts do not provide each individual with a window. Windowed offices are generally provided for upper management and meeting rooms (Heintz, 2003). A European approach was implemented in the layout to accommodate as many employees as possible to occupy the spaces with windows, natural light, and an outside view. The original plan was to have 25% of employees occupying cubicles in the center of the large space with no windows. The one advantage to the redesign was that the location was on the top floor of a three-story building and there were skylights in the roof. Natural light was available throughout most of the rooms from the actual windows or the skylights. The windows also opened and closed an advantage many office buildings do not have. Studies suggest that situating office workers near windows with the added possibility of opening the window has shown positive effects on comfort, productivity and even energy consumption (Leather, et. al., 1998). The average age of the employee was 32 years and an equal amount of men and women were in the group. Upper management made up approximately 25% of the group. The original plan placed six to eight non-management employees in the center of the floor plan in a cubicle layout, and utilized the skylights as a natural light source and plans the areas with outside windows as conference rooms and offices for upper management. The reception area was to be divided by two long counters, one counter for each department in a large open room. The two departments decided to divide the entire floor plan layout in half to separate the departments physically from one another. The departments also shared five employees who worked jointly for both departments so their location needed to be accessible to both departments. The proposed file storage areas were to be along the central wall surrounding the six to eight cubicles in the center space. The estimated time for the process of re-engineering and actual office re-design was to be completed over a period of one year and the separation of the departments began immediately.
METHOD

The building is rectangular shape, with the longer walls facing north and south and the shorter walls facing east and west. There are windows on all four sides of the building and skylights in the roof. Almost every area of the building has some natural light. All employees and managers were invited to contribute and be involved in the new design layout changes for the two departments. Information and design ideas were gathered through individual one-on-one interviews, large group design work sessions and large group meetings. Additionally, the re-engineering team consisting of managers, employees, and expert consultants completed job analysis, cost/benefit analysis, and architectural constraints. Individual interview questions asked about personal office layout and design, furniture preferences, task/job duties, lighting, temperature and noise. The individual was free to voice preferences and/or concerns to the larger group. The architect and upper management considered individual interview responses. The responses were considered in the final stages of the design layout. During the design work-session, blueprints were laid out and all participants were given the same set of criteria and asked to form groups and present a design change and/or issue to the overall group. All group presentations and ideas were considered, compiled, and implemented into the overall design. The final design result was an agreement/compromise between the managers and employees of both departments.

RESULTS

After discussions and individual interviews with employees, changes in the original plans occurred and upper management and the architect made decisions for the changes. When the discussions and group design sessions were completed, it was clear that based on literature as well as on employees’ opinions a window view was preferable. Upper management and the architect decided to change the initial plan and the architect drew up a new plan. This plan followed the European approach to the design. The employees occupied the spaces, which had windows, and the meeting rooms were placed in the interior middle space received natural light from the skylights. Most meetings convening in the building were of short duration and were not on a daily basis, whereas the employees were in the building every day, a minimum of eight hours a day, five days a week.

All outside windows were in offices of employees and upper management. The option for workers to control temperature by opening and closing the windows was seen as a benefit, as well as having natural light and view to the outside environment. The offices with windows also were less noisy and had more privacy than the original interior cubical offices. The inner area or original cubical office area in the middle of the floor plan became
the conference or meeting rooms. The issues with noise and sound remain in these areas because the walls did not meet the ceiling at the top due to the skylights and heating and cooling ducting. Several solutions found to subdue the noise level are not addressed in this paper. The two departments split the building in half with one department situating itself on the north side of the building and the other department taking the south side. The five employees who worked for both departments stayed in their original locations on the south side of the building. Accessibility to both departments for these employees was through a short hallway in the middle of the two conference/meeting rooms. The reception area changed to several L shaped counters and remained in the large open room, some noise issues remain. Several of the offices in the reception area do not have outside windows and are have a partial wall cubicle layout. Skylights do provide natural light and the reception area is not overly crowded. The overall result was optimal for most employees and upper management.

**DISCUSSION**

Crucial in this approach was the fact that the layout design preferences of the employees and upper management were clear and the opinion of the architect agreed. It was important that the management supported the decision. The optimum results were achieved through a collaborative effort on the part of upper management and employees to occupying the redesigned space for two departments. This case suggests that when workers have a say in the design of a workspace the psychological effects are positive. The concerns with overcrowding and job mixture were the catalyst for the re-design. Enlisting the help of those who occupy the space in the new layout somewhat eased the organizational changes that occurred at the same time.

By providing natural light, preferably windows, in the office layout design, workers were very pleased to have the added bonus of regulating the temperature and airflow in their space.

The outside view from the windows is spectacular and workers reported it added pleasure and a positive physical effect to their day to see the view and what was going on outside of the office.

There are differences in responses to office, privacy, and personalizing of space. Studies show that more women thought personalizing their workspace was important to their emotional state (Hooper, 2004, Wells, 2000). Studies by Yildirim, et al., (2007) show that women are more sensitive to lack of privacy and do not prefer an open layout office plan with low wall partitions. Men are bothered less by an open layout and less distracted by noise and privacy issues. Both men and women had positive responses to their office space when situated by a window regardless of
partition height. Bernstein (2004) observed that the reception area of a room is the first impression of what the building and the occupants are communicating to the outside world. In this case, the reception area has ambient light from the skylights, natural wood floors, and brick walls, which studies suggest, have a calming effect on people (McCoy & Evans, 2002).

Due to space constraints, an area of importance in workspace design that is missing in this project is a coffee or gathering area for workers. Research by Vink (2007) suggests that coffee/gathering areas are where interactions, creativity, and innovative ideas often occur. Nonetheless, individuals managed to interact and exchange ideas and in their offices or meet and gather in venues outside of the office.

This layout re-design had advantages that many office buildings do not have. From the beginning, there were many existing windows with natural light, extraordinary outside views from the windows, and skylights. By providing natural light, preferable windows in office, layout design for workers there was the added bonus of a positive physical effect. Research has shown the positive effects on productivity as well (Nicol, 2006, Heintz, 2003). The collaboration between the building occupants, builders and architects is not new, as the positive effects of participatory approaches have been used before (Vink, 2005). It was unusual and welcoming because this type of participatory process is not traditional in most American workspaces or workplaces re-design projects.

CASE 2: DANCE SPACE PROJECT

DESCRIPTION

The second example reports a difference in physical comfort and creativity in two dance studio rooms, one with windows and the other without windows. According to McCoy & Evans (2002) creativity is defined as, “the ability to solve problems with original, innovative, novel, and appropriate solutions.” Research by McCoy & Evans (2002) suggested that environments that have no windows, cool colors, and manufactured or composite materials are less conducive to creativity. The physical characteristic of the environment in this case is windows and natural light from large windows (Figure 1.) in one dance room as compared to a second dance room with no windows.
Figure 1. This is the outside wall showing the exterior second story windows at the dance studio for Workspace Project 2.

The square footage for each room is different. The dance room with windows has more square footage and is slightly wider than the room without windows. The wall and ceiling colors, flooring material, and lighting fixtures are the same in both rooms. Natural vegetation is visible through the large windows in the first dance room (Figure 2 and Figure 3). Reports by Kaplan (2001), Tennessen (2006), and McCoy (2002) suggest that a view of nature stimulate creativity, are beneficial to health and recovery, and help maintain or restore concentration and focus.
The room with no windows (Figure 4 & Figure 5) is well light. It is and narrow and long. A report by Radikovic (2004) suggests that windowless or subterranean work environments have a negative impact on health and wellbeing. According to Vithayathawornwong et al., (2003) fostering creativity and designing dynamic environments in a workspace should include windows if possible.

This project compared two dance rooms in a dance studio by administering a questionnaire to 33 individuals to self-assess a difference in physical comfort and creativity in one dance room with windows and another dance room with no windows. The answers given by students, instructors and parents provided the data for the study.

**METHOD**

Volunteer participants were informed about the study on how windows may or may not affect creativity and physical comfort being conducted at a dance studio. Each participant received a consent form questionnaire.
(Appendix A) and asked to complete fill them out. Participants were asked to specify gender, age and status, (parent, student or instructor) questions and then answer eighteen additional questions about two dance studios.

To answer the research question, does a window have an effect on physical comfort and creativity in dance studio rooms, a questionnaire was distributed to 33 people, 31 female and 2 males, ages; 51% were 9-12 years of age, 9-50, one parent, four dance instructors (one instructor was also a parent), and 28 dance students. Data analysis completed using Statistical Package for Social Sciences® (SPSS for Windows, Rel. 12.0.0. 2003. Chicago: SPSS, Inc.) A non-parametric Wilcoxon Signed Ranks Test was used to compare group differences in responses to a room with windows and a room without windows.

RESULTS

The results for the non-parametric Wilcoxon Signed Ranks Test were significant ($Z = -3.704$, $p=0.000$), for questions 4 & 13. Results suggest that people in a room with windows prefer the type of light in a room with windows rather than a room without windows. Significant results ($Z=-2.810$, $p=0.005$) for questions 5 & 14 Suggest respondents hear better in the room with windows. Significant results ($Z=-4.944$, $p=0.000$), for questions 7 & 16 suggest that the windowed room was easier to move around in. Results were significant ($Z=-4.798$, $p=0.000$) for questions 8 & 17 suggesting that respondents felt more creative in the room with windows. No significant results were found for questions 6 & 15, suggesting that both rooms were adequately lighted.
Table 1. Percentages for participant (n=33) responses to survey Q4-8 and Q13-17.

<table>
<thead>
<tr>
<th>Answers for Room</th>
<th>Windowless room</th>
<th>Room with Windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q4 &amp; 13 Like Light in room</td>
<td>Yes 36%</td>
<td>No 43%</td>
</tr>
<tr>
<td></td>
<td>Other 21%</td>
<td></td>
</tr>
<tr>
<td>Q5 &amp; 14 Hear well in room</td>
<td>Yes 64%</td>
<td>No 24%</td>
</tr>
<tr>
<td></td>
<td>Other 12%</td>
<td></td>
</tr>
<tr>
<td>Q6 &amp; 15 See well in room</td>
<td>Yes 89%</td>
<td>No 7%</td>
</tr>
<tr>
<td></td>
<td>Other 4%</td>
<td></td>
</tr>
<tr>
<td>Q7 &amp; 16 Move easily in room</td>
<td>Yes 9%</td>
<td>No 64%</td>
</tr>
<tr>
<td></td>
<td>Other 27%</td>
<td></td>
</tr>
<tr>
<td>Q8 &amp; 17 Feel creative in room</td>
<td>Yes 44%</td>
<td>No 37%</td>
</tr>
<tr>
<td></td>
<td>Other 19%</td>
<td></td>
</tr>
</tbody>
</table>

The questionnaire asked the same questions for both studios, questions 9-12 for the windowless studio and questions 18-21 for the studio with windows. The following are the paired responses to the questions.

Q9: 48% said the air felt stuffy and 15% said the air was clean, 6% said hot, 3% said cold.

Q18: 73% said the air felt clean and 9% said the room felt clean and cold. 15% wrote in their own words.

Q10: 52% said the room felt confined, 9% felt heavy, 9% felt open and 3% felt airy. 18% felt the room was both heavy and confined.

Q19: 70% said the room felt open and 21% felt the room was airy.

Q11: 33% felt the room made the mind feel sluggish, 21% said clear, 15% said confused and 3% said vibrant.

Q20: 45% felt the room made the mind clear, 24% said the mind felt vibrant.

Q12: 33% felt the room made the body feel sluggish, 21% said vibrant, 15% clear and 3% said they felt both sluggish and confused.

Q21: 40% said the body felt clear and 33% said the body felt vibrant in this room. The responses suggest that the windowless room less comfortable physically than the windowed room and the respondents felt more creative in the room with windows.
DISCUSSION

The physical comfort of the two rooms had an impact on how creative the respondent felt in each room. The room with windows was perceived as more comfortable and therefore the respondent felt more creative in the windowed room. A study by Kuller et al., (2006) reported that color and light have an effect on mood. The proximity of an individual to a window, along with what is perceived as “the perfect light”, elevates the mood positively. However, if the light is too low or too high, the mood is dampened.

The color and artificial lighting are the same in each room. Natural light and overall square footage are the differences in the two rooms. From the results, both rooms had adequate lighting and visibility. Although the results from this project suggest the “the perfect light” occurs more often in the room with windows. In another study by Veitch & Gifford (1996) found that perceived control of the physical environment had a negative effect on creativity, in fact individuals were more creative in a controlled environment. That said, the results of this project suggest that the light in the room with windows is less controlled than the light in the room without windows. Therefore, creativity should be more prevalent in the room without windows. The workspace project suggests respondents felt more physically comfortable and therefore more creative in a room with windows.

However, they also felt creative in the room without windows. The comfort felt in the window room may override the less control resulting in a creative atmosphere despite less control.

Research by Vithayathawornwong et al., 2003, McCoy & Evans, and others mentioned in this paper also suggest that the physical environment, particularly that of windows, does have an effect on creativity. Studies and more research are needed on the physical environment and the effects on creativity. Additionally, further research on preferences of the size and shape of windows by gender, age, cultural differences, and time of day/night could prove valuable to architects and builders in building creative productive workspaces (Dogrusoy & Tureyen, 2006).

CONCLUSION

Studies show that windows stimulate productivity, well-being, creativity and job satisfaction. Case one of this paper shows that this knowledge is not automatically brought into practice. Management, employees, builders and the architect collaborating on a new layout demonstrated the practice
of participatory ergonomics. The second case shows that windows are not only important for work, but also for dance studios. Results were highly significant proving that respondents felt more creative in the room with windows.

ACKNOWLEDGMENTS

Crisit Perry (Gigi) for gathering surveys and taking photographs, the dance studio participants, the two government entities for an interesting project to recap, and Alan Hedge for SPSS data runs and interpretation.

REFERENCES


Hedge, A. (2000). Where are we in understanding the effects of where we are? Ergonomics, 43(7), 1019-1029.


APPENDIX A

DANCE STUDIO WINDOW / WINDOWLESS SURVEY QUESTIONS

1. Please Circle Male Female

2. Please Circle Parent Instructor Student

3. Age

The following questions pertain to the studio without windows please circle your responses and write comments if you would like.

1. Do you like the light in this room? Yes No Other
2. Can you hear well in this room? Yes No Other
3. Can you see well in this room? Yes No Other
4. Is this room easy to move around in? Yes No Other
5. Do you feel creative in this room? Yes No Other
6. What does the air feel like in this room? Hot Cold Stuffy Clean Other

Please Circle only those that apply:

7. What does the room feel like? Open Confined Heavy Airy Other
8. Does this room make your mind feel Clear Confused Vibrant Sluggish Other
9. Does this room make your body feel Clear Confused Vibrant Sluggish Other

*13-21 are the same questions as 4-12, not shown, and pertain to the studio with windows.
4 Possibilities to Improve Aircraft Interior Comfort Experience

Peter Vink, Conne Bazley, Irene Kamp, & Merle Blok
Published in Applied ergonomics, 2012
Volume 43, Issue 2, Pages 354-359

ABSTRACT

Comfort plays an increasingly important role in the interior design of airplanes. Although ample research has been conducted on airplane design technology, only a small amount of public scientific information is available addressing the passenger’s opinion. In this study, more than 10,000 internet trip reports and 153 passenger interviews were used to gather opinions about aspects, which need to be improved in order to design a more comfortable aircraft interior. The results show clear relationships between comfort and legroom, hygiene, flight crew attention and seat/personal space. Passengers rate the newer planes significantly better than older ones, indicating that attention to design for comfort has proven effective. The study also shows that rude flight attendants and bad hygiene reduce the comfort experience drastically and that a high comfort rating related to higher “fly again” values.

Keywords: cabin comfort; legroom; passengers’ opinion; aircraft interiors
INTRODUCTION

Comfort attracts passengers

Today, people are constantly on the move, travelling for many reasons, e.g., business, leisure and family visits. Travelling by plane is growing and opportunistic for airliners. According to Brauer (2004), airliners can increase their financial margin by reducing maintenance costs. However, a reduction of 14% of the maintenance costs results in a 1% margin. Similarly, an increase of airline passengers of 1% results also in almost a 1% margin. In order to attract more passengers, data are needed to determine the selection behavior of passengers, according to Brauer (2004). It appears that passengers first select on point-to-point transport, time and price, then on aspects like marketing (frequent flyer programs), followed by comfort, past experiences and delays. For short distances, the delay aspect is more important as opposed to long distance travel where the comfort aspect plays a more important role. This paper focuses on possibilities to increase comfort and the potential marginal benefits airlines may gain by providing more comfort to passengers, thereby attracting more passengers. According to Richards (1980), passenger comfort is clearly a key variable in research on user acceptance of transportation systems, as related to passenger's satisfaction and the willingness to use the system again.

Everyone has a comfort opinion

Comfort has many aspects. In a previous literature study (Vink, 2005) the MEDLINE database showed 261 papers with comfort in the title between April 1993 and April 2003. By far most of these (140 out of 261) concern climate or thermal comfort. Other areas of study are effects of medicine or nursing (pain/patient comfort) and physical comfort (28 out of 261 papers); these include research regarding seating, posture, physical loading, and foot pressure measurements. The context of comfort does differ. However, there is a general notion in the word comfort.

Comfort is described as 'freedom from pain, well-being' in Dutch dictionaries like the Van Dale 2000. In these dictionaries, comfort is also translated as convenience of the interior. Many people associate comfort with the interior. In scientific literature comfort can be a pleasant state of physiological, psychological and physical harmony between a human being and the environment or a sense of subjective well-being.

According to De Looze et al., (2003), there are many definitions, but one point is not really under debate: comfort is a subjective experience. A product in itself can never be comfortable. It becomes comfortable (or not) when it is used. The user decides whether or not a product is comfortable or whether it leads to discomfort.
This complicates the construct of comfort, because it is not known how every individual will react to a product. For example: On a long distance airplane flight passenger one may feel that back comfort or discomfort is of greatest importance, while passenger two wants a reduction in noise and passenger three needs more space. To provide all passengers with an ideal design to address comfort situations specific to each is complicated and potentially cost prohibitive.

*Design for comfort is possible*

However, it is not impossible to design a comfortable interior. Bronkhorst & Krause (2002) designed a train interior that was described as comfortable by 83% of the passengers. Important preliminary steps were taken in the initial design process, such as assessing the characteristics of the persons (like anthropometry) and tasks done during the travel. These were accounted for and incorporated into the finished design. Several experiments were performed in as naturalistic setting as possible with a group of subjects resembling the real passengers to determine the optimum comfort experienced by end users.

*The main elements influencing passenger comfort*

Before the designing process starts, it is useful to establish the interior aspects with regard to comfort the passengers define as important. At the advanced aircraft interior conference of 2009, many aircraft interior developments were presented to improve comfort. For example, new materials, new lighting systems, new seat mechanisms and alternative seat configurations. However, the question is whether passengers notice these innovations as comfortable. A group of airlines asked the Delft University of Technology to perform a comfort study. The research question: what are important factors in the aircraft interior influencing the comfort rating during a flight?

**METHOD**

To answer the question two studies were performed. The first one was an analysis of 10,032 internet trip reports of flights from May 1st, 2008, until October 1st, 2008. A disadvantage of internet trip reports is that only internet users complete these forms. Therefore, an additional study was used consisting of 153 interviews with "just arriving" travelers at the Amsterdam airport. These subjects were questioned after passing the customs at Amsterdam airport. When the interview with one subject was completed, the next person leaving customs was asked for the interview. A student could collect 153 interviews in four days.
The internet trip reports

During the flight, passengers of the group of airlines involved in this study were shown an internet address, where they could write their trip report. It consisted of an open space, where passengers could describe their experience and closed questions like: what is the comfort rating of your last flight (0-10; 0=lowest rating, 10=highest)? What was, the name of the airline, would they book a flight again for this trip with this airline (yes, no, don’t know)? What class they were using (economy/coach, premium economy, business or first), seat position and service rating (from 0-10)? The 10,032 passengers that completed the trip reports travelled with 123 airlines. Most of these airlines were from Europe (40.9%) and North America (31%). Passengers were also asked to upload pictures of aspects related to comfort. 162 pictures were uploaded or used to illustrate the problems or positive aspects. 42 passengers gave us permission to use the pictures in public reports. Nine students analyzed the 10,032 trip reports and filled databases that were later merged into one file. First 100 trip reports were analyzed and the issues that were mostly mentioned were put in a list.

For each aspect a scale was made, mostly a scale ‘-1 negative, 0 neutral and +1 positive’. However, for aircraft type, the types were categorized in two aspects: wide body and narrow body and in old versus new planes. (This was done by putting airplanes like the Boeing 737-200/300/400/500 in the old category and the 700/800/900 in the newer, for every type of aircraft a likewise distinction was made). Airlines were categorized in low cost, charter and other airlines and the flying time was categorized in hours. For each of 27 aspects a scale was made. The nine students then analyzed all 10,032 trip reports and were instructed to derive the aspects from the reports from the 10,032 trip reports. They also checked the aircraft type specified by the passengers by looking at the flight number or, if this was not given, by using other data (e.g. Ryanair only has Boeing 737s, Aer Lingus only uses A330s on long-haul distances, etc.) and correcting the type. The students fed these characteristics into excel files that were later merged into one larger file. Statistical analyses consisted of correlation calculations. Comfort was the main issue and t-tests were used (t-test, p<0.05) to determine if a good score on a characteristic had a significant effect on comfort as compared with a bad score on a characteristic. For instance, the comfort score of the persons mentioning a positive crew attitude was compared with the group mentioning a negative attitude. Additionally, multiple regressions (forward selection procedure) were used to identify which of the aspects are related to overall comfort.

In the results the factors having a beta >0.6 are described first as well as the correlations with comfort. The main aspects influencing comfort are described and the top five most mentioned positive and negative
descriptions are mentioned and illustrated by pictures of the passengers. An additional selection criterion was added by the airlines. It was determined that an aspect mentioned by 10% is still valuable, but 5% is not. An arbitrary choice was made that an aspect should be at least 8% to be included in the results.

Interviews

After a pilot test, some revisions were made in the questionnaire used in the interviews. In the definitive version of the questionnaire, subjects had to rate the comfort of different aspects of the latest flight on a scale from 1-5 (1 = very bad; 5 = very good). In addition, some general aspects like length of the flight, age of subject, height of the subjects, etc. were taken into account.

Questions were asked about the process of check in, customs, and ended with several flight characteristics. The mean values and standard deviations were calculated per aspect.

The initial groups were split into two groups (larger and shorter persons, younger and older, short and long flight). A t-test was used (p<0.05) to test the differences between these two groups and rated comfort experience.

RESULTS

Trip reports

Descriptors strongly associated (beta >0.6) with comfort for all subjects are:

1. ‘intention to fly again with this airline’,
2. ‘enough/much legroom’,
3. ‘cleanliness of the interior’,
4. ‘nice crew’, and
5. ‘good seat’.


**Table 1:** 27 Aspects Taken From The Trip Reports, Scale Used, Correlation (Corr) With Comfort And Percentage Of Passengers That Does Mention The Issue In Their Report.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Scale rated by student evaluating the trip report</th>
<th>corr</th>
<th>% that does mention the issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort</td>
<td>scale 0-10 (10 highest comfort)</td>
<td>1.000</td>
<td>99.7</td>
</tr>
<tr>
<td>Service</td>
<td>scale 0-10 (10 highest comfort)</td>
<td>0.798</td>
<td>98.3</td>
</tr>
<tr>
<td>Fly again</td>
<td>scale -1= no, 0 = don't know, +1 = yes</td>
<td>0.730</td>
<td>100.0</td>
</tr>
<tr>
<td>Legroom</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.718</td>
<td>26.3</td>
</tr>
<tr>
<td>Hygiene</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.694</td>
<td>11.7</td>
</tr>
<tr>
<td>Crew</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.638</td>
<td>77.8</td>
</tr>
<tr>
<td>Seat</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.342</td>
<td>19.2</td>
</tr>
<tr>
<td>Luggage room</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.341</td>
<td>5.1</td>
</tr>
<tr>
<td>Food</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.331</td>
<td>3.3</td>
</tr>
<tr>
<td>Neighbor</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.330</td>
<td>4.6</td>
</tr>
<tr>
<td>Information</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.327</td>
<td>1.9</td>
</tr>
<tr>
<td>Waiting</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.316</td>
<td>2.9</td>
</tr>
<tr>
<td>Toilet</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.291</td>
<td>1.1</td>
</tr>
<tr>
<td>Noise</td>
<td>scale -1= complaint, no value = no comment, +1=smooth</td>
<td>0.221</td>
<td>0.9</td>
</tr>
<tr>
<td>IFE</td>
<td>scale -1= complaint, no value = no comment, +1=positive comment</td>
<td>0.217</td>
<td>4.3</td>
</tr>
<tr>
<td>Bumpy flight</td>
<td>in categories of 20 minutes (from 20 -5000 minutes)</td>
<td>0.216</td>
<td>0.2</td>
</tr>
<tr>
<td>Flying time</td>
<td>scale -1 = old, empty = unknown, +1=new</td>
<td>0.212</td>
<td>99.1</td>
</tr>
</tbody>
</table>
As expected the correlations coefficients of these factors with comfort are also high (see Table 1). Correlations were also found with aspects that were not often mentioned by the passengers. The factors most often mentioned in the trip reports were:

1. nice or rude crew, which could be ground staff, pilots or flight attendants,
2. legroom or pitch,
3. delay,
4. lost luggage,
5. seat aspects,
6. in flight entertainment (IFE),
7. hygiene and direct flight.

These factors correlate with comfort (see Table 1). Other factors like, climate, air quality, noise, toilet, waiting, information, food, neighbor and luggage room were mentioned in less than 8% of the cases, but still correlate with comfort. The first aspect ‘fly again’ is most often described
and is the result of the comfort experience. So, this aspect is not described as an aspect influencing comfort.

Next is shown the division of the airplanes in two categories:

1. older planes (like DC10, Airbus A300, A310, Boeing 747-200, Boeing 767-200, DC9) and
2. newer planes (like Embraer 170/190 series, Airbus A330, Boeing 737 Next generation, Boeing 777).

There is a significant difference in comfort (two sided t-test, p<0.0003, t=3.85) between these groups. The newer airplanes have a significant higher comfort. Three planes rating very high were the Embraer 170/190, the Boeing 747-400 and the Airbus 320 series. Wide body jets did not have significantly higher comfort scores, but when corrected for flying time the wide bodies have significantly better comfort. There was also a high correlation between comfort and service (r=.80). The question is, however, whether service influences comfort or comfort influences the service rating. For an airliner, this does not give concrete clues for redesign and therefore service is not considered further in this paper.

Legroom

The correlation coefficient between legroom and comfort score is 0.72. 26% of the passengers mention pitch, knee space or legroom in the trip reports. If we compare the passengers giving a positive comment on the legroom (11%) with the passengers giving negative comments (16%), the comfort scores of these groups differ significantly (two sided t-test, p<0.0001, t=13.57).

![Figure 1](image1.png) Two pictures of ample legroom. The right one clearly shows why the seat pocket enlarges the problem.

Passengers giving a positive comment regarding hygiene (8%) with the passengers giving a negative comment (4%), the comfort scores of these groups differ significantly (two sided t-test, p<0.0002, t=3.95). Examples of positive hygiene are a clean looking plane, fresh interior, clean seats, clean windows, and a bright looking refurbishment. Examples of negative
hygiene are old and shabby cabins, dirty worn out seats, smelly plane, dirt in the seat pocket and window (e.g. moldy bread and apple core in the seat pocket), and spider webs in the plane (see also Fig. 2).

![Figure 2. Pictures of travelers related to hygiene: left dirt on the seat, right: dust in the window.](image)

Crew

The correlation between crew and comfort was 0.64. In all trip reports, 60% of the average score of the flights with positive crew remarks was 8, while in the case of a complaint this was 3.9. If we compare the passengers giving a positive comment regarding the crew with the passengers giving a negative comment, the comfort scores of these groups differ significantly (two sided t-test, p<0.0001, t=12.7).

Examples of positive comments were; the crew was very welcoming; the cabin crew was friendly and helpful; young enthusiastic crew; the pilots gave clear and good information, also about the sudden movements of the plane; and the ground staff guided us very well. Examples of negative comments were; the ground staff was unhelpful, the flight crew was rude and the pilots did not seem to care if their messages came through to the passengers, the crew reprimanded people, and the crew was not interested in doing their job well.

Seat

The correlation between seat and comfort was 0.34. Comparing a good and a bad seat resulted in significant differences (two sided t-test, p<0.0001, t=11.5). The positive comments mentioned by 14% of the passengers were; nice leather seats, roomy/spacious seats, very nice covering (mostly a light color is mentioned), adjustable headrests and good to have space under the armrest.

The negative comments mentioned by 5% of the passengers were; armrests are too large and reduced the width of the seat, too much lumbar support, the seat was broken and the seats were dirty and gave a poor impression. Exactly one third of all pictures considered seat improvements. For business class, the most mentioned problem was the fact that seat angle made the passengers slant forwards.
Interviews

82 male and 71 female (mean age 34 (+/- 14), mean length 176 cm (+/- 10)) flew 36 airlines. In Figure 3, the mean comfort score of 153 passengers regarding several flight aspects and the overall comfort score of the flight (total score) on a scale from 1-5 (1=very low comfort, 5=very high comfort) is given.

![Figure 3](image)

**Figure 3.** Mean comfort score of 153 passengers regarding several flight aspects and the overall comfort score of the flight (total score) on a scale from 1-5 (1 = very low comfort, 5 = very high comfort).

The results show that legroom and personal space (space for arms, shoulders and head and stowage close to the passenger) have the lowest rating and service the highest. In fact no aspects have an average rating good (4) or very good (5). The comfort for the lack of legroom is significantly lower for taller persons (>173 cm) than for shorter (t=1.98; p<.05). The taller persons have lower comfort values for waiting at customs (t=2.03; p<.05). On the open-ended question: the aspects that need the most improvement were; 41% legroom, 11% personal space and 9.5% check in.

**DISCUSSION**

Both studies show that the most important aspects influencing comfort are legroom and the seat. The trip report study adds hygiene and crew as important factors and the interview study shows the importance of
The importance of legroom is found in other studies as well (Bloks et al., 2007; Richards & Jacobson, 1977) and it is the most important factor related to comfort. Less legroom results in lower comfort ratings, especially for taller people. The airline sector is aware of these issues. New airplanes have higher ratings and various attempts are being made to increase legroom with the same pitch (Brauer, 2004). Some seat manufacturers now have a very thin backrest giving more leg space. Nevertheless, more can be done in this area to improve comfort and attract passengers.

The hygiene aspect is conflicting in both studies. However, if we look into it in more detail it is not. Hygiene is closely related to comfort according to the first study, but has a high average comfort score in the second study. In the first study, 8% gives a positive score and 4% a negative one, which means that the average could be equal to each other. Konieczny (2001) studied aspects that influence aircraft interior comfort and concluded that hygiene is not an important factor. Of course, it depends on the definition of hygiene. In this study, hygiene is used in a very broad sense, meaning that good hygiene is also considered bright looking and brand new in this study, as rated by the students. However, in Konieczny's study, only two questions point to hygiene: cleanliness and dirt. Perhaps it would have been better to follow a stricter definition, and then again, it may not have been such an important factor.

Regarding the influence of the crew, 60% report a positive point on the crew in the trip reports. This is comparable with the results of Konieczny (2001) who also found that the crew attention had an influence on comfort. In addition, the study by Chen (2008) is in alignment with this aspect. Chen studied 300 long-haul passengers and used an exploratory factor analysis and a principle component analysis, which made it possible to identify the factors explaining the service quality in airplanes. The most important factors for a good service are the staff and facilities. It explained 19% of the variance. Of course, comfort and service are different entities, but in this study, it is shown that there is a strong correlation between comfort and service.

The seat and seat width also influence the comfort experience. This is not new. The study of Richards & Jacobson (1977) report ‘legroom’, ‘seat firmness’, ‘seat width’ and ‘seat shape’ as the main factors related to overall comfort. The gamma coefficients between these aspects and overall comfort judgments were around 0.5, while temperature and lighting coefficients were only .27.

In addition, the more recent study of Konieczny (2001) showed the importance of the seat quality. In the pictures it was surprising to see how many easy to improve things were mentioned (see Figure 4). Personal space was also related to the seat and was mentioned in the interview with
passengers, as well as the need for more separation from the neighbor and more room for privacy.

**Figure 4.** Two pictures sent in by one of the passengers with the comment: “bad seat: armrest too long, too thick (less upper leg space) and buttons cannot be reached as the leg is against it” (left); “terrible seat: lumbar support does not fit to the anatomical structure of my body and is worn out” (right).

Of course, this study has also some drawbacks. One drawback could be that the rating is influenced by the interpretation of the nine students of different countries analyzing the texts in their native language and translating this into English. However, there were no significant differences between the outcomes of the different students except for the aspect of legroom. The Asian students had a lower correlation with legroom (.637). This could be caused by the fact that the Asian population had less problems with the legroom or because the students rated these values differently. Another drawback of this study is that we focused on aspects of passenger awareness.

With other methods like context mapping (Sleeswijk-Visser, 2009) it is shown that there are also other aspects that are important to end users of whom they are not aware, i.e. lighting and noise. Mellert et al., (2008) discuss that noise could have an impact on the other aspects. They studied the impact of noise and vibration on well-being during long-haul flights and in simulators. Apart from indices to characterize the human response, they found that noise has an important impact on health indicators, comfort and well-being. For instance, passengers with swollen feet are more aware of this situation under noisy conditions.

The awareness increased 43% under noisy conditions as compared with the quiet conditions at the beginning of the flight. The same is true for neck pain. A pronounced increase of pain was experienced with an increasing noise level. Light could have the same effect, and while it is hardly noticed, it could influence other factors.

Konieczny (2001) also discusses that the pre-flight conditions are important. Konieczny found that the comfort during the flight correlates highly with the comfort preceding the flight \((r=0.407)\), fear of flying \((r=0.492)\) and flying attitude \((r=0.367)\). Therefore, soft factors like pre-
flight experience and attention of the crew are important for increasing the comfort experience.

These more complex relationships should be studied further to better understand the comfort experience in airplanes. Brindisi & Concilio (2008) introduced an approach for modeling passengers’ perceptions about environmental comfort inside an aircraft cabin by neural networks. These are useful to study comfort in future, but do not yet provide the clues for redesign. This study gives some specific indications for airliners and designers of aircraft interiors to help increase comfort: more legroom, which is possible without increasing the pitch, better cleaning of the plane, no rude flight crew and a better seat, more personal space and enough seat width, which is possible by better (smaller) armrests. It is still speculation that improving these factors will indeed increase the comfort. In this study, only relationships are established. Ideally, the improved aspects should be tested again in a case control study with subjects to determine whether it really does influence the comfort experience.

CONCLUSION

Comfort is an important issue in flying and is related to the fact of whether a passenger will book with the same airline again. We are at the beginning of understanding how the comfort experience is built. Soft factors like crew attention and pre-flight experience play a role, but physical characteristics like the seat do as well. There are also processes influencing each other. More noise is not mentioned and is a separate problem, but could influence aspects like awareness of swollen feet. This study shows that passengers are aware of the legroom, hygiene, the crew attention and the seat, which all have relationships with the comfort experience.

REFERENCES


5a Retro to New-Retro: Challenges to Planning & Designing Nine Control Room Layouts

Conne Bazley

ABSTRACT

A Human Factors Engineering (HFE) Team created a guideline to provide a path forward and a simplified process for reviewing the design(s) of the nine control room layouts for a large processing facility. The design of the new facility, based on an already existing process, and layouts, including control room design, are to replicate the reference facilities by utilizing reference facility information and lessons learned. However, changing technology and differences in codes, regulations and standards, designing new control rooms to replicate reference facility designs is challenging. The HFE design approach of the layout of the control rooms is top-down and contributes to achieving the performance objectives set for the control room. The HFE Team review of the design of control room layouts meets certain criteria of NUREG 1718.
INTRODUCTION

The design of a new U.S. facility merges the designs of two facilities located in Europe. The result is combining proven U.S. technology with concepts from the reference facilities in order to benefit from the experience they provide and still meet U.S. regulations, codes and standards. This new facility is a major component in the United States’ program to dispose of surplus weapon-grade plutonium. Although it seems simple, it is challenging and complicated to replicate the two existing facilities design into one. The U.S. facility combines not only the functions and processes of the reference facilities into one single facility but also addresses different requirements for nuclear design, security, structural design, HVAC, fire protection and electrical design, thereby creating challenges for overall design.

The prime objective of providing the HFE review of the control room layout is to ensure that the control room design supports all monitoring and control tasks for IROFS (Items Relied on for Safety) functions, including alarm response. The Integrated Safety Analysis (ISA) identifies the administrative controls associated with control room operations, e.g., human-system interface (HSI) regarding the nuclear safety panels.

The secondary objective is providing, to the extent practicable, a “good practices” review of other HSI in the control rooms as well as “Americanization” of tasks and procedures for facility operators.

NUREG 1718 Standard Review Plan

The HFE Team review of the design of control room layouts consists of meeting certain criteria of NUREG 1718, Chapter 12.0 Human Factors Engineering for Personnel Activities. In particular, regulatory acceptance criteria found at 12.4.3(E):

“The HSI design incorporates the functional allocation analysis and task analysis into the detailed design of safety-significant HSI components (e.g., alarms, displays, controls, and operator aids) through the systematic application of HFE. The HSI design includes the overall work environment, the work space layout (e.g., control room and remote shutdown facility layouts), the control panel and console design, the control and display device layout, and information and control interface design details. The HSI design process ensures the application of HFE to the HSI required to perform personnel activities. The HSI design process excludes the development of extraneous controls and displays. The HSI design documentation includes a complete HSI inventory and the basis for the HSI characterization.”
**HFE Top-Down Approach**

Using a top-down approach provides a framework where decisions on such matters as equipment selection, operating practices, working environments and furnishing selection are based around operating demands. The impetus of the top-down approach is human-centered design, while meeting the requirements of nuclear safety specified in 10CFR70, the criteria of NUREG 1718 Chapter 12.0, and the guideline provisions of NUREG 0700 Rev2. No matter how well designed a workstation may be, the overall system will fail if operators are overloaded or undertaking tasks for which they are poorly trained, e.g., straining to read displays which are illegible. Using the top-down approach automatically includes operator limitations and minimizes potential mismatches between operator capabilities and system demands. Human-centered design grounds the process in information about the people who will use the facility control rooms.

**Human-Centered Design**

Human-centered design (HCD) is a design philosophy and a process in which the needs, wants, and limitations of the end user of an interface or document is given extensive attention at each stage of the design process. The international standard ISO 13407: Human-centered design process, is the basis for many HCD methodologies and although this standard provides guidance it is not a requirement for this project. The standard provides guidance on human-centered design activities throughout the life cycle of computer-based interactive systems; however, the methods can be adapted for other purposes including the human interfaces within the control room. The chief difference from other interface design philosophies is that user-centered design optimizes the needs and wants of the user to do the work, rather than forcing the users to change how they work to accommodate the system or function.

**CONTROL ROOM**

Many factors are considered in control room design and layout. Two important aspects of a control room is configuration (i.e., the arrangement of workstations and other equipment within it – the “layout”) and its environment.
HFE considered placement of workstations and equipment (fixed and desktop) in the primary operating area (POA) to afford operators at those workstations:

- The operator now has an unobstructed view to all the control and display panels including annunciators in the POA.
- Revised layouts minimized communication distances to any point in the POA.
- Provided ease of access by the operators to the workstations and ease of performing task actions, especially IROFS tasks.
- The operator has unobstructed movement and communication.

Furnishings and Equipment Layout

The arrangement of furnishings and equipment was dependent on control room purpose, configuration, staffing, and other design features. The HFE Team included physical clearances for maintenance, testing, and emergency equipment in the layout of the control room. Operations analysis, function analysis and task analysis all contributed to understanding the control room layout. In addition, consideration was given to space requirements for “station loading” during periods of shift crossover, training, on the job training (OJT), and audits/oversight. The HFE Team ensured there was enough space around the controls and displays for groupings of people who may need access to equipment.

- Workstations and equipment were placed in the primary operating area (POA) and permitted operators at those workstations a full view of all control and display panels, supervisory control and data acquisition (SCADA) screens, including wall-mounted annunciator panels and safety panels in the POA.
- Workstations and equipment placement facilitated voice communications from operators seated at those workstations to any point in the POA.
- The control room arrangement facilitated efficient unobstructed movement and communication. HFE used “link-diagram” and “table top analysis” to help understand operator movements and communication needs.
- Process unit operator and supervisor workstations positions were designed to provide both a clear, unobstructed view of the control board(s) and allowed for easy communication between personnel. Barriers such as support columns, temporary walls, cabinets,
other desks or consoles, hanging CCTV monitors, etc., did not obstruct lines of sight and voice contact.

Environment

- The HFE Team considered the control room workspaces lighting, noise, temperature, and other environmental factors affecting operator performance.

- Control temperature and humidity was determined within acceptable limits to provide a comfortable environment. NUREG 0700 Rev 2 provided recommended thermal comfort guidelines.

- The design layouts provided adequate lighting. NUREG 0700 Rev 2 (Table 12.1), to ensure that visual effectiveness was sufficient for task performance.

- A Background noise of 45dB(A)- 65 dB(A) was determined to be most desirable because it would not interfere with verbal communication between operators or the ability of the operators to detect auditory signals (e.g., warnings on SCADA) and

- Sufficient shielding, distance and containment integrity was provided so that control room personnel were not subjected to excessive radiation doses under postulated accident conditions.

Control Room Review Process

Figure 1 and Figure 2 show a simplified process guideline for reviewing the design(s) of the nine control room layouts for the new facility. The HFE Team considered every aspect of interaction between operators and equipment and the environment, from raised flooring, acoustic concerns, indirect lighting and the well being, health, and safety of each operator.
Figure 1. HFE Control Room Review Process Step 1 through Step 6.3.
Figure 2. HFE Control Room Review Process Steps 7 through Step 11.

CHALLENGES

Changing technology and space constraints presented challenges to designing control rooms that replicate older control room designs. Other challenges for this project included, but were not limited to security requirements, U.S. Codes and Standards, U.S. Nuclear Regulatory Commission (NRC) regulations and associated safety requirements and expectations (e.g., ISA requirements), process and system changes, cultural differences, and site-specific conditions.

Several of the larger process control rooms in the new facility were combined control rooms found in the reference facilities. A deduction of approximately 20% in the building footprint occurred during the planning and designing stage of merging the two reference plants into the new facility. This reduction in size was problematic because the equipment did
not shrink and changes in processes and regulations had in fact added more equipment. The majority of the control rooms had a small engineering office inside the larger room. After discussions with operations it was determined the need for more floor area space was more important than retaining the small offices. The engineering offices were eliminated to provide more floor area.

**Workstations**

Changes in processing and differences in standards, codes and regulations demanded extra equipment and extra monitors on workstations. Determining dimensions for workspaces, and defining the shape for workstations and general layout was a challenge. A “banana” or “eyebrow” shape was the best shape for the larger control rooms because it provided the “flow” of the process to move systematically throughout the room for the operators. Workstation POA is at a minimum. The limited space for operator viewing prompted HFE to design stacked monitors and procure seismic standard racks that were transparent enough to provide line of sight for the operator to view annunciator panels on the facing walls. Staffing for the new control room was designed to accommodate 22 operators per shift, 3 shifts per day. When a shift turnover occurs, that number will double. Space constraint was the number one challenge for designing control room layouts. Additionally, it was a challenge to fit extra equipment requirements and still meet the Uniform Building Code (UBC), *Administrative, Fire and Life Safety, and Field Inspection Provision*, and NFPA 101 *Life Safety Code* in undersized rooms.

**Environment**

In several control rooms, two large HVAC units were located inside the control rooms. Normally these units are found outside the room and the air is ducted in. Noise levels of above 85 dB(A) and space constraints prompted the removal of one of the large HVAC units. Heat load calculations were performed prior to the unit removal.

**Technology**

Keeping up with technology is difficult at best. Duplicating the reference plant from a hardware and software standpoint was a challenge. A decision to move from analog to digital was determined. Originally, large flat screens were in the design although not considered because in order to keep with the reference plant designs the smaller screens were retained.

Moving from paper to electronic procedures and what type of device to use, the architecture, where to place it on the already crowded POA was a challenge. Changes in technology are rapid, so it is possible that more changes will be made before Start-Up.
Control Room Conceptual Design Layout to Final Design Layout

There are challenges designing layouts to meet the needs of the operator and the needs of the facility. Figure 3 shows the original conceptual design of one of the nine control rooms for the new facility. After evaluation and of the system processes the HFE Team redesigned the layout illustrated in Figure 4, to fit the needs of the new facility.

Figure 3. Control Room layout in conceptual design phase.

Figure 4. Control Room layout in the final design phase.

The nine control rooms meet the NFPA 101 life safety code, albeit they appear crowded. Final design includes a complete layout design of the control room, complete equipment list, and separate layout designs and equipment lists for each workstation type in that specific control room.

HFE met the challenges and found solutions to these difficulties and others including requirements and factors that contribute to design differences for this new facility.

LESSONS LEARNED

Other factors included in control room design included the incorporation of lessons learned from the operation of the reference facilities as well as
design optimizations resulting from value engineering studies, design reviews and requirements of the U.S. regulators.

Changes were required to accommodate for the US regulations, codes and standards, and process designs. Lessons learned from the reference facilities were not applicable in some instances. For example, extra equipment and the safety PLC (SPLC) system not used in the reference facilities were additions to control rooms and operating procedures. HFE conducted system processes “Americanization” with SDG and Operations. Reference plant operators performed tasks or used procedures differently than the operators of the new facility in a large part due to cultural differences.

CONCLUSION

Typically, the first question HFE asks is “is it safe?” followed quickly by “is it sane?”

The HFE design approach of the layout for the nine control rooms is top-down and contributes to achieving the performance objectives set for the control room.

The HFE Team followed these five activities for design and layouts for the nine control rooms:

1. Plan the human centered process (identify the need to use HCD).
2. Specify the context of use. Identify who will use the facility control rooms; what they will use it for, and under what conditions they will use it.
3. Specify requirements and guidelines. For successful control room layout and design, identify the control room requirements, guidelines, and the operator needs and goals.
4. Create control room design and layout solutions. Doing this part of the process in stages helps the HFE Team in building from a rough concept to the complete design and layout.
5. Evaluate the control room designs. The most important part of this process is that the evaluation, verification and validation – ideally through “usability testing” with actual operators.

Final design for the nine control rooms was not without challenges. The nine control room layouts and designs were achieved after numerous layout revisions, evaluations of the system processes, engineering change requests, workstations design reviews, anthropometric data collection, interviews, “link-diagram”, "table top analysis”, task analysis, operator experience reviews, lessons learned, and equipment lists inventories were
conducted by the HFE Team. After demonstrating compliance with the appropriate NUREG 0700, guidelines the control room process ended and the HFE Team released the control room layout to design engineering to update the necessary drawings and records. The design approach of HFE for the layout of the control rooms was top-down and contributed to achieving the performance objectives set for each control room. Additionally, HFE created a guideline and checklist to provide a path forward and a simplified process for reviewing the design(s) of the plant control room, layouts with design challenges in mind.

REFERENCES


10 CFR70, Domestic Licensing of Special Nuclear Material (effective as amended in U.S. Federal Register).
5b Expectation Changes and Team Characteristics in a Participatory Design Process

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Published in Work: A Journal of Prevention, Assessment and Rehabilitation, Feb 2012, Issue 41, Pages 5099-5107

ABSTRACT

A human factors specialist researched the expectations of a culturally and professionally diverse team throughout a yearlong participatory design process of a large processing facility. For a deeper understanding of high-level team expectations and characteristics, the specialist collected data and information through in-situ ethnography and traditional case study methods, personal interviews, and a questionnaire that included a likert scale rating for expectation levels. Results found that expectation levels rated extremely satisfied for individual team members and the overall team itself before and during the participatory process. In contrast, expectations for upper management from the team were satisfied before the participatory process, but changed to uncertain, to unsatisfied, to extremely unsatisfied during the process. Additionally, the participatory design team exhibited high-level team characteristics to include honesty, competence, commitment, communication, creativity, and clear expectations.

Keywords: expectations; team characteristics; participatory design process; control room design; diversity
INTRODUCTION

A human factors team attempted to review the completed designs for all control rooms in a large reprocessing facility. After realizing previous control room designs were incorrect, a human factor specialist formed a small professionally and culturally diverse design team to produce new control room designs. The participatory design process and research discussed in this paper span one year and discuss the expectation changes and high-level team characteristics exhibited by a small design team.

In the workplace, human factors specialists and ethnographers have similarities. Both disciplines use a form of observation of the process of work, the behavior of human beings interaction with each other, the work culture, the environment, time and space and are often times translators between engineers, designers and upper management. Additionally both are likely to be a part of a work team or participant of the group or team in a study (Jordan & Dalal, 2006).

Participatory Design

Participatory design is often used within smaller projects to generate prototypes that feed into an overall project’s design process (Fidgeon, 2009). This paper focuses on a larger project. By participating and observing the design process, the researcher determined whether expectation changes occurred during the process. Participatory design does not just ask users’ opinions on design issues, but actively involves them in the design and decision-making processes (Schuler & Namioka, 1993). Steen, et al., (2007) state that, “in participatory design end-users articulate a problem in their current situation and researchers/designers try to solve that problem together with them. In ethnographic fieldwork, the researcher/designer shifts towards the end-users by interviewing and observing them in their current work situation. Both aim to get insight in a current situation of end-users or to solve a current problem for them.”

Expectations

Osvath & Osvath (2008) conclude expectations in humans as “planning for future needs that relies heavily on two capacities, both of which lie at the heart of our cognition; and self-control. Detached mental experience of a past or future event often defines the suppression of immediate drives in favor of delayed rewards, and mental time travel. Future planning is linked to additional high complexity cognition such as meta-cognition and a consciousness.” Expectation can be defined as a belief about (or mental picture of) the future, anticipating with confidence of fulfillment, or the feeling something is about to happen (Collins English Dictionary, 2010).

One of the characteristics of team performance is expectation. Team members come to a team with their own past experiences and what is
expected from them, as well as what they themselves expect from the team they are joining (Katzenbach & Smith, 1993).

**Teams**

Forming multicultural teams is becoming more common as companies become more global. Janssens & Brett (2006) wrote, “Collaborations are generally organized in the integration and/or the identity model or the coalition model. Dominant coalition sets the scene, overrides differences that are not in line with its logic, revise and suppresses other perspectives. This, in turn, creates a less culturally intelligent team model because it discourages meaningful participation in information extraction and decision making.”

The most common alternative approach, the integration and/or identity model, requires all team members to sublimate their cultural identities to that of the entire team by adopting "super ordinate goals" based on their common interests. The approach has the advantage of encouraging every team member to participate. However, it carries two risks. In the interest of unity, team members might submerge their cultural identities, and hence their ability to think differently. In addition, the effort to include everyone in decision-making may bring about cause the team to function at the level of its least-creative member (Janssens & Brett, 2006). The fusion concept aims to overcome that type of problem by ensuring that every member contributes his or her expertise to the team’s discussions. This takes careful organization and team management as every member contributes.

According to Douglas (2009) successful teams have five things in place and a set of common characteristics i.e., (1) clear sense of purpose, (2) well understood norms of behavior, (3) measurable success indicators, (4) clear roles and responsibilities and (5) operating rules.

Additionally, successful high-level performance teams adopt a set of positive behaviors that include, dynamism, flexibility, action focus, and new challenge acceptance. Team attention directs itself towards capitalization based on competencies, high mutual trust, unconditioned team attachment, innovation, continuous learning and development. High performance teams respond to change and initiate it (Abrudan & Brancu, 2009).

Horwitz & Horwitz (2007) suggest that teams with denser expressive and instrumental social networks tend to perform better and remain more viable. These effects are especially potent when the network structures precede initial bouts of performance, but they diminish as time elapses and the familiarity between team members grows.

In this study, the definition of expectations are examined and measured by a likert scale for changes in expectations during the participatory design
process, and high-level team characteristics are observed and recorded through interviews and a questionnaire during the participatory design process.

Research Questions:

1. How do expectations of the design team members evolve during the participatory design process and what factors influence the change in expectations?

2. Does the team exhibit high-level characteristics that make teamwork successful?

METHOD

The process presented here explores the high-level team characteristics and expectations of the small team as reported by the human factor specialist who was also a team member who gathered data by in-situ ethnography and traditional case study methods as well as personal interviews, and a questionnaire. The ethnography entailed detailed observations and records of design meetings and outings to examine expectation levels and high-level team behavior and characteristics. For this study, a questionnaire and personal interviews were used to collect data and expectation levels were rated from 1-5 with 1 being extremely satisfied to 5 being extremely dissatisfied.

The Design Process

The design process for the control rooms began over ten years ago and prior to the formation of the small design team discussed in this paper a team of two human factors engineering specialists were to complete reviews for the control rooms in the new facility. They created a guideline to provide a simplified design process for those reviews. The design of a new facility, based on an already existing process, layouts (including control room design) were to replicate the reference facilities located in a foreign country.

Preliminary layout designs and equipment lists were incomplete for all the new control rooms due to differences in standards and regulations from the reference facilities to the new facility. The human factors engineering group was assigned to redesign all of the control rooms as well as conduct the final review.

The control rooms involve the entire facility and inclusion of other departments and facility groups i.e., nuclear safety, operations, chemical engineering, manufacturing and laboratory system engineers, procurement and other groups was necessary to gather needed information about equipment and other control room needs. HFE held
several large meetings over a year with many representatives from other departments to discuss the new layout designs. After several of the large meetings, it was apparent that the formation of a smaller layout participatory design team was necessary to complete the control room layouts. The smaller design team distributed the knowledge gathered from their own design meetings to the large groups through email once a week or by invitation to large group meetings that were scheduled quarterly or as needed depending on what major issues ensued.

The Design Team

To work effectively in a culturally diversified team requires listening, open mindedness to different perspectives of critical thinking and problem solving techniques. Additionally, it is important to accept that the parties at the table come with a unique frame of reference, lessons learned, and preconceived expectations (Janssens & Brett, 2006). The small design team met once a week for over a year. The team sent new layout information for review and comments to the larger groups for discussion and confirmation for final layout design.

The organizer, and data collector was a human factors specialist and applied psychologist, from the western USA, who facilitated and participated with a small design team:

- Team Member (1) A British senior instrument and control and software engineer, with 20 plus years of corporate, government, and military working experience,
- Team Member (2) A French software engineer from one of the reference plant facilities, was very detailed oriented and wore two hats; one for operations and the other for software design,
- Team Member (3) A chemical engineer in Operations from the southeastern USA with several years of operations experience was intense and dramatic, and
- Team Member (4) an electrical designer with excellent technical skills who paid particular attention to what went on “outside the box”, also from the southeastern USA.

In addition to working on model layouts, the Team members preferred to conduct on-site visits to the structure itself while under construction. The experience of being in an actual room helped with special determinations and the future physical control room environment. During outings and meeting times the team often referred to the overall project as the “French Castle” or “French Fortress” due to the massive scale of the building and extreme thickness of the double walls filled with debris surrounding the inner core structure (Figure 1.).
Due to the 20% reduction in the building footprint from the original design and also an added extra amount of equipment and piping needed to comply with the new standards and regulations, the rooms were crowded and the team speculated on what type of control room operators might fit and work in the cramped, low-ceiling labyrinth environment.

The Questionnaire

The questionnaire contained ten main questions. The questionnaire was given before and during the design process. The first six questions asked the team members about the participatory process and discussed in detail during the interviews. The next four questions ask for comments, and a yes and no answer, and the last two questions were rating scales on expectation levels.

The team was asked to rate the outcome of their expectation levels before and during the participatory design process (a) for themselves as a team member, (b) their own expectation for the small team as a whole, and (c) the expectations they had for upper management. A likert rating scale was used from 1-5, with 1 being extremely satisfied and 5 being extremely dissatisfied. Some examples of the questions asked: What were the main expectations from the control room project for you and were your expectations met? What expectations did upper management have for team performance? Were upper management's expectations met? Other questions asked about the design process were covered during the interviewing sessions but are not the focus of this paper.
RESULTS

For this study, the expectations from the team members included the explicit sharing of the quality and project completion values: goal, visions and objectives from the part of all team members. Strong focus on results, the sense of priorities, and clarity in decision were also fundamental for the team to meet high performance standards. However, the team was extremely dissatisfied with the expectations for upper management and other groups in terms of communication and rated them very unsatisfied on the expectation scale.

Expectations

During the participatory process experience, the team began to share their expectations for the assignment.

Team member (2) stated, “I tried to share my knowledge of the French control rooms processes” and Team member (3) said, “The expectations of the TEAM are the SAME as my own” and Team member (1) added, “Team member 3 is forceful and knows (usually) what she wants but can be told differently. Team member 2 and myself know what we are talking about and do not appear to be too stuck on any position. Team member 4 does a fantastic job interpreting what we decide. The human factors specialist is a good organizer / coordinator that get the meetings to happen and drag us back on track etc.”

The ratings for the Team members themselves and for the small Team before and during the design process, were all 1’s, (1 being extremely satisfied) despite challenges and compromises, The Team’s expectations did not change during the participatory design process. Team member (4) said, “Each step was exciting - Eager, to make this design and the project one to be proud of and able to use it as a presentation if necessary to the client. This was a virgin control room and so therefore there were no roots to follow as far as numbering, sizing, baseline furniture, steps or procedures to follow or milestones to track.”

However, expectation ratings for upper management did change and were mixed before the design process with several 4’s, (4 being dissatisfied), and several 5’s, (5 being extremely dissatisfied) Expectations for upper management during the design process scored a 5 for all team members, (5-extremely dissatisfied). Upper management did not appear to be interested in control room layouts and did not express satisfaction or dissatisfaction with the team. The team viewed this as disinterest and lack of communication that existed in previous lower level design efforts in this overall project.

Team member (3) said, “I don’t know if upper management expectations for the team were met. I know upper management did not meet team
expectations, not good communication with the Team.” Team member (1) said, “I think the overall project and upper management had this expectation for some sexy, futuristic wall mounted large screen monitors that telepathically display whatever the operator desires. Therefore, if that is what they expected, their expectations were not met; on the other hand, if they expected a complete design, than yes, expectations were met. Upper Management was missing in action. If they cared they would have pushed some of the other groups into actually doing some work.”

Team member (3) said, “Upper management’s main interest was to finalize the design. Some (upper management) did not care if the design was right or not, but just finalize it for construction.

The good news is that the (small design layout) team made sure it was correct.” Team member (4) responded, “Pushing out the project in unreasonable time, the time constraints were not measured in dates, but measured in the dates given with the time allowed to spend on project per day or week.”

Along with the expectations of upper management, additional expectations were apparent from other project groups (those involved in the larger review meeting). Issues and frustrations with other groups and expectations from the small group for the larger group and vice versa were expressed although not rated but voiced during the interviews:

Team member (1) said, “Dealing with the ‘human factor’ aspects, OK a console uses up so much space and you have to decide where to put it. Explaining this to annoying humans in a large group meeting though will just keep on wasting time. Two frustrating things really: firstly getting the stuff to fit in the space allocated and secondly the human problems: getting the individual disciplines to come up with their requirements. Luckily the second one got solved by drastically cutting down the number of individuals who really worked on the layouts and this cut out those who liked to ramble on, distract the meeting and just complain.”

Team member (3), “It was definitely a negotiation with other larger groups.”

Team member (4), “Groups who don’t know what they want or need in the control room, as if we can wait until later on when they make their minds up to get their stuff in there and we are expected to integrate changes with incomplete or inaccurate inputs (from other groups). The team made the best decisions at the time for the problems that were at hand. The team did not foresee the objections later in the project by others, and the team made all efforts and changes to abide by their new policies (for lack of a better term).”
Team Characteristics

When finished, the reprocessing facility building will be windowless, concrete, gray, cold, and mammoth. The missing effects: are the drawbridge, a moat (filled with the local alligators) and the roofline adorned with security guard gargoyles spurring fire, hot oil or gushing water after a momentous rainstorm.

The team often used narrative and communicative behavior on their outings and in their meetings. According to Herman (2003), “stories help organize the turn-taking behavior of the parties engaged in narrative communication and narrative is a means of redressing problems that arise when anticipated similar experiences do not materialize. Stories can be told prior to or in the absence of any real failure of expectation, in order to question the explanatory limits of expectation-inducing and – sustaining typifications.” Finding adequate space for equipment and workstations were and continue to be the biggest challenges to this project from the standpoint of design. Additionally, providing adequate, comfortable workstations for a large number of operators continues to be hampered by space constraints.

Team member (1) during a personal interview who said, “Initially, there was all this moaning about how little space we had and this concern seemed overdone expressed the realization and response to space constraints. However, when things started to be shoved and stuffed in the first control room; more and more stuff kept appearing and then actually seeing the space allocated for the first control room, (obviously which was seen on drawings), but the reality of just how low the ceiling was etc., made me into a true “believer” to keep stuff out of the control rooms.”

The following is an example of team frustration paired with team creativity. The design team did not have a designated designer assigned specifically to the control rooms and the need to work on a preliminary layout continued without a designer. Team member (1) and the human factors specialist came up with the idea to cut out colored pieces of paper for workstations (Figure 1). Team member (1) brought the to-scale cut out pieces of papers to represent workstations to a team meeting. The team members worked together and fitted the cut outs on the preliminary drawing in the correct process order. During the creation time through link analysis each member filled in the gaps, discussed workstation placement and work flow and what equipment or workstation needed to be near each other and why. The meeting time was calm, easy, and fun.

There were no arguments, just a lot of laughter. Hence, images of vampire penguins (hybrid) who were short and small, able to fit at the undersized workstations, withstand the cold, able to see in the dark, have wings, can fly, able squeeze in and out of tight spaces and walk through walls. Sleeping accommodations and ways to feed the hybrids were discussed.
Flying monkeys were also considered because they have tails and could hang off the pipes to perform maintenance duties in hard to reach places and spaces.

Herman (2003) discusses narrative representatives behavior where, “stories can be used to engage in “problem rising” i.e., to throw into relief ways in which situations and event depart from the typical or the expected. On the other hand, received stories about the world provide a context of typicality in terms of which unexpected occurrences can be interpreted, enabling various modes of problem-solving.”

Team member (4) finally said, “This is a billion dollar project and we are using tape, colored paper, a ruler, and markers to design a control room for operators to work in for twenty years. This is not normal, is it?” In reality, this is a common way to do design according to conversations with design professionals. The humor was a redeeming quality in an often times depressing and oppressive environment of conceptual design mishaps and constant design changes. Upper management was obsessed with the concrete and construction schedule and was not amenable to necessary design changes, although those changes are inevitable. The team was very professional and strived for perfection in the layout designs.

Figure 2. To-scale colored paper for workstation designs.

High Level Team Characteristics

The high-level team discussed in this paper adopted the fusion concept. Additionally, the team did not have a leader hence the fusion team style ensured an equal input of expertise from all members. The human factors
specialist organized and facilitated all meetings and the gatherings, but each member contributed equally (Janssens & Brett, 2006). To counteract diminished effectiveness, this case study suggested introducing new players to the team intermittently, especially when expertise is required from lead engineers or those individuals familiar with the reference plant operations and processes.

DISCUSSION

Not unlike comfort levels, expectations are subject to interpretation. The English language complicates it even more by using the word in different contexts (Collins English Dictionary, 2010). That said the study did ask that each team member rate his or her own expectation level, the level of the team as a whole, and the expectations upper management had for the team as a whole.

The team felt that upper management was not interested in the design process of the control rooms. Upper management had the appearance of a quasi Laissez-faire leadership style where the leader’s role is peripheral and the teams manage their own areas of the business; the leader therefore evades the duties of management and uncoordinated delegation occurs. The communication in this style is horizontal, meaning that it is equal in both directions, however very little communication occurs in comparison with other styles. The style brings out the best in highly professional and creative groups of employees, however in this project, being creative was not encouraged and not all managers had the same style. This style of management often leads to a lack of staff focus and sense of direction, which in turn leads to much dissatisfaction, and a leads to a poor company image (Douglas, 2009)

Team members noticed a lack of communication with and from upper management and voiced strongly that upper management’s main concern was a construction schedule deadline. The team originally envisioned and expected state of the art control room designs. They were disillusioned and distressed by the lack of interest from upper management. Upper management tended to isolate or silo groups from one another other making communication difficult. This was the preferred upper management style and caused design issues for the team because the control room layout involved the “big picture” to include all stakeholders in the layout designs. These types of problems typically stemmed from the top.

Ideally, in order to assist teams with change, leaders themselves present a positive attitude and help teams envision the opportunities. Change leaders may ensure the necessary safety for teams willing to take risk, as
well as the necessary instruments to have teams innovate necessary change. High performance teams have not only to respond to change, but also initiate it (Abrudan & Brancu, 2009).

Janssens & Brett (2006) found that managers often set up their teams to fail because they themselves fail to help the team anticipate changes or communicate the changes in a timely fashion. Two of the basic elements of fusion are meaningful participation and coexistence. The team was expected to provide innovative solutions to problems. Figure 3. shows an example of the original conceptual design before the team began the new layout designs. Figure 4. shows the final design after numerous design meetings, outings and discussions.

![Figure 3. Control Room layout in conceptual design](image)

![Figure 4. Control Room layout in final design phase](image)

Although the team was multicultural, cultural differences did not interfere with the expectations or participatory process. Multicultural differences were not a hindrance but beneficial due to the international nature of the project design. The team appreciated the differences and thereby enhanced the process by the sharing of diverse perspectives on problems and creative solutions. The team enjoyed the humor of Team member (1) and looked forward to the meetings and outings because they expected to have a good time together, albeit frustrating at times. Creative solutions to
the problems often came out of a heated discussion or funny comment and the team would regroup and be ready to move forward.

Deutsch (1949) considered the effects of co-operation versus competition on group performance. He found two important practical implications of the results of his study: (1) greater group productivity results when the members are co-operative rather than competitive in their interrelationships; (2) competitiveness produces greater personal insecurity (expectations of hostility from others) than co-operation.

This team exhibited the following qualities of a successful team. Being honest with themselves and others involved in the design process through frank dialog and providing professionalism, expertise and competence in presenting those aspects in well-thought out control room designs. The team expressed an overall commitment to the project through frustration, collaboration, innovation and creativity, clear expectations from themselves, expectations for other team members and those for upper management, and communicated clearly and concisely the needs of the team as often as possible and forwarding their results to other groups and stakeholders throughout the layout design process.

CONCLUSION

The participatory design process resulted in a successful high level, multicultural design team. Team factors included honesty, competence, commitment, communication creativity, clear expectations and moderately happy consensus with layouts considering project challenges. The team was collaborative, determined, strived for perfection and worked diligently to create control room layouts for the health and safety of future facility operators. The team demonstrated the characteristics of a successful team according to Douglas (2009) and Abrudan & Brancu (2009).

Expectations

Expectation levels were extremely satisfied for individual team members and the overall team itself, at the beginning and during the design process. Expectations from the team for upper management at the beginning were dissatisfied, although during the design process the expectations became less certain and rated extremely dissatisfied. The extremely dissatisfied ratings may have been largely attributed to management agendas and priorities i.e., Concrete pour schedule, unrealistic due dates, different management styles, and major attrition in upper management and general employment personnel that occurred throughout the design process.
Team Characteristics

Challenges prompted responses from team members and required innovation honesty and collaboration to formulate viable solutions as demonstrated by the revised control room designs.

The team exhibited a clear understanding of what each individual expects from themselves and the team as a whole and a commitment to being part of a team but still reflecting their own characteristics. It showed competence and the strength of the team as directly proportional to its members’ abilities and initiative, clear and honest communication with each other, cooperation and efficiently working together, and creativity and innovative spirit and open to new ideas and initiating change. The aforementioned characteristics are key aspects in a high-level team.

Communication deficiencies with upper management and others leads in the larger groups were and continue to be the most challenging to the team expectation levels and progress in the layout design process overall. Managers are attuned to hearing findings directly from technical experts, the systems developers, customer account managers, market analysts, and computer scientists we work with may contribute substantially to a change of attitude in the company (Jordan & Dalal, 2006). This is also true with human factor specialists who are included in multicultural teams with professionals from different disciplines. Individuals from all disciplines can demonstrate the importance and benefits of human factors to the success of the project.

Participatory Design

According to Chapanis (1991), “human factors are a body of knowledge about human abilities, human limitations, and other human characteristics relevant to design. Human factors engineering is the application of human factors information to the design of tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use.”

During the layout process, the team realized the importance of including the ‘human factor’ into the layout designs. Team member (1), “This process has really put in perspective, for me, the importance of the ‘human factor’ aspects.” Team member (2), “I learnt a lot about the ‘human factors’ issues.” Team member (3), “We were pushed for space so ‘human factors’ became a big player in this part of the project.” Team member (4), “How we can maximize space in the control room including incorporating ‘human factors’ elements into the design?”

Participatory design team opportunities provide for the inclusion of both human factors and ethnography in present and future design and system development work. Additionally, the inclusion of ethnography in the usability methods for this study and future projects prove beneficial as a complimentary evaluation technique for a deeper understanding of
diverse team expectations, team behavior and work culture throughout a participatory design process.

ACKNOWLEDGEMENTS

This project would not have been possible without the insights, input, innovations, humor and support of the Control Room Design Layout Team. Thank you.

REFERENCES


Osvath, M. & Osvath, H. Chimpanzee (Pan troglodytes) and orangutan (Pongo abelii) forethought: self-control and pre-experience in the face of future tool use.

6 Interior Effects on Comfort in Healthcare Waiting Areas

Conne Bazley, Peter Vink, Alan Hedge, Annelise De Jong & John Montgomery

Manuscript accepted in Work: A Journal of Prevention, Assessment and Rehabilitation, Special Issue on Environmental Design, 2015

ABSTRACT

Patient comfort has become increasingly more important in the design of healthcare facilities, especially in waiting rooms. This study asked if properly placed amounts of Feng Shui elements found in the waiting rooms have a positive effect on participants (patients) waiting for an appointment. Participants completed a self-rated comfort survey, throughout the day, and rated their physical, intellectual, and emotional comfort levels upon waking, arrival for an appointment and after the appointment. The researcher assessed the amount of Feng Shui present in each waiting area. Results showed that environments using Feng Shui principles in conjunction with medical treatment possibly influenced the comfort of participants. The comfort surveys revealed significance for emotional comfort upon waking and before the appointment. Comparing waiting area settings with high and low levels of Feng Shui design elements may elucidate a possible influence on comfort and health, and provide an additional dimension to environmental interior design and comfort research for many types of built environments. Suggestions for future comfort research include, over-time, pre-experience, expectations and beyond the physical aspects of people, possibly in controlled environments, to isolate the influencing factors.

Keywords: Feng Shui, patient comfort, healthcare, waiting room design, pre-experience
INTRODUCTION

Optimal human comfort and well-being requires that internal and external environmental conditions, including good quality air, water, and climate, adequate space, smooth flow of work, general safety and safe working conditions, promote occupants' physical comfort and health (Ong, 2013; WHO, 2010). Other factors to consider beyond the physical environment, which may also promote comfort and well-being, are the psychological (intellectual and emotional) aspects of occupants. Including all these factors promotes well-being e.g. emotional growth, cognitive flexibility and creativity (Oswald, et al., 2009; INQA, 2005; Warr, 1999; Pavot, & Diener, 1993).

Comfort is a term associated with a subjective physical state that may be influenced by an environmental factor, such as temperature, noise, light level, space, furniture design, etc. (Ong, 2013). Helander and Zhang (1997) note that discomfort due to sitting in a chair is related to static postures, compression at pressure points beneath the ischial tuberosities and the stiffness of associated joints. Participants in the study linked comfort more to terms such as luxury, relaxation and feeling refreshed (Helander and Zhang, 1997). Richards (1980) stresses that comfort involves the sense of subjective well-being, and is the reaction a person has to an environment or situation. According to De Looze et al., (2003)], some issues generally accepted in comfort literature are: (1) comfort is a construct of a subjectively defined personal nature; (2) comfort is affected by factors of a various nature (physical, physiological, psychological), and (3) comfort is a reaction to the environment. Slater (1985) defines comfort as a pleasant state of physiological, psychological and physical harmony between a human being and his/her environment. There is ample research available on many scientific databases regarding physiological comfort. The psychological (intellectual and emotional) and socio-cultural aspects of comfort are less studied and data are difficult to quantify due to subjectivity (Höppe, 2002).

This concept of discomfort or comfort discusses the need for opposites to comprehend and appreciate the difference. For example, Vink (2014) explains it as the 'sweetness of discomfort'. Comfort is experienced best when a greater degree of discomfort has previously occurred. For example, if a person sits in a comfortable chair immediately after sitting on a very hard uncomfortable one, the difference is obvious.

Most comfort research focuses on the effect of a physical intervention and previous experiences and expectation are not taken into account (Vink et al., 2012). However, more information is surfacing about the influence pre-experience has on the comfort experience in the recorded moment (Vink, 2014). For example, Konieczny (2001) found that 40% of the comfort in an airplane was determined by preflight experiences. The comfort experience
also changes over time, which is evident during a flight (Vink et al., 2012). Part of a holistic approach to comfort in an interior built environment is taking into account the previous experiences and expectations of occupants and time as a factor to consider in a comfort study. This study compares patient (participant) pre-experience and perceived comfort levels upon waking, before, during and after a healthcare appointment.

There is an increasing interest in applying a Feng Shui approach to Western design. According to the Feng Shui principles a “holistic” approach to built environments, e.g. workspace and workplace design, includes design elements that are purported to improve the comfort, health and well-being of occupants (Mak & Ng, 2008)

**Feng Shui**

Feng Shui is an ancient Chinese system of geomancy that has and continues to influence design in many Asian countries, but is seldom considered in building design in the Western World (Mak & Ng, 2005). It is challenging to link Feng Shui with Western scientific literature and culture and it is difficult describe in scientific terms because Feng Shui is not generally accepted as science in Western academia. Some researchers have attempted to study Feng Shui scientifically. Mak (2009) developed a structured framework and a prototype model using a ‘knowledge based expert systems (KBES) approach’ to Feng Shui. It is linear and a challenge from the standpoint that Feng Shui is considered a more ‘holistic’ process and the KBES model may be comparable to the human factors engineering top-level analysis tool (functional requirements and allocation) used in the preliminary design process(Stanton et al., 2009)

Feng Shui developed over 3,000 years ago in China and is a complex body of knowledge that balances the energies of the environment to assure good health and good fortune for the inhabitants and has made a significant contribution to design in the eastern world for many centuries (Mak, & Ng (2005). It is an ancient Chinese system of geomancy with a growing influence on Western architecture and design and literally means “wind “and “water” (Chuen, 1995).

Feng Shui emphasizes harmony with nature, surroundings, and cycles of time, with the goal of creating and maintaining positive ‘qi’, or energy. Chi or ‘qi’ is pronounced “Chee” and is literally translated as "life-force energy". Wind and Water symbolizes the flowing Chi or ‘qi’, which can be translated as “vital energy flow” or, “breath of nature”, because ‘qi’ can be gathered by water and flowing energy (Xu, 2003). Feng Shui recommends situating the human built environment in locations in space and time where ‘qi’ is balanced. This balancing of the energies of the environment is believed to assure the health and good fortune of those inhabiting the given space (Tchi, 2009). Feng Shui has an extensive influence on Chinese architecture and has made a significant contribution to built environment
design in the Eastern world for many centuries. In Western society, the primary concern when constructing a building has included methods involved in scientific analysis using measurable data. Both of these approaches are included in bioclimatic design, ecological design, and environmental psychology (Chuen, 1995; Lee, 1986). In the West, a more scientific approach is the norm for many designers and architects. Lee (1986) describes architects are trained in practical design to include comfortable living and built environments. Architects often unconsciously applied some rational Feng Shui principles (Mak & Ge, 2012).

There are two main schools of thought and practice in Feng Shui: the Compass school and Form school. The Form School analyses the shape of the land and flow of the wind and water to find a place with ideal ‘qi’. It also considers the time of important events such as the birth of the resident and the building of the structure (Mak & Ng, 2005). There are five elements associated with Form School: Earth, Wood, Metal, Fire and Water. Figure 1 represents the shapes found outside and in the landscape as well as inside or interiors of the built environment (Wei, 2006).

The correct use of these elements is the key to implementing proper Feng Shui. Table 1 explains the interaction of the five elements in three types of cycles: the "Productive Cycle", the "Controlling Cycle" and the "Reductive (weakening) Cycle". It is necessary to know the cycles of the five elements and to understand how to balance and enhance ‘qi’ in the environment. Each of the five elements is related to one another and affects each another in various ways depending on the cycle (Tchi, 2009; Chuen, 1995).
Table 1. Balancing ‘qi’ in the environment is dependent on the relationship between elements and cycle phases.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Productive Cycle</th>
<th>Controlling Cycle</th>
<th>Weakening Cycle Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire and Earth</td>
<td>Yes</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>Fire and Metal</td>
<td>No</td>
<td>Yes</td>
<td>Earth</td>
</tr>
<tr>
<td>Earth and Metal</td>
<td>Yes</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>Earth and Water</td>
<td>No</td>
<td>Yes</td>
<td>Metal</td>
</tr>
<tr>
<td>Metal and Water</td>
<td>Yes</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>Metal and Wood</td>
<td>No</td>
<td>Yes</td>
<td>Water</td>
</tr>
<tr>
<td>Water and Wood</td>
<td>Yes</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>Water and Fire</td>
<td>No</td>
<td>Yes</td>
<td>Wood</td>
</tr>
<tr>
<td>Wood and Fire</td>
<td>Yes</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>Wood and Earth</td>
<td>No</td>
<td>Yes</td>
<td>Fire</td>
</tr>
</tbody>
</table>

The productive cycle: Wood produces fire. The decay of wood provides fuel for fire. Fire produces earth. The burning of wood by fire produces ash that feeds the earth. Earth produces metal. Earth compacts and pulls inward forming metal. Metal produces water. When metal contracts it condenses and liquefies. Water produces wood. Water stimulates growth in wood. The controlling cycle: wood burdens earth; fire melts metal; earth blocks water; metal pierces wood; and water diminishes fire.

The weakening cycle: wood absorbs water; water corrodes metal; metal moves earth; earth reduces fire; and fire burns wood (Moran, Yu & Biktashev, 2005). The ideal environment strives to have the five elements in the productive cycle. In Feng Shui, numerous cycles change the combinations of the elements. However, if a controlling cycle is approaching through a cycle of time, for example a yearly cycle, the weakening cycle may be applied to offset negative ‘qi’ from the controlling cycle.

Classical Feng Shui is not as simple as the aforementioned relationships and cycles of the five elements are not black and white. There are exceptions to the rules. The element number combinations change through
cycles of time. There is no one simple chart or table to explain all the nuances associated with Feng Shui and the principles. Therefore, this paper attempts to introduce a very basic overview to help clarify the tools used to perform the Feng Shui assessments for properly placed Feng Shui elements for the three waiting areas by the researcher.

The Feng Shui Bagua is a tool used by Form School practitioners. The Bagua model represents the five elements, cardinal directions, areas of life and other aspects specific to each section of the grid. The bagua is a blueprint placed over a specific area or in this study an interior layout (Moran, Yu & Biktashev, 2005). Figure 2 illustrates a Feng Shui Bagua. The bagua consists of the eight trigrams of Yijing and represented by the blue ring in Figure 2. The five elements of Feng Shui (Water-Wood-Fire-Earth-Metal) and associated aspects are identified in each square of the bagua (grid), e.g., color, compass direction, and body part.

![Feng Shui Bagua](image)

**Figure 2.** Feng Shui Bagua (The Spiritual Feng Shui, 2012).

The Compass School is based on the eight cardinal directions, each of which is said to have unique ‘qi’. The main tool is the Loupan, a disc marked with formulas in concentric rings around a magnetic compass.
The Flying Star is a system that calculates the ‘qi’ pattern of a building according to the building orientation and date of construction (Moran, Yu & Biktashev, 2005; So & Mak, 2011).

A Feng Shui assessment considers cycles of time important as life is not static and change is constant and inevitable. Feng Shui studies the connection and change of the human, heaven and earth through cycles of time. Energy changes with time. Therefore, the time dimension is important when assessing or studying the energy of a space based on direction, shape and landscape, such as in Feng Shui practice. The Chinese measure time with both lunar and solar calendars.

The method of Feng Shui known as San Yuan (Flying Stars) uses the solar calendar (Hsia calendar) for the study of time dimension (Walters, 1991). The Flying Stars map consists of the numbers 1-9 that fill a grid, establishing nine time periods.

Each period lasts for 20 years and a complete cycle lasts 180 years. The Earth’s magnetic forces are in constant movement according to planetary bodies’ movement therefore, Feng Shui influences do not stay constant. For example, every 20 years, Saturn and Jupiter come into a new alignment. When this alignment occurs, the repercussions are taken into account through a cycle and over time (Walters, 1991).

**HYPOTHESES**

This study compared the effects of pre-experience and expectations on participant comfort upon waking, arrival for and after an appointment. It also assessed and compared properly placed Feng Shui elements for three healthcare waiting rooms. The three waiting rooms were designed differently. A professional Feng Shui practitioner designed the first waiting area. A doctor with some familiarity with Feng Shui principles designed the second waiting area. The third waiting area was a conventional Western design that did not incorporate traditional Feng Shui principles.

*Hypothesis 1* predicted that properly placed Feng Shui elements found in the interior environment (healthcare waiting areas); the more comfort is experienced by occupants.

*Hypothesis 2* predicted that comfort levels before experiencing the arrival for an appointment influence comfort levels upon arrival to the office waiting area.
METHODS

Research Sites

The three different healthcare office locations were based on contacts of the researcher, but care was taken that all three selections had varied amounts of Feng Shui elements at the entrance and in the patient waiting area. The waiting area sites are named by Area and the properly placed Feng Shui (FS) elements in the specific waiting area. The designations for the three waiting areas are as follows: Area 1 (ideal FS), Area 2 (many FS), and Area 3 (less FS).

Area 1 (ideal FS): The entrance door was red entrance door and opened into a spring green and cream color space, tile floor, and wide space not broken up by walls. A decorative screen placed in the middle of the room guided occupants directly forward to a table with information literature or to the right for ‘holistic’ merchandise and a sitting area with comfortable chairs or to the left to a sitting area and refreshments (tea and water) and receptionist desk. Behind the screen were exercise machines for patients to use while waiting for an appointment. The air was clean, the light was soft but well lit, although the temperature was a bit cool.

Figure 3. Waiting area one with ‘ideal’ properly placed Feng Shui elements (photo by Bazley, 2012).
Area 2 (many FS): The entrance door was a French glass door that opened into a long and narrow space. There were blue accented rugs on a wooden floor and sitting areas on either side of the door with comfortable blue chairs and tables with informative literature and magazines. The receptionist desk was to the left of the direct path from the door and had glass panels, which reflected the natural light from the windows. The air was clean and the light was subdued. The temperature was a bit on the cool side.

Area 3 (less FS): The entrance door that was solid wood and a bit worn and opened directly into a room with yellow walls, green carpet and a large receptionist desk. The desk was very high and the receptionist was hidden from view. The furniture was large for the space and the room felt tight and constricted. There were chairs lining the walls on either side of the door. The traffic flow or way finding was erratic and the air was stuffy. The light was fluorescent and a bit harsh, although there were windows. It was also cool in temperature.

All locations were in the southern USA and research was conducted at the same time of the year. The healthcare service, provided at each location, was similar. Doctors at each location granted permission for the
researcher to conduct a self-assessment comfort survey of participants (patients), assess the waiting areas using Feng Shui principles, and report the results of the study.

Feng Shui Assessment & Intention Interviews

The researcher used a standard compass and the Feng Shui (Business Model) Bagua, and Flying Star system to assess the proper placement of Feng Shui elements in the three healthcare waiting areas. The foundation of the Feng Shui assessment was a ‘to scale’ room layout, overlaid with a modified Feng Shui Bagua (see Figure 6), and the compass reading.

<table>
<thead>
<tr>
<th>Feng Shui Bagua for Business</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wealth</strong></td>
</tr>
<tr>
<td><strong>Wood</strong> - 4</td>
</tr>
<tr>
<td><strong>South-East</strong></td>
</tr>
<tr>
<td>Financial flow,</td>
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<tr>
<td>Communications,</td>
</tr>
<tr>
<td>Transport</td>
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<td>Purple, Green, Red</td>
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<td><strong>Reputation</strong></td>
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<tr>
<td><strong>Fire</strong> - 9</td>
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<tr>
<td><strong>South</strong></td>
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<td>Advertising, Sales,</td>
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<td>Marketing,</td>
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<tr>
<td>Public Relations</td>
</tr>
<tr>
<td>Red</td>
</tr>
<tr>
<td><strong>Partners</strong></td>
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<tr>
<td><strong>Earth</strong> - 2</td>
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<td><strong>South-West</strong></td>
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<tr>
<td>Co-Workers</td>
</tr>
<tr>
<td>Clients</td>
</tr>
<tr>
<td>Red, Pink, White</td>
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<tr>
<td><strong>Community</strong></td>
</tr>
<tr>
<td><strong>Wood</strong> - 3</td>
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<tr>
<td><strong>East</strong></td>
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<td>Customer relations</td>
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<td><strong>Metal</strong> - 7</td>
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<td>Financing,</td>
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<td><strong>Earth</strong> - 8</td>
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<td>Resources</td>
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<td>Learning and</td>
</tr>
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<td>Motivation Center</td>
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<tr>
<td>Black, Blue, Green</td>
</tr>
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<td><strong>Career</strong></td>
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<tr>
<td>Contacts, Vendors</td>
</tr>
<tr>
<td>White, Grey, Black</td>
</tr>
</tbody>
</table>

*Figure 6.* The Feng Shui Business Bagua Grid represents the five elements, cardinal directions, life areas and other aspects specific to each section of the grid and a modified version of the Feng Shui Bagua discussed earlier and shown in Figure 2 (Too, 1997).
The researcher conducted “intention interviews” with each doctor/owner of each office. An “intention interview” discussed the ‘power of intention’ when setting up the environment after a remodel, new construction or after a space clearing (Walters, 1991; Tchi, 2009). The interview consisted of questions (see Figure 7) about the office space and environment, as well as what the interviewee/doctor desired or intended for the waiting area environment or space.

1. What were your intentions for the space?
2. Did you achieve the design and the intentions you envisioned? How and in what ways?
3. What worked and why? What did not work and why?
4. In what ways does the design provide comfort psychologically, emotionally, and physically?
5. What is most comfortable to you? What is least comfortable and why?
6. What would you change?
7. Did you use Feng Shui principles? If yes, which did you use?

**Figure 7.** Example of ‘intention interview’ questions asked to the doctors/owners of the three waiting areas.

**Participants**

Table 2 shows the overall participant characteristics from eighty-one participants from the three different healthcare office locations. Most of the participants were retired workers, working professionals or homemakers.
Table 2. Participant characteristics for the one-day comfort self-assessment survey.

<table>
<thead>
<tr>
<th>Ideal FS Characteristic</th>
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<th>%</th>
<th>Many Characteristic</th>
<th>n</th>
<th>%</th>
<th>No FS Characteristic</th>
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<th>%</th>
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<td>100</td>
<td>Total</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

Research Instruments and Procedure

The healthcare office staff distributed a comfort self-report survey (Figure 8 and Figure 9) to each participant over a two-week period, with no repetition of participants. Each participant who completed the self-assessment comfort survey also signed a permission form, allowing the researcher to report the findings of the study. Participants were asked to self-assess and rate their comfort level (physical, intellectual, and emotional) where each was rated from 1 to 5 for three different times the day of their appointment, and answer several questions relating to comfort.
The survey asked participants to recall their waking comfort level (physical, intellectual, and emotional) and respond using a 1-5 rating (1 rated as excellent and 5 rated as very bad). In addition, participants were asked to circle a word and a color that best described their comfort level upon waking. Participants were asked whether they were looking forward to the appointment (“yes” or “no”).
Participants were also asked to rate their comfort level (physical, intellectual, and emotional where each was rated 1-5), a word and a color to best describe comfort levels in the waiting room upon arrival at the medical office. Additionally, participants circled the word that best described the most significant thing they saw and most significant thing they heard on their way to their appointment.

The last part of the survey was completed after the appointment in the waiting room. Participants were asked to rate their comfort level (physical, intellectual, and emotional where each was rated 1-5) with a word and a color that best described their comfort level immediately after treatment. In addition, they circled a word that best described what made them most comfortable and a word that made them the most uncomfortable in the waiting area.

Data Analysis

The one-day self reported comfort survey data were coded and analyzed using a multivariate statistics package (SPSS version 17). Paired comparisons between each test group were made for each time-period using the Mann Whitney statistical test for difference of medians (ranked data). A significance level (alpha) of p<0.05 was applied to the research results.

RESULTS

The results for the Feng Shui (FS) assessment for each waiting room were based on a compass reading, Feng Shui bagua (business model), and waiting room layout. Figure 10, Figure 11, and Figure 12 show completed Flying Star layouts for each waiting area (Moran, Yu & Biktashev, 2005; Walters, 1991). All three waiting areas were similar in size and square footage. Each waiting room area had the main door facing East and the back of the space or sitting direction to the West. The dates of construction for the three waiting areas were in different periods, 1 (ideal FS) and 3 (less FS) were in period six and 2 (many FS) in period eight. The periods correspond to the year the buildings were constructed.
Figure 10. Waiting area 1 (Ideal FS) Flying Star chart.

Figure 11. Waiting area 2 (Many FS) Flying Star chart.
A Feng Shui practitioner designed the waiting area in location 1. After taking a reading of the interior space and using the Feng Shui principles to establish the placement of Feng Shui elements, area 1 (ideal FS) had the most ideally placed Feng Shui elements, e.g., water elements in the northeast (fountain) and wood to offset the fire and water in the south sector (plants and green wall color). Metal was properly located in the west (reception area metal desk and southeast where the exercise machines were located. The northeast seating area had a balance of all properly placed elements, following the productive cycle.

Waiting area 2 incorporated many Feng Shui elements in the interior design of the office. The doctor had some familiarity with the concept of Feng Shui and attempted to incorporate some of the principles. A reading of the interior space determined that area 2 (many FS) had many properly placed Feng Shui elements. Many of these elements included wood in form of plants and a sculpture in the south-east corner of the office. However, the brown earth elements blocked the blue water elements in the northeast or southeast sectors to reduce the controlling cycle. Metal was properly placed in the northwest sector. The fire elements were not placed properly in the northwest or northeast sectors.

The Feng Shui assessment of the third waiting area location 3 (less FS) revealed the fewest properly placed Feng Shui elements. The placement of the wood element was ideal in the southwest and south sectors. The wood elements (green carpet) overburdened the earth element (yellow walls) and brown (chairs).
The Feng Shui reading indicated the need for the fire element in four of the nine sectors of area 3 (less FS) waiting room. There were however, no fire elements found in the waiting area. The water element was incorrectly placed in the west sector. Metal was present but placed in the northwest sector and pierced the wood element. The water element placed in the northwest sector would have nourished the wood.

In summary, The three waiting areas varied from low to high on properly placed Feng Shui elements and are shown in Figure 13 in the following sequence: 1 (ideal FS interior elements), 2 (many FS interior elements), 3 (less FS interior elements).

![Feng Shui elements in waiting areas](image)

**Figure 13.** The amount of the Feng Shui five elements properly placed in the three waiting areas. The ideal FS waiting area had all the Feng Shui elements properly placed. *Properly placed elements: Fire = 3, Water =3, Earth = 9, Metal = 6, and Wood = 6.*

In addition to the Feng Shui analysis of each location, this research also produced data concerning individuals’ feelings about their physical, intellectual, and emotional state, at each location, and at different times (waking up, before the appointment, and after the appointment).

Table 3 provides a breakout of the data patterns for Location 1, Table 4 the data for Location 2, and Table 5 the data for Location 3.
Table 3. Location 1 summary data for individual feelings (physical, intellectual, and emotional) at different times of the day. Data are both counts and relative frequency of the different scales. N=17.

<table>
<thead>
<tr>
<th></th>
<th>Physical</th>
<th>Intellectual</th>
<th>Emotional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wake Up</td>
<td>Bef Appt</td>
<td>Aft Appt</td>
</tr>
<tr>
<td>Excel</td>
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<td></td>
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<tr>
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<td>30.77</td>
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<td></td>
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<td>46.15</td>
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<tr>
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<td></td>
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<td>38.46</td>
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<td>4</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>38.46</td>
<td>3</td>
</tr>
<tr>
<td>Very Bad</td>
<td>7.69</td>
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</tbody>
</table>

Location 1 exhibits the highest (in percentage) improvement from wake up to after the appointment, especially in physical and emotional feelings. Intellectual change is also very positive but the pattern does not have as much strength in terms of percentages. These descriptive results provide strength to the general idea that more Feng Shui elements in an office space creates a more positive influence on individual physical, intellectual, and emotional feels about care in a health office.
Table 4. Location 2 summary data for individual feelings (physical, intellectual, and emotional) at different times of the day. Data are both counts and relative frequency of the different scales. N=51.

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</thead>
<tbody>
<tr>
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<td>After Appt</td>
<td>Wake Up</td>
<td>Bef Appt</td>
<td>After Appt</td>
<td>Wake Up</td>
<td>Bef Appt</td>
<td>After Appt</td>
</tr>
<tr>
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<td>1</td>
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</tr>
</tbody>
</table>

Table 4 provides the results from Location 2, which had many Feng Shui elements, but was not optimal. It appears that the health office environment is aligned with good improvement in physical, intellectual, and emotional well-being. Location 2’s fewer Feng Shui elements may have influenced the smaller (percentage-wise) increases when compared to Location 1.

Table 5. Location 3 data for individual feelings (physical, intellectual, and emotional) at different times of the day. Data are both counts and relative frequency of the different scales. N=17.

<table>
<thead>
<tr>
<th></th>
<th>Physical</th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th>Emotional</th>
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<tbody>
<tr>
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<td>After Appt</td>
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<td>Bef Appt</td>
<td>After Appt</td>
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</table>

Location 3 shows results that one would expect from an office with a minimal number of Feng Shui elements.
While the after appointment physical feeling is strong compared to the before appointment (and stronger than Location 2), the other results (intellectual and emotional) are much less positive than the other locations. This pattern falls in line with the comfort expectations for a healthcare office location with the least number of correct Feng Shui elements.

Table 6 presents the results of the paired statistical comparisons. This table illustrates important patterns within and between the three locations. Location 1, the location with the strongest Feng Shui elements, showed significant differences between “before” and “after” the healthcare treatment with the three comfort levels. This same pattern applies to Location 2, which exhibited fewer Feng Shui elements. Location 3, which holds the fewest Feng Shui elements, departed from this trend with intellectual and emotional support. All three locations exhibit significant differences between the “before” and “after” healthcare treatment regarding physical comfort.
Table 6. Mann Whitney pairwise statistical comparison of average comfort score (rank) at three healthcare areas at different times of day.

<table>
<thead>
<tr>
<th>Healthcare Area</th>
<th>Waking Up/Before Appointment</th>
<th>Waking Up/After Appointment</th>
<th>Before/After Appointment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYSICAL COMFORT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location 1 (Ideal FS) N=13</td>
<td>W=203.5 p=.1250; Not Significant</td>
<td>W=250.0; p=.0001; Significant</td>
<td>W=227.0; p=.0049 Significant</td>
</tr>
<tr>
<td>Location 2 (Many FS) N=51</td>
<td>W=2753.0; p=.3686 Not Significant</td>
<td>W=3411.5; p&lt;.001 Significant</td>
<td>W=3347.0; p&lt;.001 Significant</td>
</tr>
<tr>
<td>Location 3 (Less FS) N=17</td>
<td>W=327.0; p=.2118 Not Significant</td>
<td>W=398.0; p=.0001 Significant</td>
<td>W=377.5; p=.0014 Significant</td>
</tr>
<tr>
<td><strong>INTELLECTUAL COMFORT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location 1 (Ideal FS) N=13</td>
<td>W=195.5; p=.2827 Not Significant</td>
<td>W=242.5; p=.0003 Significant</td>
<td>W=222.5; p=.0104 Significant</td>
</tr>
<tr>
<td>Location 2 (Many FS) N=51</td>
<td>W=2618.0; p=.9548 Not Significant</td>
<td>W=3021.0; p=.0044 Significant</td>
<td>W=3032.5; p=.0032 Significant</td>
</tr>
<tr>
<td>Location 3 (Less FS) N=17</td>
<td>W=315.5; p=.4832 Not Significant</td>
<td>W=315.5; p=.4832 Not Significant</td>
<td>W=297.5; p=1.0 Not Significant</td>
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<tr>
<td><strong>EMOTIONAL COMFORT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location 1 (Ideal FS) N=13</td>
<td>W=184.5; p=.6447 Not Significant</td>
<td>W=252.0; p&lt;.001 Significant</td>
<td>W=237.0; p=.0010 Significant</td>
</tr>
<tr>
<td>Location 2 (Many FS) N=51</td>
<td>W=2543.5; p=.5584 Not Significant</td>
<td>W=3072.5; p=.0014 Significant</td>
<td>W=3195.5; p&lt;.0001 Significant</td>
</tr>
<tr>
<td>Location 3 (Less FS) N=17</td>
<td>W=302.0; p=.8666 Not Significant</td>
<td>W=324.5; p=.2928 Not Significant</td>
<td>W=323.0; p=.2881 Not Significant</td>
</tr>
</tbody>
</table>

For intellectual and emotional comfort, the differences were also significant with the exception of office location 3 (less FS). For the physical comfort ratings, there were no significant effects for any comparison. Results show that physical comfort levels were comparable between groups of participants for each phase of data collection. However, the differences between pre-and post-healthcare treatment in physical comfort were significant.
A similar analysis for the intellectual comfort levels showed no significant differences between the three groups of participants or the three time-periods. There were significant differences for emotional comfort (see Table 6).

The correlation coefficient between the comfort score at the beginning of the day and the score at the time of the appointment and after the appointment are shown in Figure 14.

![Figure 14. Correlation between comfort scores throughout the day.](image)

The correlations were higher between the start of the day, or upon waking and before the appointment, than upon waking and after the appointment. This is especially true for the physical comfort.

**DISCUSSION**

*Addressing the first hypothesis that predicted the more properly placed Feng Shui elements found in the interior environment; the more comfort is experienced by occupants.*

Results from this study show a relationship between properly placed Feng Shui elements present in a therapeutic environment and greater emotional comfort levels reported by participants.

As mentioned before, Feng Shui embraces the concept of “flow” or ‘qi’ movement of energy throughout a space over time. According to Heim (2001), flow is a smooth, unimpeded movement through space-time. It is an aesthetic quality of spatial movement and occurs throughout the physical world.

The most comfortable area, of the three healthcare areas was area 1 (ideal FS). Although this study reports only a relationship, the layout, intention
interviews, Feng Shui assessment and comfort surveys reported good ‘flow’, comfort and a positive calming energy for patients, visitors and staff. The concept of ‘flow’, comfort and a positive energy for patients, visitors and staff was also reported for waiting room 2 (many FS). From the intention interview and Feng Shui analysis area 3 (less FS) concentrated less on the waiting room layout and physical environmental comfort of patients and relied instead on the quality of the treatments to provide patient comfort. The physical “temperature” was the most uncomfortable factor for area 1 (ideal FS) and 2 (many FS) locations and the second most uncomfortable factor for area 3 (less FS). Other studies confirm that discomfort due to temperature is often the number one complaint in the workplace. The majority of scientific papers on comfort also focus on temperature (ASHRAE-ANSI/ASHRAE Standard-55, 2010; Vink, 2005; Ong, 2013).

Taking into account the responses from the comfort survey (circling a word or circling a color to describe comfort), the aforementioned waiting area descriptions and impressions are related to the Feng Shui assessment as described in the survey results. The words participants used to described their comfort when they arrived for the appointment are as follows: 27 circled “calm”, 18 “tired”, 15 “anxious”, 14 “relaxed”, 3 “excited”, and 3 “upset”. Green, blue and yellow, in that order, were the colors circled for equating a color to the comfort level upon arrival for the appointment. This is of interest as the wall or accent colors in each of the waiting areas correspond to the color selection. Area one, had a green theme, area two, blue, and area three was yellow. It is worth noting that the color green was chosen most often in the surveys from all three waiting areas. The word and color, “relaxed” and “green”, were circled most often after the appointment.

Comfortable interiors have a sense of ‘Placeness’. 'Placeness' is another concept that embraces intention. The spatial features of a built environment support the formation of places and facilitate significant occupant experience/qualities (Koskinen & Norros, 2010). An alternative for improving the physical environment, maybe to design for comfort and flow first, in order to achieve flow with intention. Feng Shui establishes intention and identifies the “flow/energy” or ‘qi’ of an environment.

Another source of flow is social interaction, resulting from optimal interaction, with a person or people (Kihlstrom, 2013). People and their energy are constantly changing the visible and invisible flow of the physical environment (Heim, 2001). The number one aspect that participants indicated made them most comfortable in all three waiting areas was “people”. However, “people” was selected as the most uncomfortable factor for area 3 (less FS).
The “people” factor may relate to the receptionist, staff or doctor or that patients go to a healthcare appointment because they do not feel well and anticipate feeling better after the appointment. The receptionists, staff and doctors in offices make or break the comfortable atmosphere in the room. If patients are listened to and taken care of, the response is usually a comfortable situation. If, on the other hand, patients are ignored, or given curt replies to inquiries, the response is usually an uncomfortable situation. Additionally other patients can cause discomfort by being loud, rude or overbearing towards the staff or other patients. Comfort in these cases goes beyond physiological and touches the emotional aspects of comfort. These aspects, although important, are difficult to quantify (Höppe, 2002).

The findings from this study suggest that applying some of these aforementioned principles to the design of therapeutic environments may provide a further dimension for improving the design of the built interior environment. Feng Shui is an environmental design process about which architects from the West are gaining knowledge and applying to the built environment (Mak & Ge, 2012; Mak & So, 2011; Mak & Ge, 2010; Too, 1997; and Chuen, 1995). Some Feng Shui practitioners use the concept of biophilic design in their work. Biophilic design brings fourteen patterns from nature into workplaces and workspaces and purports to promote health and well-being (Ryan et al., 2014; Terrapin Bright Green, 2012; Wilson, 1984).

Addressing the second hypothesis of comfort levels, before experiencing the arrival for an appointment, influence comfort levels upon arrival to the office waiting area.

In this study, after the appointment, all three-comfort levels improved, with the physical level being the most significant. The physical improvement results are consistent with other medical studies that show comfort level improvement after healthcare therapy (Gionis & Groteke, 2003; Winstead & Kijek, 1999; Krieger, 1975). For therapy treatment offices, patients generally do not feel well before treatment, that is why they are seeking treatment. The physical comfort level is generally worse before treatment and most patients feel better and more comfortable after treatments (Gionis & Groteke, 2003).

Medical studies often measure pain throughout the day and throughout the treatment series (Kolcaba & Fisher, 1996). Other studies conclude that after treatment therapy a release of physical pain causes an emotional surge (Winstead & Kijek, 1999; Krieger, 1975). Participant physical comfort levels improved the most throughout the day, followed by emotional comfort.

It appears that pre-experiences and expectations may relate to comfort levels since there was a significant difference between waking and arriving
at the appointment but not right before and after the appointment. Other studies found (Konieczny, 2001; Vink et al., 2009; Nugent, 2012; Bazley et al., 2012) correlations between the comfort before arriving at the office and being in the office. If previous experiences, such as found in studies conducted by Vink et al. (2012) and Konieczny (2001) can explain 40% of the comfort, it is essential that the pre-experience be taken into account for comfort studies.

What participants saw and heard on the way to the appointment may relate to their increased emotional comfort level between waking and waiting for an appointment. The majority of participants were looking forward to their appointment, probably because they hoped to feel better after the treatment. However, the majority also heard singing and talking on the way to the appointment and saw roadway, people and nature.

For example, if a person heard a beautiful song and/or saw a wonderful sunrise on the way for an appointment, the emotional comfort may be assumed much different from if a person saw a car accident and/or heard a depressing news story on the radio. What participants saw or heard is possibly related to the higher emotional comfort rating between waking and before the appointment. Additionally, it may be related to what the participants did while waiting in the room before the appointment, e.g., who they spoke with, was music in the room, did they smell or touch something that sparked emotional comfort?

Bakker (2014) concluded that people experience the environment with four physical senses, four affective senses and four cognitive senses. An overall ‘feeling’ or ‘vibration’ of the interior emerges within a person and feelings of comfort or discomfort emerge.

Blok et al. (2007) found that if passengers lose luggage, the best interiors do not compensate or override the distress over the lost luggage problem. This is important as comfort may be experienced more intensively after an uncomfortable experience (Vink, 2014). It is not clear if the waiting room environment or the healthcare treatment intervention had more impact on comfort.

**LIMITATIONS**

Some limitations of this study could have influenced the outcome: One waiting room was evaluated for each Feng Shui condition. Comfort data were self-reported and the patient sample size was sufficient but not large. Results show a sufficiently strong effect to warrant further research. Another limitation is that self-reported data are used.

On the other hand, comfort is a subjective phenomenon (Vink, 2014)], which makes self-reporting the most appropriate way of studying comfort. The limitation of this study is also that the same subject reports the various comfort experiences in time influencing the correlations between
the various recordings. However, other studies also report on pre-comfort influences (Konieczny, 2001; Vink et al., 2009; Nugent, 2012; Bazley et al., 2012). It is not new that participants’ feelings are influenced by previous experiences. Park et al. (2010) confirmed that after walking in the forest participants felt more relaxed than after walking in an urban environment. The forest environment promoted lower concentrations of cortisol, lower pulse rate, lower blood pressure, greater parasympathetic nerve activity and lower sympathetic nerve activity.

Some other drawbacks of this study are possible learning effects as the same scale was used several times in succession. Limited measures were made to ensure that participants had the same understanding of the terms emotional, physical or intellectual comfort. There was no measure of the duration that each Participant spent in the waiting room and no measure of the number of times that patient had been in that particular waiting room. The amount of time a patient spent in an office waiting room or the number of appointments they had in the past was not information the researcher collected. However, these are important points to take into account for future research. The human-to-human relationship influences and actions may disturb comfort study outcomes. There is often one or several researchers conducting the comfort research and it is possible based on the data that the researcher ‘people’ influence the outcome.

Another limitation is that the comfort differences between areas arose because of other characteristics in the interior or because of different sample characteristics. On the other hand, the interviews with the owners of the area showed that Feng Shui was used as an inspirational source for at least two of the waiting areas.

Despite these limitations, this study is a first indication that having more properly placed Feng Shui elements in the interior of healthcare waiting areas increases the comfort experience and pre-experiences and expectations preceding the comfort recording and do influence comfort upon arrival for an appointment. Further studies are recommended to assess whether other healthcare waiting area interiors in other countries are experienced similarly.

CONCLUSION

The effect on comfort was studied in three healthcare area waiting areas, each with different amounts of Feng Shui elements. Comfort ratings were recorded for physical, emotional and intellectual comfort upon waking, before going to a healthcare appointment and after the appointment. The influences of pre-experiences before and during the appointment were also recorded. The results indicated that emotional comfort differed between waking and arrival for an appointment. The
three waiting areas layouts were different. Emotional comfort was higher when ideal Feng Shui elements were present and properly placed in the waiting area environment. Comfort levels at the beginning of the day correlated more strongly with comfort levels after arriving at the waiting area and before the treatment than after the medical treatment. Comparing area settings with high and low levels of Feng Shui design elements may help to elucidate the possible influence on comfort and health, and provide an additional dimension to “holistic” environmental interior design and comfort research for healthcare facilities.

Although eastern and western disciplines do not use the same elements for design, the ultimate purpose of both is to live in harmony with nature and benefit human health. The results of this study are not to challenge conventional design principles but rather to suggest a consideration of an alternative system of analysis and design (Mak, 2009). Ideally, the aspects should be tested again in a controlled case study or within a subject design study where subjects determine whether they influence the comfort experience. Further research studies, in possibly controlled environments, are warranted to assess if similar effects are found in other Feng Shui influenced healthcare waiting areas and office interiors worldwide.

ACKNOWLEDGEMENTS

The author would like to thank the doctors and participants involved in this study for their time and permission to report the findings in this article.

REFERENCES


Vink, P. (2014), The sweetness of discomfort, inaugural lecture TU-Delft, Delft, NL.


Winstead F & Kijek J. (1999), Therapeutic Touch, Alternative Therapies in Health and Medicine, 5(6) pp58-67


Xu, Jun. (2003), A framework for site analysis with emphasis on feng shui and contemporary environmental design principles. University Libraries, Virginia Polytechnic Institute and State University, Blacksburg, VA.
7 Environmental Comfort Design Considerations for Future Control Room Interiors

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Published in Advances in Social and Organizational Factor, 2014
Boca Raton, Vink, P., Kantola J., Eds., FL: CRC Press: Pages 3-10

ABSTRACT

Today, there are a significant number of research projects focusing on human health and well-being and the connection between the environment and human psychological responses. Perceived comfortable environments exhibit a strong connection with humans when sensory communication and socio-cultural aspects are included in the design. Here, comfort is seen as an achievement, not an attribute. Holistic approaches to attain “placeness” are emerging to integrate operators, control room communications and well-being with comfortable interiors. This paper illustrates the shifting focus of environmental design to environmental comfort design and discusses the socio-cultural aspects of comfort and the sensory communication aspects of environmental comfort design considerations for future control room, interiors.

Keywords: comfort, future control rooms, socio-cultural, environmental design, holistic
INTRODUCTION

Environmental Design

The National Academy of Environmental Design (2009), states, “Environmental design addresses the impact of the built environment on individuals and the natural world and creates a wide range of interventions informed by human and environmental systems. Environmental design comprises architects, planners, landscape architects, interior designers, preservationists, building technology specialists, and researchers from a wide range of disciplines. Their shared body of knowledge and professional skills affect communities, landscapes, buildings, products, and the individuals who occupy and use them.” The term has expanded to apply to ecological and sustainability issues (Szokolay, 2008). Most people relate the term to “green” buildings, global warming, sustainability, and focus on the technical and efficiency aspects of environmental design. While there is a great deal of discussion on the exact meaning and implications of the term (Parris & Kates, 2003), there is widespread consensus that sustainability is an integrative concept, tying environmental, socio-cultural, and economic aspects together in one framework. Laws et al., (2004), suggests sustainability, characterized by an ongoing inquiry on efficient resource use in order to keep systems within its functional limits and to respect the needs of future generations. However, for this paper a human factors psychologist presents the term environmental design from a psychosocial viewpoint.

Humans need air, water, food and shelter to survive. Some of the early forms of shelter were caves. Caves are an excellent choice for steady temperature, protection from the elements and intruders. Some environmental designers believe the beginning of environmental design can be traced back to the drawings on cave walls during the early Paleolithic to Neolithic period (35,000 to 4,000 B.C.). Researchers continue to study the true meaning of primitive rock art and cave drawings found in different cave locations around the world (Evans, 2014). According to the Maude Group (2013), “Contemporary environmental designers have long understood that sensory communication has remained the most meaningful way to connect to an audience since its invention in the Paleolithic period”. The drawings may be the beginning of communicating narratives visually (Figure 1.). Communicating narratives visually has profound influences on the viewer. Therefore, most building or room interiors perceived as ‘comfortable’ would comprise of elements that replicate some aspect of sensory communication.
Comfort

The most common definition for comfort found in literature is “a state of physical ease and freedom from pain or constraint”, (Google, 2014). A Science direct review of 318 papers, with discomfort in the title, written from 2003 to July 31, 2013, revealed that 52% of the papers related to patient pain studies. Emotional and psychological issues are not often mentioned in titles, although were sometimes mentioned in the papers. Helander & Zhang, (1997) note that discomfort is related to biomechanics and fatigue factors, and comfort to a sense of well-being and aesthetics. Comfort is a term that is often associated with a physical state or an environmental factor.

According to Looze, Kuijt-Evers & Dieën (2003) generally accepted definitions in comfort literature are; (1) comfort is a construct of a subjectively defined personal nature; (2) comfort is affected by factors of a various nature (physical, physiological, psychological); and (3) comfort is a reaction to the environment. Green & Jordan (2002) discusses how environmental sustainability interrelates between comfort, pleasure and the usability of products. Richards (1980), stresses that comfort involves the sense of subjective well-being. That is, the reaction a person has to an environment or situation. Slater (1985) defines comfort as a pleasant state of physiological, psychological and physical harmony between a human being and the immediate environment.
Chappells & Shove (2005) discuss comfort as a universal physiological construct or a negotiable socio-cultural construct. Kuijer & Jong (2012) argue the universal physiological construct is problematic for reducing energy consumption and negotiable socio-cultural construct offers novel opportunities for sustainable design for exploring practices of thermal comfort. A consequence of negotiable socio-cultural construct is that comfort is seen as an achievement rather than an attribute. Understanding the psychological and emotional connections between human and the environment goes beyond physical comfort (Ong, 2013).

**Environmental Comfort**

Environmental comfort is a new term, although the topic is taught at in all architecture schools. It is the comfort criteria in the design of the built environment in terms of heat, light and sound. Recently air quality was added to the list and sometimes the list includes physical comfort. Environmental comfort is the middle space between the human and the environment beyond (Ong, 2013). Heat or thermal temperature is not considered one of our senses although it is complex and important. If a failure to maintain body temperature within set limits, means death. Thermal temperature in building design is fundamental and important. Temperature is the number one complaint by occupants and affects productivity and health (Vink, 2005). People prefer to be in control of their own temperature and they will move in and out of varying temperatures not only for comfort but also for social interaction. The connection between the two activities leads to overall satisfaction. Studies concluded that people are more adaptable to a wider range of environmental conditions than is acceptable within the current comfort standards (Heschong, 1979; Schiller, 1990). Light in this context is defined in terms of adequate brightness, lack of glare, neutrality of color. A sense of outdoor light or the actual daylight helps with the sense of time. There are lighting comfort standards but no visual comfort standards. Research continues on the health benefits of day lighting and an awareness of the external climatic conditions (Aripin, 2007). The human sensory system welcomes variety, some degree of randomness referred to as contrast pattern recognition, or sensory variability (Heerwagen, 1992). Unchanging environments are boring. Humans experience physiological and emotional daily cycles. Life is through the senses and need changing patterns of stimuli to activate them (Humphery 1980; Platt 1961, Cooper 1968; Schooler 1984; Cabanac 2005). Sound is more true to the measurements than heat and light. Air quality is a growing issue in buildings as well as outdoors, especially in large cities. Circulating fresh outside air is best but not always practical depending on the building location to outside noise or pollutants. Ong (2013) states, “Environmental comfort is not a scientific dispute but one that argues for a greater recognition of the diversity of human culture.”
INTERIOR AND ENVIRONMENTAL DESIGN CONSIDERATIONS

Control Room Features

The control room originated around fifty years ago and its main purpose was to protect workers and equipment from harsh and often dangerous working conditions. Designs were rudimentary, lacked soundproofing, windows were a rarity and controls were limited to emergency stop buttons and evacuation alarms. After WWII, new technologies emerged and socio-economic changes occurred in industrialized countries (Figure 2.). The type of work and skills required to perform the new work brought about an increased interest in worker and workplace psychology.

![Figure 2. A power plant control room from 1950, (photo by Dazeley, 1950).](image)

The Information age, internet and aging population and emergence of the knowledge worker accelerated the need to develop control rooms based on engineering criteria and scientific frames of reference for the past thirty years.

In late 1990, control rooms were purpose built and industrial and commercial control room standardization emerged. The nuclear renaissance and heightened interest in alternative power, i.e., solar, wind and bio-fuels provided the impetus for new control room design (Ivergard & Hunt, 2010). The purpose of a control room varies from a recording studio, a driver's seat in a car, a plane cockpit or a rapid transit operations center. An important aspect to control room design is to understand the operators and the purpose and guide the operators through effective
design to achieve the end purpose. With a renewed interest in thrift and sustainability, designing cost effective, low maintenance, sustainable, comfortable environmental interiors, for present day control rooms is a challenge (Ivergard & Hunt, 2010).

Today the implementation and construction of new, state of the art control room runs a risk of being outdated by the time it is built. New control rooms race against the expeditious growth of new technology, world economic downturns, political and social unrest and climate change. The cost of space in a control room is at a premium, some control rooms are designed without the necessary human factor assessments, and they sacrifice space to offset costs. The resulting control room layouts are challenging and inadequate to provide productive, environmentally comfortable interiors. Retaining highly skilled operators in an environmentally uncomfortable interior is not optimum. Future control rooms may face the same issues with space and cost restraints.

In fifty years, will control rooms be needed? The need to control processes from a room may not be necessary. Imagine an operator monitoring a power plant from a remote device located off shore on a yacht. Future control rooms and maintenance may be operated and performed by robots or avatars.

Many factors affect future control rooms and control room interiors not included in this paper. Economic, political and societal decisions made today shape our co-existence with the environment for the future. This paper discusses the socio-cultural aspects of comfort and the sensory communication aspects of environmental design for future control room interiors.

*Designing Control Room Interiors*

The control room dimensions are usually determined by the task analysis. A task analysis is a multi-disciplined effort. Various task analysis methods are preferred depending on the functions, systems, and purpose of the control room (Brown, 2001). With advent of screen technology Cognitive Work Analysis (CWA) is becoming more widely used. According to Lintern, (2012) resulting screen displays permit operators to deal more effectively with unexpected situations than the traditional display. However, CWA is an arduous process and requires a long lead-time.

Maintenance is an area that will grow quickly as future control rooms are designed. Maintenance is often the last item addressed. However, there are maintenance requirements in the control room. With the focus now on sustainability and risk assessment, maintenance should move to the forefront of sustainable design. More automation means less operators and more maintenance work. General and preventative maintenance, replacements, repairs, redesign installations work tasks are required by
humans or machines. Sufficient space for tasks should be assessed for environmental comfort during the design phase.

Traditional control room layouts (Figure 3.) have basic considerations (Salvendy, 2012; Stanton 2005). Going beyond the basics and layout considerations, additional environmental considerations are taken into account, e.g. lighting, and temperature.

![Figure 3. Conceptual layout for a control room by CGM, (2014).](image)

**Socio-Cultural Aspects and Sensory Communication**

Comfortable interiors appear to have aspects of the outdoor environment. Throughout history, the great wonders of the world are a blend of art, architecture, science and engineering, a form of usable beauty (Figure 4.).
Beyond the visual aspects, the other senses (hearing, taste, smell, touch) are stimulated. Traditional control room interiors tend to be stark, perceived as cold or non-organic, shape edged and devoid of color. An artist’s replication of a traditional control room diorama, hand carved from birch and maple wood and formed from steel, encased and frozen in time, void of human presence, making the inherent function obsolete. The viewer of this diorama is to consider their pre-conceived knowledge of the mechanics and functions of a control room, as well as open up to the possibility of how this knowledge can, and will, change through time and context (Figure 5.).
New and retrofitted control rooms benefit from on-going innovations in lighting, air and temperature, flooring, acoustics, glass and building materials, screen design, chairs and workstations, and clothing fabric (Brooker, Reynolds, & Martin, 2011; Lecher, 2012). All of these innovations provide options to the more traditional control room physical interiors. Additionally, the operator is realized as an integral part of the system and considerations are made to accommodate the operator's physical, psychological, and emotional attributes in the design of future control room interiors.

Sensory communication and socio-cultural aspects of control room design are considered by Koskinen & Norros (2010) who propose that control rooms are comprehensive human-system interfaces and places in which the operating personnel accomplish their work and that are incorporated with cultural norms and social meaning (Figure 6a.). In order to fulfill the demands of work the operators need at all times to understand the state of the process. Situation awareness, sense of control and sense of presence are experiential states and reflect this understanding (Figure 6b.).
Figure 6a. Sensory affordance forms the primary level on the bases of which cognitive, social and physical affordances are build. Functional affordance connects to the environmental features to the intentions of the users in an activity context (Bradner, 2001; Hartson, 2003).

Figure 6b. Affordances that plays prior role in different action sequences set into the human machine interaction model adapted from Urhema et al. 2010 (Rasmussen, 1986).

The spatial features of control rooms that support the formation of places facilitate these functionally significant user experience qualities. Koskinen & Norros (2010) created a “Placeness profile” that supports designers to
create a control room space in to a control room place when used by the operators. A “Placeness profile” is a design tool that draws attention to the spatial characteristics of control room systems that are important for the appropriate functioning of the control room in its future usage. The intention is to inform the designers of such spatial features that have psychological, social and cultural implications and instead of focusing on spaces and their physical characteristics only, the design should be targeted to facilitating places in which people act. (Koskinen & Norros, 2010).

Environmental comfort design is the middle space between the human and the environment beyond. Understanding the psychological and emotional connections between humans and the environment goes beyond physical comfort (Ong, 2013).

**FUTURE CONTROL ROOM INTERIORS**

What if future control room operators are drones, robots, or avatars? What will control room interiors looks like? Who will maintain the drones, and robots? The workforce will change dramatically from operations to maintenance. Technically other drones or robots could perform repairs and maintenance on each other, although human intervention and invention will eventually intervene.

Automation and robotics has come a long way since the 1960’s. People would rather have someone or something do mundane, repetitive, dangerous work. Robots and drones are an option. Mistrust comes with new advances in technology (Figure 7.). Fear of the unknown, and the use or misuse of new technology. Trust in automation is an ongoing discussion (Hancock, Billings & Schaefer, 2011).
Recent purchases of numerous robot technologies by Google piqued the interest of the public, particularly because the intention for use has not been disclosed. The use of drones for military missions has drawn interest, criticism, and concern on a global level. Concern that war kill targets are set-up like a game with a joy stick, big screen, and gaming chair sets off alarms for psychological and emotional issues for those acting on orders to attack, recipients of the attacks and those that order the attack (The Economist, 2014). The military has the resources to conduct Research and Development, e.g., Defense Advanced Research Projects Agency (DARPA) on a large scale. DARPA recently has given a grant to Arizona State University in the research and development of a transcranial pulsed ultrasound that could be inserted into the helmets of Soldiers on the battlefield which will allow Soldiers to manipulate brain functions to boost alertness, relieve stress, or even reduce the effects of traumatic brain injury (Dillow, 2010). There is public concern over manipulating the brain or controlling a solider to perform on demand, and merits ethical considerations. Although the future may hold that Robots, drones, and avatars control or monitor the running of a power plant, drones, robots, and avatars have still have to be maintained, serviced, and probably controlled at some level by humans. Where will the human do the control? At home, perhaps with a remote device, bio-implants? While technology rushes forward, we need to take some time out to ensure that not only lives, but also a concept of the value of human life, are preserved in the long term (Moor, 2005). Ethical responsibilities for robots, drones, or avatars or those who promote and control them are looming.
When new technologies appear, there is a commendable concern to do all of the ethics, first or place a moratorium on technological development until ethics catches up. Both approaches are better than saving ethics until after the damage is done. Both approaches have limitations. Moor (2005) suggests realistically taking into account that ethics is an ongoing and dynamic enterprise, establishing better collaborations among ethicists, scientists, social scientists, and technologists (a multi-disciplinary approach) and develop more sophisticated ethical analyses. Ethical theories themselves are often simplistic and do not give much guidance to particular situations. Often the alternative is to do technological assessment in terms of cost/benefit analysis. This approach too easily invites evaluation in terms of money while ignoring or discounting moral values that are difficult to represent or translate into monetary terms.

New technology changes life as we know it and will continue to do so. The future holds many unknowns but drones, robots, avatars, holo-deck simulators, indoor environments regulated by sensors sensing physical, psychological and emotional oddities and intensities, smart houses, smart clothes, smart phones are here or coming soon. There is opportunity to achieve comfort rather than be a passive recipient. Oskar Levander, Rolls Royce's vice president of innovation, engineering and technology considers now a road map to unmanned vessels of various types (Figure 8.). Sometimes what was unthinkable yesterday is tomorrow's reality. Is it better to have a crew of 20 sailing in a gale in the North Sea, or say five in a control room on shore (Wakefield, 2014)?

![Figure 8. Is a fleet of robotic ships a possibility in the next decade? (Wakefield, 2014)](image)

Cinema, games, art, fantasy and science fiction provide us with a plethora of future possibilities for control room. The science fiction movies like “Enders Game”, (See Figures 9a. & 9b.), “Iron Man”, and “Pacific Rim”, are
visual representations of the futuristic control room interiors and integration of the sensory communication aspects of environmental comfort design and socio-cultural aspects of comfort for control room interiors.

One of the most famous imaginative control rooms is Dr. Who’s TARDIS control room. The TARDIS has gone through updates and upgrades, not unlike real control rooms (Naser, 2005). According to Naser (2005), the TARDIS features relatively open floor plans, in which the control console is
vaguely in the middle of the room. Control rooms, interchangeably called console rooms, usually contain walls with roundels, scanners for viewing the TARDIS exterior, and have sparse furnishings. No known TARDIS control room allows for the operation of the console from a seated position. The shape, size and ambience of a control room is highly variable, even within the Doctor's TARDIS. A control room's look can transform over time. The process by which an operator can transform a control room is simple, like changing a "desktop theme". On some occasions, a TARDIS manages the change itself. Once, the Doctor regenerated with extreme violence, destroying much of his control room; the TARDIS was able to completely redesign its interior and console room without the Doctor's assistance. The console room has gone through at least twelve redesigns, though the TARDIS reveals that she archived 30 versions. Once a control room is reconfigured, the TARDIS archives the old design "for neatness". The TARDIS effectively "curates" a museum of control rooms in the Doctor's personal past and future (Figure 10.).

Imagination suggests that future control room interiors are a holistic blend of art, science, engineering, and human centric. Future control rooms have a feel of “place”, feel organic, the temperature, lighting, color and shape of the room are optional, chairs, gaming full sensory type models, and sit/stand or mobile workstations regulate workload and situation awareness for the operators.

Operators of the future enjoy customizing their work area for temperature, light, sound and color. Temperature, lighting and color variation and management keep operators alert and clear-headed. Walls, floors and ceilings for future control rooms have individualized light and color
schemes for different groups of operators or may change color by sensing mood changes or workload stress or situation awareness cues and direct operators to appropriate tasks. Clothing (to regulate temperature/sense operator stress/distress/ work load/fatigue) and added sensory devices, either implanted or external enhance visual, audio, smell, etc. Sounds for alarms are easily recognizable (perhaps in music form) and accompanied with vibrations or sensations to inspire alertness and action. To address a global workforce with mixed ages, genders and cultures a collaborative workforce requires teamwork, cross training and seamless communication. Workflow moves effortlessly amongst workstations and equipment. Information is displayed three dimensionally and narrative and pattern form.

A holistic design for future control room, interiors includes the physiological, psychological and emotional well-being of occupants and supports communication, situation awareness, all the senses, environmental elements, is comfortable, self-fulfilling, safe, secure, and has character of place.

CONCLUSION

Since the earliest evolutionary phases of human life, we have had a visceral, survivalist need to be sensitive and responsive to our surroundings, (Bilchik, 2002). Today, there is a significant amount of research projects focusing on human health and well-being and the connection between the environment and human psychological responses.

Environments have a strong influence on humans beyond the physiological aspects. Perceived comfortable environments have a strong connection with humans when sensory communication and socio-cultural aspects are included in the design.

Comfort is seen as an achievement not an attribute (Chappells & Shove, 2005). Studies by Koskinen & Norros (2010) suggest that perceived good control room space is a character of place that supports situation awareness, sense of control and sense of presence when occupied by operators. User experience concerning situation awareness, sense of control and sense of presence may be a sign of achieved placeness.

Most of the predictions for future control rooms (Montague, 2012; Wood, 2013; Schwarz, Stedinger & Howard, 2010) envision a human centric design focusing on comfortable, seamless collaborative workspaces. The work is incident or crisis management and keeping up with technology. The workforce is diverse in culture, gender and age. The nature of work in the future itself will be holistic and collaborative rather than hierarchal
and compartmentalized. The use of the large screen displays (LSD) in nuclear power plants control rooms is still under debate according to a recent report by Myers & Jamieson (2013). There is mention of new innovative products to provide for physical comfort for temperature, airflow, and lighting. However, the psychological aspects are mostly referred to as interaction amongst people or in groups of people (human centric design), not the holistic integration of the psychological, emotional or all of the senses with the physical interior design elements of the control room.

Future research and designs of control room interiors may consider including holistic models and integration of physiological, psychological, and emotional elements of comfort to include socio-cultural and sensory communication aspects of environmental comfort design (Figure 11.).

Figure 11. The Concept Plane for Airbus (2014) shows morphing seats adapt to the body and holographic communication technologies.

Holistic models on comfort and the inclusion of physiological, psychological, and emotional elements to include socio-cultural and sensory communication provide environmental designers with a deeper understanding of perceived comfort design beyond the physical requirements and standards.
REFERENCES


Health and Safety Executive (HES). (2010). “Best practice applicable to the design of control rooms.” Health and Safety Executive.


CHAPTER 8
8 Reflections and Conclusions

As described in Chapter 1, people live a significant amount of his and her life in a built environment. However, these built environments are not always ideal for humans and there is room for improvement. One of the implicit reasons for an uncomfortable built environment is that non-physical effects receive limited attention in the design process. The promising areas of research, to increase comfort holistically were presented in this PhD thesis: to offer more control possibilities to the occupants, stimulate people interaction, and provide sensory variability (mimicking nature) for built environments. The focus of this PhD thesis was to discover if the influences of these three elements exist in built interior environments and the inclusion of the three elements in the holistic design process for design of comfortable built environments.

This Chapter discusses the results and conclusions from the previous chapter case studies in relation to the research questions and hypothesis, the limitations of the case studies, and suggested future research.

The case studies selected for this PhD thesis included at least one or more of three selected comfort elements. The theoretical hypothesis is that by designing built environments, beyond the physiological realm, where occupants have more control, have pleasant interactions with one another, and occupy a space with sensory variability, increases the probability of creating and providing a comfortable environment. The objective was to present the theoretical effects with affirmed empirical data gathered in a natural environment. The underlying foundation is to gain more knowledge about the psychological and emotional aspects of comfort including a holistic approach to improve the process of designing built interior environments. To substantiate the research questions,

1. How influential are the three elements (being in control, stimulating people interaction and sensory variability) for comfort?

2. How might the three elements be included in holistic design for a built interior environment?

The locations of the case studies are largely varied, however the approach was holistic and the effects were studied in a naturalistic setting. The environments used in this PhD thesis were waiting rooms for therapy, control rooms, offices for administrative and engineering work, dance studios and aircraft interiors. The case studies show that it is far from simple to gather data in a natural setting as the conditions cannot be controlled and the researchers are dependent on finding appropriate and available study locations and willing participants.
However, using a combination of different methods to study the effects is useful when the data gathered from the different methods indicate similar results. Other studies have shown showing the significance of the three elements ‘being in control’, ‘stimulating people interaction’ and designing for ‘sensory variability’ is well worth studying. However, in the context discussed in this PhD thesis, the three elements were new and it was not known whether similar effects could be found.

**MAIN CONCLUSIONS FOR STIMULATING PEOPLE INTERACTION**

The interaction between people is one of the main components in the built environments and deserves serious consideration in the design process. Two chapters show the importance of interaction when designing interiors and four chapters describe the importance of interaction within the built interior environment (See Table 1) and in particular social interaction is an important issue.

In Chapter 2, the resulting factors influencing comfort most often mentioned in two of the three case studies were ‘people’ which was an interesting finding. The interaction with other people influenced the comfort positively as well as negatively. The interaction with people was an important finding in comfort research because people can emit positive or negative energy that felt and is not always tangible but can effect and change the surrounding environment. In Chapter 3 (project one) it was important to have a choice of a workspace where one could choose whether to interact with colleagues.

Chapter 4 concluded that contact with the airline crew influenced the comfort dramatically and neighboring passengers had an effect on experienced comfort as well. Chapter 7 discussed a team centered collaborative control room. Therefore, designing spaces for creative interaction and non-work related discussion in the overall design is encouraged for future design.

On the other hand, Chapters 5, 6 and 7 show ‘people’ as a factor related to the lowest comfort levels. The challenge for future research is to design or guide a design process for built environments that stimulate the positive aspects of human interaction and diminishes the negative.

**MAIN CONCLUSIONS FOR BEING IN CONTROL**

Many case studies in this PhD thesis show the importance of **being in control** of interior design and the use of the interior environment. The results in Chapter 3 (project one) clearly demonstrated the positive effects of having control over opening and closing office windows.
Another aspect of 'being in control' was demonstrated in team involvement and decision-making (participatory design approach) in the design process, which was discussed in Chapters 5a and 5b. Participants had a stake in the design of the interiors and knew the background of worker tasks. They guided the design of the built interior environment to meet standards and work safety for employees. The results and outcomes in Chapter 3 were unusual and welcoming because this type of participatory process is not traditional in most American government workspaces or workplaces. This workplace was unique in other ways, it allowed dogs in the office with their owners and most employees had been working the same job and same place for 15-20 years. Having the control to bring some of their personal life to work had a positive effect on their job satisfaction and employment longevity.

Chapter 6 primarily focused on 'sensory variability'. However the fact that the owner/doctors decided on the interior design of the waiting area, showed the element 'being in control' from the results of the interviews that concluded that the interior design of each waiting area design was adapted to the intentions of the design by each doctor. Kastelein (2013) mentions both of these aspects of control: changes to the interior and influencing the effects of an interior for the occupants through the design process.

In Chapter 7 most of the predictions for future control rooms (Montague, 2012; Wood, 2013; Schwarz; Stedinger & Howard, 2010) envision a human centric design focusing on comfortable, seamlessly collaborative workspaces, and a multi-disciplined, multicultural and human centric collaborative workforce.

**MAIN CONCLUSIONS FOR SENSORY VARIABILITY**

The fact that the human sensory system welcomes sensory variability (Heerwagen, 1993) is perhaps the most complex of the three elements. The variability creates comfort, self-fulfillment, safety, security, and has character of ‘place’. Chapters 2a, 2b, & Chapter 6 described the importance of 'sensory variability'. Results in comfort levels showed improvement from waking to arriving at an appointment or work place with increased sensory variability. Most of the participants observed nature and heard music before arriving at work or for an appointment.

Chapter 6 assessed and compared three healthcare waiting areas for properly placed elements following the design principles of Feng Shui. The study results showed that participants perceived the waiting area designed by a Feng Shui practitioner as most comfortable. The Feng Shui design approach seems promising, but is rather unknown in the western world.
There is, however, a strong connection between the characteristics of Feng Shui influenced buildings and the influence of nature. These natural elements influence human comfort and wellbeing. Although eastern and western disciplines do not use the same elements for design, the ultimate purpose of both is to live in harmony with nature and benefit human health. Eastern and western schools of design agree that humans experience physiological and emotional daily cycles. Many disciplines agree and conclude that structure also needs variety or the composition of things, patterns, structure, variety and placement found in nature and in great art. “We live through our senses and need changing patterns of stimuli to activate them (Humphery 1980; Platt 1961, Cooper 1968; Schooler 1984; Cabanac 2005)”. The results of this study did not challenge conventional design principles but rather suggested the consideration of an alternative system of analysis and design.

The importance of windows and the outside view were detailed in project one and project two of Chapter 3. Windows provided changes in light throughout the interiors in both studies. In project one, the outside view also provided changes in patterns and reduced boredom. Results from project two concluded that the natural light in the windowed dance studio stimulated and calmed the participants.

This office design and dance studio highlighted the importance of providing something varied in light and pattern, such as a window. The outside world has interesting patterns and changes in light and dark. The challenge for designers is providing the right amount of balanced light and pattern for comfort, not chaos or boredom for the built interior environment.

Chapter 7 explained the future design of a complex working environment. ‘Sensory variability’ is an integration of the senses with the environmental elements and includes the physiological (intellectual), psychological and emotional well-being of occupants. It supports socio-cultural, communication, and situation awareness.

In summary, the influence of the three elements for built environment is evident from the results and conclusions presented in the afore-mentioned case studies. Defining the exact comfort elements and combinations required for comfort with these three promising comfort elements warrants more research.
Table 1 is an overview of the case studies showing the three elements (shaded boxes) contribution to the comfort (C) experience and/or case studies that utilized a design process or guideline (D).

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Being in Control</th>
<th>Stimulating People Interaction</th>
<th>Sensory Variability</th>
<th>Comfort</th>
<th>Design Process/Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a Patterns in Discomfort</td>
<td></td>
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<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>2b Influences on Comfort at Work</td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>3 Changing the View Inside to Outside</td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>4 Aircraft Interior Comfort</td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>5a Retro to New-Retro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D</td>
</tr>
<tr>
<td>5b Expectation in Participatory Design Process</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D</td>
</tr>
<tr>
<td>6 Interior Effects on Comfort</td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>7 Considerations for Future Control Room Interiors</td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td>D</td>
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</tbody>
</table>

**LIMITATIONS**

This PhD thesis has limitations and it is important to alert future researchers to the main limitations or a broader understanding of the outcomes. The aforementioned case studies were located in natural settings and conducted in the participants’ natural environment. The advantage of a natural setting is that no effects of artificial laboratory conditions are measured and the effect of an environment can be evaluated more holistically. However, in a natural setting many variables are not under control conditions are hard to manipulate. Although quantitative results can be reported, many variables exist in real life studies and generally require qualitative reported results.

**Limitations for Chapters 2a, 2b, 3 (project two), 4 & 6:**

Chapters 2a, 2b, 3 (project two), 4 and 6 administered self-assessments surveys for comfort levels. Comfort is a subjective phenomenon (Vink, 2005), which makes self-reporting the most appropriate way of studying comfort. The survey method utilized a standardized set of questions, which allowed respondents’ answers to be systematically compared and/or contrasted. Limitations for these studies were possible learning effects as
the same scale was used several times sequentially and the fact that limited measures were used to ensure that participants had the same understanding of emotional, physical or psychological comfort terms. Therefore, generalization of findings should be done with care, although the findings can be transferable to another setting (Anderson, 2010).

The surveys enabled the researchers to reach respondents in a variety of locations. The response rate for self-administered surveys can be relatively low, compared to other methods such as interviews or researcher-administered questionnaires (Anderson, 2010). Therefore, the researchers conducted follow-up interviews for these studies. This allowed the researchers the opportunity to explore the research question further by collecting qualitative data. However, the research quality is heavily dependent on the individual skills of the researchers and more easily influenced by personal biases and idiosyncrasies (Anderson, 2010).

There are varying discomfort and comfort tolerances for different age groups and genders. These variations provide difficulty for determining degrees of discomfort levels. Although quantitative results can be reported, many variables exist in real life studies and generally require qualitative reported results. Non-laboratory work-study results often conflict with laboratory models, Heschong (1979) and Schiller et al. (1998). According to studies by Vink (2005), physical conditions are an important comfort factor. However, the emotional and psychological connections, although defined by Höppe (2002) difficult to quantify or as “difficult to deal with”, may be more important for the sustainability of comfort (Ong, 2013; Green & Jordan, 2003).

Another limitation of these studies was that the same participants reported the various comfort experiences over time, influencing the correlations between the various recordings. However, other studies have reported also on pre-comfort influences (Vink et al., 2012; Koniecny, 2011). It is not new that participants’ feelings are influenced by previous experiences (Park et al., 2010).

Ideally, a case study analysis should have multiples of situations included. However, in the case of Chapter 2a it was not easy to find numerous field studies researching discomfort throughout the day and throughout the week for different occupations in different countries. Additionally, Chapter 6 only researched three locations and used self-reported survey data.

However, the researchers attempted to locate similar healthcare providers, similar geographic climate and time of year for the three studies. Chapter 3 (project two) only compared one dance studio for with or without window effects on creativity. However, results show a sufficiently strong effect to warrant further research and are in line with other findings in the literature (e.g. Ulrich et al., 1984).
Chapter 6 also had no controls to establish whether differences between waiting areas arose because of different Feng Shui elements or because of different sample characteristics. On the other hand, the interviews with the owners of the office showed that the healthcare waiting area perceived as most comfortable used Feng Shui principles as an inspirational source. This variability may produce noise in the data, but the presence of significant effects, despite this noise, can ensure some confidence in its validity. In these studies, only relationships are established. Ideally, the aspects should be tested again in a case control or within subject design study with subjects to determine whether they influence the comfort experience.

**Limitations Chapters 3 (project one), 5a, 5b, & 7:**

Chapter 5b and Chapter 3 (project one) were case studies applying the participatory design process. Additionally, Chapter 5b was an ethnographic study. Both studies required rather high efforts in planning, recruiting, and executing compared with other methods. These case studies had much longer study periods and therefore required much goodwill among the participants and honest reporting.

A limitation for both these studies and the previously mentioned studies were that results from surveys recorded on paper did not always reflect results obtained from an actual observation or during an interview. Rooden’s (2001) studies on observational research concluded discrepancies between what people say and what they do. Rooden (2001) also noted “aspects such as empathy and sensitivity may be more important than 'hard' ergonomics knowledge”.

Bakker (2013) found a similar limitation in color research and stated; “Discrepancies were recorded between subject’s responses to the questionnaires and observed behaviour and/or the interview results, showing ambiguous relationships.” Bakker (2013) recommended that interviews should directly follow questionnaires to understand participant motives and researchers using the questionnaire method should include other sampling techniques.

Chapter 3 (project one) and Chapter 5b were time consuming, involved many players, were political and required checks and balances on the part of the researcher because of the possibility of too much trust and bias. The researcher was an employee for both of these studies.

The researcher also ran the risk of becoming more of a “facilitator” of the research and learning process, and less of a “researcher”. This is a particular issue if the nature of the learning was about eliciting and documenting values and knowledge held by participants to meet traditional requirements of academic scholarship (Mackenzie et al., 2012). However, the richness of including ethnography and participatory design
in the usability methods for these studies proved beneficial as a complimentary evaluation technique for a deeper understanding of diverse team expectations, team behavior and work culture throughout a participatory design process. The acquired human experience data was powerful and sometimes more compelling than quantitative data (Anderson, 2010).

The limitation for Chapter 7 was that authors could only speculate what the future will be in terms of designs for control rooms through literature reviews and collaborative speculation.

Each research method had its own drawbacks and limitations. In the case studies of this PhD thesis, different methods of research were used and the influences of the three elements, ‘occupants being in control’, ‘stimulating people interaction’ and ‘sensory variability’ were found independently of the different methods used. This supports the fact that these influences may be realistic and warrant further research.

**INCLUDING THE THREE ELEMENTS IN HOLISTIC DESIGN**

*How may the three elements be included in holistic design for a built interior environment?*

The objective of this PhD thesis is to foster and encourage a first step towards a holistic approach for comfort research and design, beyond comfort in built environments. By utilizing, eastern and western design principles, architects and designers create a sense of “placeness”, balance, and comfort in built interior environments. The design should go beyond the required standards, regulations, and physical aspects of environmental design.

To substantiate this question, the locations of the case studies are in different interior environments and demonstrate that it is far from simple to conduct research in a natural setting. However, using a combination of different methods and results pointing in the same direction was useful and should be utilized for future research. Control case studies in a natural environment could confirm the effects of holistic approaches influenced by eastern design methods. The empirical data gathered in these case studies indicate that ‘being in control’, ‘stimulating people interaction’ and ‘sensory variability’ play a role in the appreciation and comfort of interior built environments.

The participatory design cases and the windows case indicate the importance of ‘being in control’. Being involved in the interior design process increases comfort as it is part of one’s own action, but it also takes into account the purposed activities, which take place in the room.
The office cases and the aircraft interior case demonstrate that the interaction with other people may be influential in creating comfort. Built environments should consider including designed areas that to ‘stimulate interactions between people’. The window view case and the Feng Shui waiting area study show the importance of paying attention to ‘sensory variability’ in the built interior environment.

Based on the literature and case studies noted above, architects and interior designers may benefit by a participatory design approach, and explore opportunities to provide people suitable control of the systems, layout, and artifacts of the built environment. Furthermore, the literature and noted case studies suggest that architects and interior designers should preferably incorporate sensory stimulation and variability, 'sensory variability', aspects (patterns that mimic nature, variation in light and texture, stimulation of the senses) in built environments to promote human comfort and well-being.

Additionally the literature and case studies suggest that architects and interior designers should take into account; if, when, and where ‘stimulating people interaction’ should be encouraged (in situations i.e. team work, innovation, camaraderie) or not (in situations that require individual privacy or quiet reflection). These specific needs should be addressed, located, and adapted within the built environment interiors.

A built interior design process, which includes the three aforementioned elements, has a greater possibility of creating comfort, but more research is necessary to understand the principles and affirm the effects.

MODELING THE REFLECTION

The theoretical hypothesis is that by designing built interior environments, beyond the physiological realm, with attention to one or more of the three elements (being in control, stimulating people interaction, and sensory variability) will increase the probability of creating and providing a comfortable environment.

Many of Chapters in this PhD thesis assessed participant comfort levels of the environment through self-assessment surveys. The right amount of ‘sensory variability’ aspects in a perceived comfortable environment largely depends upon the person and the intended use of the environment. For example, when a person enters a built environment, the senses are flooded with information.

Bakker (2014) concluded that people experience the environment with four physical senses, four affective senses and four cognitive senses. An overall ‘feeling’ or ‘vibration’ of the interior emerges within a person and
feelings of comfort or discomfort emerge. A person’s expectations and/or pre-experiences contribute to the interaction.

Figure 1 shows the comfortable built environment model from Chapter 1(Figure 7) with the added three comfort elements discussed in this PhD thesis. This model emphasizes time or change as an important model component, discussed in Chapter 1. Many of the case studies in this PhD thesis recorded comfort over time and fluctuations in the day or in the week in the experimental set up. Additionally, verification, validation and feedback should continue throughout the lifetime of any system, in this case the built interior environment. An open system, such as the built environment, is rarely stagnant. Change is eminent and should be considered by including time in the process design and implementation.

![Comfortable Built Interior Environment](image-url)

**Figure 1. The comfortable built environment model, introduced in Chapter 1 (Figure 7.) shows the addition of the three elements in the area of the comfortable built environment.**

The Comfort Model for Human Interaction and the Built Environment, shown in Figure 2, demonstrates the process of a person interacting with a built interior environment based on the comfort model of Vink & Hallbeck (2012) and Figure 1. The model depicts how a person comes to the decision: the built environment is comfortable or uncomfortable. The human includes the physical, psychological, emotional aspects = (H) and
(SC) = the socio-cultural aspects of the human. The human (H) acting together with the socio-cultural (SC) aspects and built environment = (BE) determine the interaction = (I), perceived through time = (P/T) and influences whether the built environment = (BE) is a comfortable = (C) or uncomfortable = (U).

**Figure 2. The Human Interaction and the Built Environment Comfort Model.**

The model is a possibility for an architect or designer to revisit the built environment = (BE) for a redesign based on the assessment of the comfort elements = (CE) and by studying and assessing the human (H) and socio-cultural (SC) aspects relating to the comfort elements (CE). The process then repeats for an evaluation of the effective of implementation of comfort elements into the redesign of the built environment.

**RECOMMENDED FUTURE RESEARCH**

This PhD thesis emphasizes the importance of comfort, the interaction of the human factor in environmental design and proposes the melding of eastern and western approaches to designing comfortable built environments. Furthermore, it suggests that built environments perceived as comfortable contain comfort elements.
This is a first step towards a holistic approach to comfort, utilizing eastern and western concepts and ergonomic principles to create comfortable built environments. Although eastern and western disciplines do not use the same elements for design, the ultimate purpose of both is to live in harmony with nature and benefit human health. The results described in Chapter 6 indicate that more Feng Shui influences lead to more experienced comfort. It is a promising area of research, and could be applied in other settings, and in possibly controlled environments to assess if similar effects exist in Feng Shui influenced built interior environments. The collaboration of eastern and western methodology could provide perspectives on a comfortable built interior i.e. healthcare waiting areas and office interiors worldwide. Research could study how cultural differences influence which elements are considered comfort elements. The gathered information could be useful for design comfortable multi disciplined and, multi-cultural facilities.

This PhD thesis demonstrates that by using a combination of different methods and results pointing in the same direction is useful and should be utilized in future research. Control case studies in a natural environment could confirm the effects of holistic approaches influenced by eastern design methods. Ulrich (1984) conducted a study on the effectiveness of a window view on gall bladder recovery. Conditions for both groups were the same except for the window, and then measuring the effect of the window view against the number of days in the hospital, medication consumption and comfort. This methodology is a possibility for the aforementioned control case studies in a natural environment.

Three of the comfort elements ‘being in control’, ‘stimulating people interaction’ and designing for ‘sensory variability’ were discussed and further research should specifically define which parts of the three elements are essential for comfort and which design approach to the three elements are effective. Accomplishing this is possible by comparing various approaches, studying the effects, and recording what happens, precisely, by means of the participatory and ethnographic methods as demonstrated in the several case studies in this book.

Based on the research and studies in this PhD thesis researchers and designers should consider combining design guidelines, checklists and requirements that include both eastern and western assessment tools and models for comfortable interiors i.e., combining an ergonomic checklist or user centered design model with a the Feng Shui bagua model.

Holistic assessment methods and comfort studies could benefit research in built environments where there is little margin for human error and situational awareness and vigilance are primary tasks, e.g., nuclear power plants or air traffic control centers. Ideally, implementation of holistic
design at the beginning of a project is preferred and particularly in the task analysis and functional allocation stages of design.

Research should continue concerning job design and job allocation on how, when, and why patterns of discomfort evolve and occur during the day and week incorporating comfort over time and fluctuations in the day or in the week component. Experimental setups show the importance of the pre-event experience and expectations. The research and design of comfortable built environments in the area of customer service and product satisfaction. The research should include teams of multidiscipline professionals and knowledge experts working together to provide optimal ambient and workspace conditions and safety which satisfy the physiological, psychological, emotional and socio-cultural requirements of people. Designs should also provide supportive built environments that foster positive responses in people.

Predictions for future interior designed environments envision a human centric design focusing on comfortable, seamless collaborative workspaces and research is growing but more studies are needed (Montague, 2012; Wood, 2013; Schwarz, 2012; Stedinger & Howard, 2010). This PhD thesis proposes a holistic design process and participatory design methods, to address the growing need for a comfortable built environment that focuses on human centric design and comfortable, seamless collaborative workspaces. More active partnerships and crossed barriers between cultures are needed now to achieve this prediction.

REFERENCES


Summary

Every person on the planet lives a significant portion of his or her life in a built indoor environment. Ideally, the built environment serves as protection from the extremes of the outdoor environment and is preferably comfortable. The first ‘built environment’ was a painted cave. The cave served as a shelter and the wall paintings represented a connection to nature and events occurring outside of the cave. Today, most people live and work in separate built environments. A comfortable built environment may attract visitors; have a positive effect on employee work performance and well-being. This thesis gathered and studied new information on traditional physical comfort issues, but also considered emotional and psychological comfort in traditional and non-traditional interior environmental design. Additionally, the studies took pre-comfort experiences and expectations into account and the importance of studying comfort over time.

The following factors for a comfortable built environment are addressed in this PhD thesis, because they have been studied infrequently and are important:

- ‘being in control’ of the built environment
- a built environment that ‘stimulates people interaction’
- and a built environment that has ‘sensory variability’

The case studies selected for this thesis include at least one or more of these three elements. The theoretical hypothesis is that by designing built environments, beyond the physiological realm, where occupants have more control, have pleasant interactions with one another, and occupy a space with sensory variability, increases the probability of creating and providing a comfortable environment. The objective of this PhD thesis is to present the theoretical effects with affirmed empirical data gathered in a natural environment. The underlying foundation is to gain more knowledge about the psychological and emotional aspects of comfort including a holistic approach to improve the process of designing built environments. To substantiate this question the locations of the case studies in this book were in different interior environments. The environments included a dance studio, professional offices, airplanes, control rooms, and healthcare waiting areas.

In Chapter 2a, patterns of discomfort were studied throughout the workweek and during the day in three different countries for three different occupations. The comparison study was about discomfort, accumulation, and fluctuation over the course of the day and the workweek. Physical discomfort increased during the day and was maximal in the middle of the week in all three studies. A peak in discomfort during
the week suggested that the variation in the environment or ‘sensory variability’ of the tasks in all three studies was lacking. The element of ‘stimulating people interaction’ was present in this study because “people” made the participants most comfortable and uncomfortable in the working environment.

Chapter 2b is a further analysis of one of the studies mentioned in Chapter 2a. A self-assessment survey documented the physical, psychological and emotional comfort levels of participants throughout the day and workweek for an engineering office. The element ‘sensory variability’ was present due to variation in the environments sensed by the human body during waking, travel to work, being at work and at the end of the workday. The need for sensory variability was evident and possibly improved through layout rearrangement (and sometimes walls) of the office cubicle and computer desktop screens (identical in all cases). The element of ‘stimulating people interaction’ was present in this study because “people” made the participants most comfortable and uncomfortable in the working environment.

Chapter 3 comprises of two studies. It is a comparison study of built environments with and without windows. The first study was a project for an office layout for two United States government entities sharing one large space. The project followed a participatory process and suggested design guidelines to divide the larger space into two smaller spaces. The new design provided the employees an outside view i.e. window, which gave them more control of the indoor temperature and increased ‘sensory variability’ with a view of the outdoors. The second study considered the effect of windows on creativity and comfort in a dance studio. Subjects gave their opinion (through a survey) regarding physical comfort and creativity in a room with windows and without windows. The element of ‘sensory variability’ was found in the dance studio (project two), with the variation of light or no natural light due to the windows or no windows.

Chapter 4 concerns a study on aircraft interiors and the study of the influencing factors on comfort. Assessment of comfort used key words from the trip reports of 10,032 passengers, as well as a scale for the overall comfort of the flight duration. The lack of leg room was the factor influencing comfort the most, but service by flight attendants ‘people interaction’ was the second most important factor and also had a large effect on the comfort experienced by passengers.

Chapter 5a shows the challenges of replicating an older control room design of the 90s in France into a new facility of 2016 in the USA. Ideally, a control room designed ergonomically for safety, usability, provides end-users the capability of system control and ‘being in control’. However, technological feasibility, budget, and space constraints made it difficult to implement an ergonomically ideal situation. Challenges included change in
technology, cultural differences, new codes, regulations and standards. Additionally, noise, room and equipment, layout, workstations and temperature were dominated by the space constraints of an older design and older technology.

Chapter 5b discusses a participatory design process applied to nine control rooms and includes the element of 'being in control' of the design of the built environment. A human factors specialist researched the expectations of a culturally and professionally diverse design team throughout a yearlong participatory design process. This participatory design process resulted in active participation as team members influenced and partly controlled the design process to provide a comfortable optimal working environment for control room operators, but the team struggled with space, cost constraints, and management to meet this goal.

Chapter 6 focused on the importance of including 'sensory variability' for the interior design of healthcare waiting areas. A Feng Shui expert, using Feng Shui principles, designed one waiting area. The doctor using some Feng Shui principles and some western design principles designed another one and the third waiting area used only western design principles. The interior design effects on patient comfort were studied. 'Sensory variability' is an important element in the Feng Shui design approach. The element of 'sensory variability' was most often present in the interior designed by the Feng Shui expert and showed the highest comfort level for the patients.

Chapter 7 is a theoretical treatise on designing future control rooms and all three elements; 'being in control' of the environment, 'stimulating people interaction' and 'sensory variability' are discussed for a holistic design guideline process. The design process includes future solutions for heating, lighting, and other physical, psychological, and emotional environmental design aspects as well as, advancement in technology, automation and robotics, a multi-disciplined, multicultural, and human centric collaborative workforce.

The empirical data gathered in these case studies indicate that 'being in control', 'stimulating people interaction' and 'sensory variability' play a role in the appreciation and comfort of interior built environments. The participatory design cases and the windows case indicate the importance of 'being in control'. Being involved in the interior design process increases comfort as it is part of one's own action, but it also takes into account the purposed activities, which take place in the room. The office cases and the aircraft interior case demonstrate that the interaction with other people may be influential in creating comfort. Interior environments should be designed to 'stimulate interactions between people'. The window view case and the Feng Shui waiting area study show the potential of paying
attention to ‘sensory variability’ in the built environment. A built interior environment, which includes the three aforementioned elements, has a greater possibility of creating comfort, but more research is necessary to understand the principles and affirm the effects.

This is a first step towards a holistic approach to comfort, utilizing eastern and western concepts, and ergonomic principles to create comfortable built environments. The goal is to go beyond the physiological and include the psychological, emotional, and socio-cultural aspects in a multidiscipline design process. Further research will help define specifically, which design approach of ‘being in control’, ‘stimulating people interaction’ and designing for ‘sensory variability’ is effective.
Samenvatting

Iedereen brengt een belangrijk deel van zijn leven door in gebouwde omgevingen. Idealiter beschermt deze omgeving de mens en zorgt deze omgeving voor comfort. De eerste omgevingen waar de mens leefden waren grotten. Er zijn van voor 4000 voor Christus B.C. grottekeningen van buffels ontdekt in de grot van Altamira in Spanje, wat erop duidt dat er toen al mensen decoraties maakten in het interieur. Nu hebben we nog steeds aangeklede interieurs. Het doel hiervan is ook vaak het vergroten van comfort. Dit is ook het onderwerp van dit proefschrift, waarin verschillende omgevingen worden bestudeerd, zoals kantoren, dansstudio's, controlekamers en vliegtuiginterieurs. De meeste literatuur tot nu toe gaat over het fysieke comfort, zoals temperatuur, licht en kantoorstoelvorm. Dit proefschrift is meer op de psychologische en emotionele aspecten van het interieur gericht. De visie is hier dat een meer holistische benadering tot een meer comfortabel interieur leidt. Binnen die holistische aanpak, zijn er drie gebieden die veelbelovend zijn. Er zijn indicaties in de literatuur dat het hebben van controle over de omgeving, een interieur die bijdraagt aan een betere interactie tussen mensen, en een gevarieerd interieur dat de menselijke sensoren stimuleert, het comfort verhoogt. Om na te gaan of dit een fenomeen is dat van belang is zijn acht case studies uitgevoerd in diverse omgevingen. Deze studies zijn als aparte artikelen in tijdschriften en conferentiesamenvattingen verschenen.

In het eerste artikel (chapter 2a) is vastgesteld dat het fysieke comfort fluctueert gedurende de dag en de week. Voor drie beroepen (stukadoors, administratieve medewerkers en ingenieurs) in drie landen zijn gegevens verzameld met verschillende methoden over het comfort. En het blijkt dat het comfort het hoogst is aan het begin en einde van de week, en het discomfort toeneemt gedurende de dag. De factor die het comfort het meest beïnvloedt in positieve en negatieve zin is de samenwerking tussen collega’s, wat aantoont dat een interieur die deze samenwerking positief beïnvloedt waardevol is.

In het tweede artikel (chapter 2b) is naast het fysieke comfort ook het emotionele en psychische comfort bestudeerd bij ingenieurs. Ook dit comfort had een vergelijkbaar patroon. Uit de studie blijkt ook dat collega’s inderdaad van invloed zijn op alle vormen van comfort, maar dat daarnaast ook variatie in het interieur om de sensoren te stimuleren had beïnvloed. Tijdens lopen en reizen van en naar het werk was het comfort hoger dan bij het zitten en kijken naar ‘saaie wanden’

In de derde studie (chapter 3) werd de dansstudio met daglicht als meer comfortabel ervaren en leidde deze tot meer creativiteit dan de dansstudio zonder zicht op natuur en zonder daglicht. Dit toont het belang van ‘sensorische variabiliteit’ weer aan. Naast de dansstudio werd ook een

In de vierde studie (chapter 4) zijn 10,032 verslagen van vluchten van passagiers bestudeerd. Het meest genoemde punt gerelateerd aan comfort was de beenruimte, maar vlak daarna volgde de service van medewerkers van de luchtvaartmaatschappij (stewardessen en piloten). Zowel in positieve zin als negatieve zin heeft de communicatie een groot effect op comfort. Ook hier is dus interactie van belang.

In de vijfde studie (chapter 5a) is het ontwerp van negen controlekamers onder de loep genomen. Het bleek heel moeilijk om de ideale ergonomische situatie te creëren waar medewerkers goede controle over de situatie hebben. Daarnaast waren ook het geluid, de layout en de temperatuur moeilijk te beïnvloeden, omdat de technologie al vastgelegd was, er richtlijnen en codes zijn en budget limiterend werkt. Dit laat zien hoe belangrijk controle in de ontwerpfase is. Dat heeft weer effect op controle in de fase dat de controle kamer in werking is.

De zesde studie (chapter 5b) bediscussieert een participatief ontwerp proces van negen controlekamers, waarbij werknemers, ontwerpers, human factors specialisten en ingenieurs betrokken zijn, waardoor ze in principe meer controle over de situatie zouden kunnen hebben. De deelnemers vonden het ook fijn actief betrokken te zijn. De realiteit toont ook in deze case echter aan dat de invloed beperkt is omdat technologie en budget veel bepalen.

In de zevende studie (chapter 6) staat de ‘Sensorische variabiliteit’ als integraal onderdeel van de Feng Shui ontwerpaanpak centraal, en een case met dit onderwerp lijkt interessant om het effect hiervan te bestuderen. Hiertoe zijn drie wachtkamers van chiropracticussen gevonden in de USA, die verschillen qua Feng Shui invloed. Eén daarvan was geheel volgens Feng Shui principes ingericht. Een ander was slechts gedeeltelijk volgens Feng Shui ingericht, en de laatste wachtkamer was traditioneel ingericht zonder kennis van Feng Shui. Het effect op comfort van de patiënten in de wachtkamers is onderzocht en het was duidelijk dat bij naar gelang er meer Feng Shui invloeden waren het comfort steeg.

De laatste studie (chapter 7) beschrijft een theoretische inrichting van controle kamers, waarbij de holistische aanpak wordt gevolgd met aandacht voor alle drie de aspecten: controle over de omgeving, een interieur die bijdraagt aan een betere interactie tussen mensen en een gevarieerd interieur dat de menselijke sensoren stimuleert en het comfort verhoogt. Het ontwerpproces omvat toekomstige oplossingen voor verwarming, verlichting, en andere fysieke, psychologische en emotionele milieu-ontwerp aspecten alsmede vooruitgangen in de
technologie, automatisering en robotica, en een multi-gedisciplineerd, multicultureel, en gebruikers-georienteerd participatief team.

Al deze studies tonen aan dat tenminste een van de factoren ‘controle’, ‘interactie’ en ‘variatie’ een rol kunnen spelen bij comfort in interieurs. Controle over klimaat (chapter 3) of over het ontwerpproces van inrichten (chapter 5) verhogen de kans op comfort. Ook een inrichting die een goede ontmoeting tussen mensen stimuleert kan het comfort verhogen (chapter 2 en 4). Een indicatie voor het feit dat mensen graag een goede sensorische variatie in de omgeving willen ervaren staat in het hoofdstuk van de dansstudio met uitzicht en de Feng Shui wachtkamers (chapter 3 en 6). Verder onderzoek is nodig over wat van belang is in het ontwerp en hoe het ontwerpproces hierop aangepast moet worden.

Een holistische aanpak voor ontwerpproces van interieurs lijkt veelbelovend, maar meer onderzoek is nodig naar de combinatie van westere en oosterse (Feng Shui) methoden en hoe deze gecombineerd kunnen worden met ergonomische principes. Het doel is verder te gaan dan de fysiologische aspecten, en de psychologische, emotionele en socio-culturele aspecten in een multidisciplinaire ontwerpproces te omvatten. Verder onderzoek zal helpen bij het bepalen welke ontwerp aanpak van de drie aspecten effectief is.
Acknowledgements

This PhD project was not possible without the support and contribution of many people. I wish to thank personally the following people for their contributions, inspiration, knowledge, and other help in creating this book. First, thank you Peter for your inspirational guidance, insightful intellect and sense of humor throughout this PhD journey (sweetness of discomfort) and Annelise for your support and encouragement. To the members of my PhD committee I thank them for their valuable feedback and time. Furthermore, I would like to thank all participants in the studies because without the participants, no research would have been possible and I am grateful for their willingness to share their comfort experiences with me.

I thank my daughter Rachael for her artistic contribution and Barbara, Henry, and my sister Cori for your patience with my numerous rewrites. I am also grateful to my PhD days and HFES colleagues and friends who have shared their stories, listened to mine and helped me with experiments and/or writing articles. Thank you, Ellen, Deb, Joan, Michelle Nancy L, Symone, Iris, Irena, Barbara, Liesbeth, Elsbeth, Suzanne, Alexa, Sigrid, Mirian, Valerie, Alan, Nancy S., Michael, John, Paul, and Tom.

Thank you my family for your continued love and support, to husband Jim, son Cameron daughter-in-law Meghan, step dad Dick, and of course Marty and Chexs, the dogs. I am also very proud that Iris and my sister Cristi (Gigi) are my paranymphs for the formal ceremony. Lastly, I am grateful to my forward thinking Mom, who introduced me to ‘Feng Shui’, and my Dad who taught me to appreciate the great outdoors, ‘beyond the built environment’.

Thank you all!
Curriculum Vitae

Conne Mara Bazley was born in Glenwood Spring, Colorado. She grew up in Carbondale, Colorado, in the United States of America, where she climbed mountains, rode horses, raised a family, and worked as a ski instructor.

She taught in public and private schools; was adjunct faculty for Colorado Mountain College. She also worked as a planning analyst for Pitkin County in Aspen, Colorado. Conne Mara obtained a Bachelor of Arts, with a Minor in Psychology, in 1994 and a Master of Arts in Applied Psychology in 1996, from Regis University, Denver, Colorado, USA. She receives her PhD in Design and Engineering from TU Delft, NL, in September of 2015. She is a Certified Human Factors Professional (CHFP) and Senior Human Factors Engineer.

Conne Mara works for private, military, government and academic workforces as a consultant and is president of JimConna Inc., Engineering and Design. She served as Chair, Program Chair and Newsletter Editor for the Environmental Design Technical Group (EDTG) for the Human Factors & Ergonomics Society (HFES). She has published papers, presented at and chaired sessions, panels, and workshops at both national and international conferences. She has served as president, chair and is a member of numerous civic, professional and volunteer organizations.
Publications

Articles * indicates the Chapters used for this PhD


Conference papers


Books


Workshops & Presentations


Guest Speaker and Presenter on Human Factors and Feng Shui for Professional Organizations in CO, TX and SC & OR (1994-2014).