INVESTIGATING INTERACTIVE BIOPHILIC DESIGN IN INTERIOR ENVIRONMENTS

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree

Master of Design

by

Marion Lanktree

School of Industrial Design
Carleton University
September 2010

Your file Votre référence
ISBN: 978-0-494-71543-7
Our file Notre référence
ISBN: 978-0-494-71543-7

Abstract

Advancements in digital technology present the possibility to create an aesthetic experience for interior environments, one inspired by nature and potentially resulting in overall well-being for the user. The use of nature or its influence in interior environments is called biophilic design (Kellert, 2005). This study investigated how elements of biophilic design in large-scale installations and responsive technology may create an enhanced experience for the user through interactivity. This comparative study consisted of observations and interviews at the Decode: Digital Design Sensations exhibition at the Victoria and Albert Museum. The findings indicated that participants on average spent more time engaged with biophilic installations when compared to non-biophilic. Data revealed that younger participants spent less time at all the installations, with a consistent increase in age and viewing and interacting time. The younger age groups preferred the non-biophilic installations, while the older participants preferred the biophilic installations. Most participants could imagine biophilic installations integrated into everyday environments. This knowledge contributes to an understanding of the type of users and environments that could benefit from creating an interactive aesthetic experience in interiors.

Keywords: biophilic design, digital technology, interactive installations, and responsive biophilic aesthetic

Acknowledgements

I could not have completed this thesis without the guidance and encouragement of my extraordinary thesis advisors, Lois Frankel and Gitte Lindgaard. Both assisted me in different ways and their different backgrounds enriched this study. I am extremely appreciative of Carleton University for the educational experience it has provided me, and I thank my incredible and supportive friends and colleagues. I would also like to thank the Victoria and Albert Museum, and those who participated in my research study. A very special thank you goes to Ryan and my family, who offered me unconditional love and support throughout the course of this thesis. To each of the above, I extend my deepest appreciation.

Table of Contents

List of Figures

List of Tables

Glossary of Terms

Biophilic Design: Biophilic design is to be understood as the "deliberate attempt to introduce... biophilia into the built environment" (Kellert & Wilson, 1993; Wilson, 1984). This is accomplished by the use of environmental features, natural shapes and forms, natural patterns and processes, light and space, place-based relationships, and evolved human-nature relationships (Heerwagen et al., 2008).

Biomimicry: Is the act of learning from nature, borrowing designs and strategies that have worked for billions of years. This emulation of life is a natural part of biophilia (Benyus, 1998; Heerwagen et al., 2008).

Human Well-being: Human well-being is understood as a result of pleasure and delight. Humans constantly seek pleasure, which can come from the artifacts that surround us. For centuries human beings have tried to create decorative and functional artifacts that have raised the quality of life and brought pleasure. A sense of pleasure ultimately leads to well-being (Green & Jordan, 2002).

Natural Elements: Natural elements are to be understood as a representation of nature within a designed feature in a built environment (Heerwagen et al., 2008).

Technology: Technology is employed as a term describing computing. This study refers to technology in the context of computers, specifically those that have the ability to generate images. Therefore, technology is, for this research study, considered to be the computational contribution to a designed aesthetic (Greenfield, 2006; Norman, 1996).

Aesthetics: Aesthetics is to be understood as the visual and auditory stimuli from which the user forms an aesthetic judgment. An aesthetic judgment is to be understood according to the definition by Immanuel Kant, who determined the term to describe "a

subject's feeling of pleasure (or displeasure) according to the representation of an object" (Henry, 2001).

Decorative Arts: A traditional Arts and Craft term for the production of decorative and functional works in a range of materials such as, ceramic, glass, metal, wood, textiles etc. (Honour and Fleming, 1977).

Decorative Features: Decoration used to embellish the interior of building or object. A wide variety of decorative styles and motifs have been developed for interior design and the applied arts including furniture, pottery, and metal work. In textiles, wallpaper and other objects the decoration may be the main justification for its existence (Darley & Philippa, 1986).

Interactive Installations: Installation-based art/design involves the viewer in a way that allows the piece to achieve its purpose. Interactive installations feature digital technology, which are designed to respond to viewer input through a designed dynamic output (Fox and Kemp, 2009; Bullivant, 2006).

Responsive Aesthetic: A responsive aesthetic is an aesthetic (visual stimuli) that responds, senses, or changes according to a users' interaction with it. Aesthetic elements are planned aspects, which altogether constitute the aesthetic, such as texture, colour, light and other design considerations that might constitute an appearance (Collect, 2005; Dunne, 2005; Heerwagen et al., 2008; Jordan & Randall, 1977; Wingfield, 2003).

Responsive Biophilic Features: Responsive biophilic features refers to the use of environmental features, natural shapes and forms, natural patterns and processes, light and space, place-based relationships, and evolved human-nature relationships in

combination with sensors which enable these features to respond, sense and change according to a users' interaction.

Introduction

On average, Americans spend 90 percent or more of their time indoors (Moresco, 2009), and studies suggest a strong relationship between the absence of nature or natural elements in interiors, decreasing productivity and overall well-being (Heerwagen, 2008). In the Western world, our lives are conducted more in fabricated spaces, specifically institutional interiors with little reference to nature or natural patterns. People with contemporary lifestyles in urban settings, spend their time in static environments, characterized by florescent lighting and air-conditioning, and a lack of reference to nature or natural patterns (Heijdens, 2005).

Natural elements, when integrated into interiors, are believed to introduce a greater sense and appreciation of nature into our daily lives (Heerwagen, 2008). Additionally, greater incorporation of nature in everyday environments may encourage well-being, both physical and emotional (Ulrich, 1980). Design incorporating such elements of nature in interior environments already exists; it is called biophilic design (Kellert, 2005).

Biophilic design as well as interactive installation-based design are emerging fields. However, little empirical evidence surrounding the hybridization of biophilic design elements and interactive design within the context of large-scale interactive installations in interior environments exists (Fox and Kemp, 2009; Bullivant, 2006). Thus, the empirical foundation for these claims and beliefs in the potential benefits of including elements of nature, or quasi nature, in our interiors let alone those that are also interactive, is extremely scarce. The aim of this research was to begin to remedy this by exploring the degree to which people may prefer being surrounded by technology-based

interactive objects that remind them of nature in some way over interactive objects without such elements. The research also aimed to generate guidelines for designers concerning the use of responsive biophilic elements in interior design. With the advancement of, and growing interest in, digital technology, it is possible for our interiors to be designed with technologies that sense and react to our physiology (Picard, 1997). This provides designers the possibility to introduce dynamic interactive simulations of nature and natural processes into our interior environments through the use of technology. Digital technology inspired by nature can enable a range of reciprocal interactive relationships between the user and the enhanced environment (Decode V&A exhibition manual, 2010). Through using digital technology, sensors can infuse design elements with responsive behaviors that reference nature through imagery, movement, scale etc. The digital environment can respond, react and interact in a similar way to nature outdoors.

One way to begin to provide empirical evidence is to employ data collection and analysis techniques from experimentally oriented disciplines such as the social and behavioral sciences. To explore how best to conduct the present research therefore, expertise and literature from several academic fields were consulted.

The remainder of the thesis is outlined as follows. The next section explores two major themes. First, literature pertaining to 'design inspired by nature' will be discussed, followed by literature on the 'responsive aesthetic in design'. Thereafter, the research study, which took place at the Victoria and Albert Museum in London, UK, will be presented through the 'preliminary study' section, followed by the 'formal method' section. Subsequently the 'results and discussion' section follows and presents and

discusses the main findings. The 'general discussion' section proceeds and provides an overview of the: main findings, implications and contributions of the study, limitations, future research, the need for interdisciplinary collaboration, and finally suggestions for designers based on this research.

Design Inspired by Nature

To establish the historical context for this study, the discussion here addresses the concept of 'nature as decoration in design' and discusses the significance and usage of nature as a decorative element in design, specifically in interior design. 'The biophilia hypothesis' is then introduced to establish the theoretical context of the human attraction to nature. Some supporting empirical evidence of the biophilia hypothesis is also presented. The contemporary field of 'biophilic design' is also introduced along with the main attributes of this discipline.

A brief history of nature as a decorative element in design.

Natural objects, shapes, and processes have often acted as a source of inspiration throughout the history of adornment within art, design and architecture. Perhaps the most obvious example of this inspiration can be found in interior decoration and design, which often contains representations that are closely similar to, or reminiscent of, the animal and plant world (Breidbach, 2007; Joye, 2007).

Decorative elements influenced by nature are most apparent in the Victorian Decorative Arts movement (1800 – 1900), which refers to the style of decorative arts that began during the Victorian era (O'Neill, 2007). Several notable decorative periods were involved in the movement; they were all heavily influenced by natural imagery and

natural themes (Grady, 1955). The most memorable and influential movements that followed were: the Arts and Craft Movement and Art Nouveau. William Morris founded the Arts and Crafts Movement in the late 19th century, and applied plant and animal designs to draperies, wallpaper, tiles and furniture (Flannery, 2005). Breibach (2007) argues that the long-standing tradition of nature used as a decorative element in interiors suggests that human preference for biophilic design is tenured and widespread. The conceptual lens of nature as decoration was perhaps only possible in a society whose culture was rapidly developing in urban areas in which the immediate environment lost connection with nature (Breibach, 2007). Figure 1 below shows an example of William Morris's wallpaper and tapestry pattern design inspired by flora and fauna traditional to his British environment (Flannery, 2005).

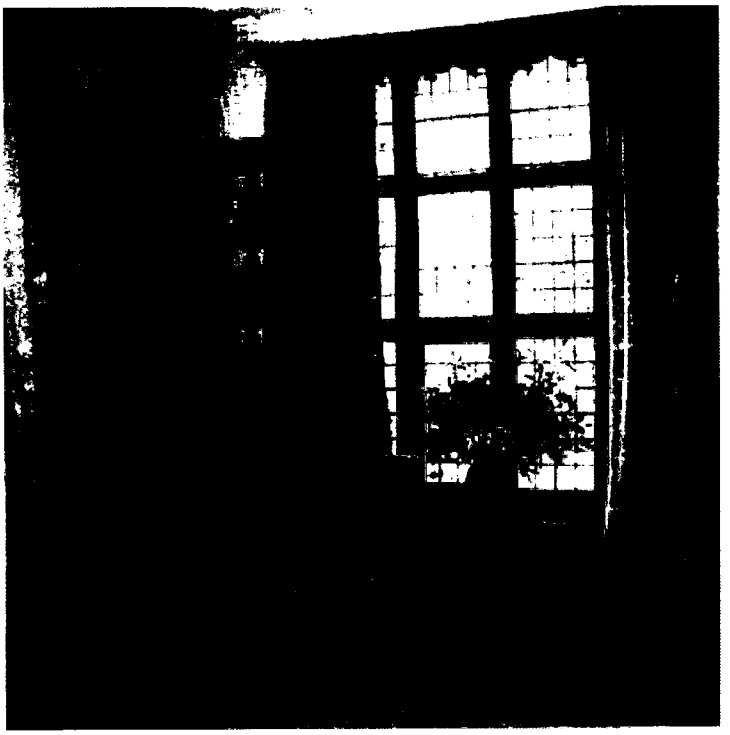

Figure 1. William Morris, Billiard Room, Wightwick Manor, and Staffordshire

Art Nouveau continued in this tradition, though more stylized (Flannery, 2005). The biologist Ernst Haeckel's work was one of the later influences on Art Nouveau, where vegetation, marine life and coral are found in common images as decorative features in interior spaces and architectural detailing (Breidbach, 2007). Haeckel's influence, particularly on Art Nouveau, is significant, and can be seen in the works of Rene Binet (See Figure 2), who took inspiration from Haeckel's illustrations, specifically in his design for the monumental entrance gate to the 1900 Paris World's Fair, in the interest of architecture as decoration (Flannery, 2005). Abandoning flat two-dimensional decoration, Art Nouveau predominantly employed motifs from the plant world as structural elements in design, transforming objects into embodiments of life and the growth process inherent in their structure. These tendencies can be observed in both the floral and the more abstract versions of Art Nouveau (Grady, 1955).

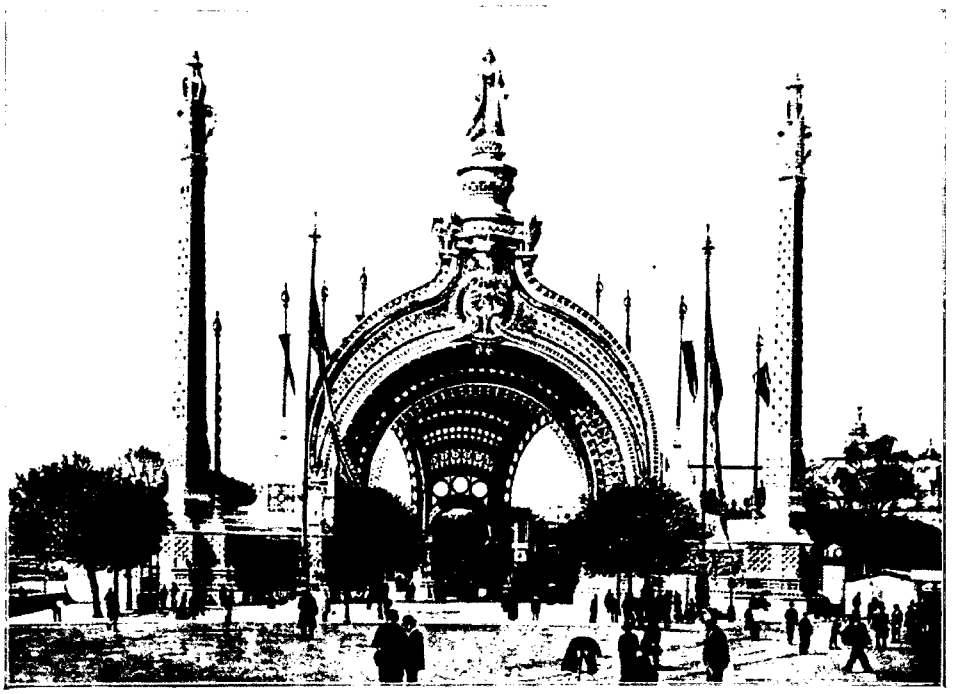

Figure 2. Entrance gate to the 1900 Paris World's Fair, Rene Binet

The late 19th century was seemingly the height of the use of nature as a decorative element in design, but it was hardly the end of it (Bloomer, 2000). The ecology movement of the 1970's created a new interest in nature and the introduction of nature-inspired décor into interiors. Then the 1980s several companies began manufacturing and mass-producing nature-related images, which are commonly used in healthcare settings, such as hospitals, and doctor's waiting rooms (Flannery, 2005). A recent example of these images is provided below, Figure 3.

Figure 3. Henry Domke, Nature Art for Healthcare (2007)

Artificially simulated nature as decorative features has proven beneficial in our interior environments (Heerwagen, 2001). Many people now live apart from the natural world, so pictures, statues, flowers and other reminders of nature are thought to be ways of trying to satisfying biophilic urges (Kellert & Wilson, 1993). Thus, the use and influence of natural themes as decoration in decorative arts, interior design, and architecture spans many centuries. That alone suggests an affinity of human beings with

nature. The next section presents and discusses the biophilia hypothesis, within the theoretical context of environmental psychology, which introduces the human desire and attraction to nature.

The biophilia hypothesis.

Researchers in environmental psychology claim that humans have innate aesthetic preferences for nature, possibly a remnant of our shared evolutionary history in natural environments (Heerwagen et al., 2008). It is claimed that this tendency became biologically ingrained because it proved instrumental in enhancing human physical, emotional, and intellectual fitness during the long course of human evolution (Kellert & Wilson, 1993). The evolutionary context for the development of the human mind and body was mainly the sensory world dominated by critical environmental features such as light, sound, odor, wind, weather, water, vegetation, animals, and landscapes (Heerwagen et al., 2008). Norman (2004) further asserts that humans evolved to coexist in the vicinity of other humans, animals, plants, landscapes, weather, and other natural phenomena. As a result, Norman argues, we are attuned to receive emotional signals from the environment that get interpreted automatically at the visceral level.

The biologist, Edward O. Wilson developed the biophilia hypothesis in his publication titled 'Biophilia' in 1984. The biophilia hypothesis predicts that there is an instinctive bond between human beings and other living systems (Wilson, 1984). Wilson defines biophilia as "the inherent human inclination to affiliate with natural systems and processes instrumental in human health and well-being" (Wilson 1984, Kellert & Wilson 1993). Kellert (1993), an environmental psychologist, explored Wilson's definition further by stating that biophilia is the "innate tendency to focus on life and life-like

processes" (p. 42). For Kellert, the biophilia hypothesis involves claims that human dependence on nature extends far beyond the simple issues of material and physical sustenance to include the human craving for aesthetic, intellectual, cognitive, and even spiritual, meaning and satisfaction (Kellert, 1993).

This literature seeks to explain why humans have an inclination to be influenced and attracted to natural elements. Research suggests that humans possess a basic need for contact with natural systems and processes (Kellert 2005). This empirical research will be presented in the following section.

Empirical evidence – human well-being and contact with nature.

Ulrich (1984), an environmental psychologist reported the following study from a healthcare setting. On a surgical floor of a 200-bed suburban Pennsylvania hospital, some rooms looked onto a stretch of deciduous trees, while others faced a brown brick wall. Postoperative cholecystectomy patients were assigned to one or the other kind of room, based purely on room availability. Ulrich (1984) reviewed records of all cholecystectomy patients over a ten-year period. He was looking at the length of hospitalization stays, and the need for pain and anxiety medication. According to Ulrich, patients with tree views had statistically shorter hospitalization stays, 7.96 days compared to 8.70 days, a decreased need for pain medications, and fewer negative comments noted by the nurses, compared to patients with brick wall views (Ulrich, 1984). This study does suggest that a view of greenery may correlate with shorter patient hospital stays. However, it does not provide an unequivocally causal relationship as other factors not accounted for may also have contributed. The study, for example, does not take the participants' age into account. It is feasible to argue that older patients might take longer to recover than

younger ones; they are also more likely to suffer from multiple illnesses. Without knowledge of how patients representing different age groups were distributed in the two kinds of rooms, it is impossible to ascertain the effect of the views from those rooms. Further well-controlled studies should investigate the relationships between age, co-morbidity, medical history, and so forth. All these factors may play a part in determining the impact of nature on recovery from surgery as well as on general human well-being. In addition, it would also be important to question potential participants about their preferences for natural elements before assigning them to a particular type of room, and that way, to ensure that the distribution of patients to rooms is controlled in such a manner that any preference-based biases can be discounted from the results.

Another study from a healthcare setting was conducted in Japan (Nakamura & Fujii, 1992). They (1992) measured the participants' stress and relaxation through electroencephalographic (EEG) recordings taken while participants were seated in a real outdoor setting viewing a hedge of greenery, a concrete fence, or a fence consisting of part greenery and part concrete. The EEG data suggested that greenery encouraged relaxation, while the concrete evoked stress in the participants (Nakamura and Fujii, 1992). As with Ulrich's (1984) study, it is unclear what ages were selected by Nakamura and Fujii, and in presenting their data; age was not taken into account. Both of the above studies suggest that a view of real nature may influence well-being in healthcare settings. The studies offer an opportunity to investigate this link between nature and human well-being in more detail.

Kaplan (1993), another environmental psychologist, conducted a field study of office workers involving 615 employees with sedentary administrative, clerical, or

secretarial positions all within the same organization. This study by Kaplan included a five page survey, which consisted of questions on "... health, psychological functioning, life satisfaction, job environment, satisfaction with job and its setting, recreational activities and home setting, as well as demographic questions" (p. 198). Participants were additionally asked about "the difficulty of seeing outside and their likelihood of doing so" (p. 198). A checklist was provided of potential features, which could be seen out of the window in the office setting. These were categorized subsequently as 'built' (street, parking lot, other buildings) or 'natural' (trees/bushes, grass, flowers). There were also questions on their satisfaction with the view from the workplace and satisfaction with the opportunity to look out and on whether the view was restorative. Participants were asked about the difficulty of seeing outside and their likelihood of doing so. In addition, a checklist was provided of potential features that could be seen out of the window. Kaplan (1993) found that workers who had window views of nature felt less frustrated and more patient, and reported more overall life satisfaction and better health than workers who did not have visual access to the outdoors or whose view consisted of built elements only. This study did not consider the office workers' personalities, or temperaments or ages. It is reasonable to assume that all of these could affect one's ability and capacity to cope with tension in the workplace.

In a study of windowed and windowless offices, Heerwagen and Orians (1986) found that occupants of windowless space used twice as many (195 versus 82) visual materials (posters, photos, and murals) to decorate their offices, which were dominated by nature themes. In windowless spaces, simulations are one of the few ways to recreate the beneficial aesthetic experience of nature.

De Kort et al. (2006) conducted a study that looked at the quality of simulated nature within the domain of mediated environments (virtual, projected, and video). De Kort et al. assert that mediated environments can be associated with 'restorative environments' within the field of environmental psychology. De Kort et al. (2006) state, "restorative environments are environments that can help restore depleted attention resources or reduce emotional and psychophysiological stress" (p. 309). The study investigated the influence of immersion (manipulated through screen size) on the restorative potential of nature presented to the user via media technology. It was hypothesized that as the mediated environments were presented in a more immersive way, engendering a stronger experience of presence, restorative effects would be stronger. Participants comprised 80 students with a mean age of 24 who watched a film of a restorative environment under low or high immersion conditions after being exposed to a stressor consisting of a mental arithmetic task in combination with uncontrollable industrial noise. Immersion was manipulated by varying screen size. Participants were randomly assigned to the two immersion conditions, and skin conductance level along with heart rate were recorded. Participants filled out and performed the pre-stressor affect questionnaire, the stressor task and the post-stressor affect questionnaire; they then watched the nature film and again filled out the affect questionnaire. Results on physiological measures largely corresponded with De Kort et al.'s predictions. Both physiological measurements confirmed the hypothesis that immersion enhances restorative effects of a mediated natural environment (De Kort et al., 2006).

While the abovementioned studies purport to present empirical data that explores how real and simulated nature in interiors can have an affect on occupants, the quality of

the research is unconvincing for the reasons previously mentioned. Advancements in new media technologies present the need for robust, well-designed empirical research within the area of interactive simulations of nature (De Kort et al. 2006). The studies are, however, relevant as they reveal that interior design strategies can use simulated natural elements and potentially have effects; this is especially relevant to institutional spaces where real nature is often not available (Gibbs, 2005). Kellert (2005) suggests that the ways we decorate our interiors provides some evidence suggesting that biophilic design may benefit human well-being. The next section presents and discusses the discipline of biophilic design including the main approaches, elements, and attributes of this contemporary field.

Biophilic design.

The design community has adopted the concept of biophilia and has begun a discussion regarding its use, called biophilic design (Benyus, 2008; Heerwagen, 2008; Kellert, 2008; Orr, 2006; Wilson, 2008).

Biophilic design incorporates "real or simulated natural elements into built environments in an effort to promote well-being" (Sole-Smith, 2006, p. 2). In Building for Life, Kellert (2005) says that the aim of biophilic design is to "reestablish positive connections between people and nature in the built environment" (p. 9). It is an attempt to bring people back in touch with nature through the design of a space or building. Kellert further explains, "The goal of biophilic design is to create places imbued with positive emotional experiences - enjoyment, pleasure, interest, fascination, and wonder - that are the precursors of human attachment to and caring for place" (Heerwagen et al., 2008, p. 53). Environmental psychologists believe that biophilia in design contributes to:

productivity, health, healing, learning, and enhanced appreciation of nature, which directly affects the way people, treat the environment (Wilson, 1984).

There is a growing interest in biophilic design practices as it relates to sustainability, however these practices have yet to be integrated into standards or guidelines (Kellert et al. 2008). Biophilic design is a fairly young discipline, and a detailed understanding of the discipline remains meager (Kellert 2005, Heerwagen 2001). Therefore it is important to build an understanding of the different approaches, elements, and attributes, which have begun to be outlined within the design discipline.

Heerwagen (2007) explains that the three main approaches to biophilic design are: 1. Literal, a connection and experience of real natural features and elements, specific examples are biodiversity, plants, trees, water, shade, and light. An example is the living sculpture created by the collaborative design studio WRT's New York office in 2009, and installed at One Bryant Park in New York City (Figure 4).

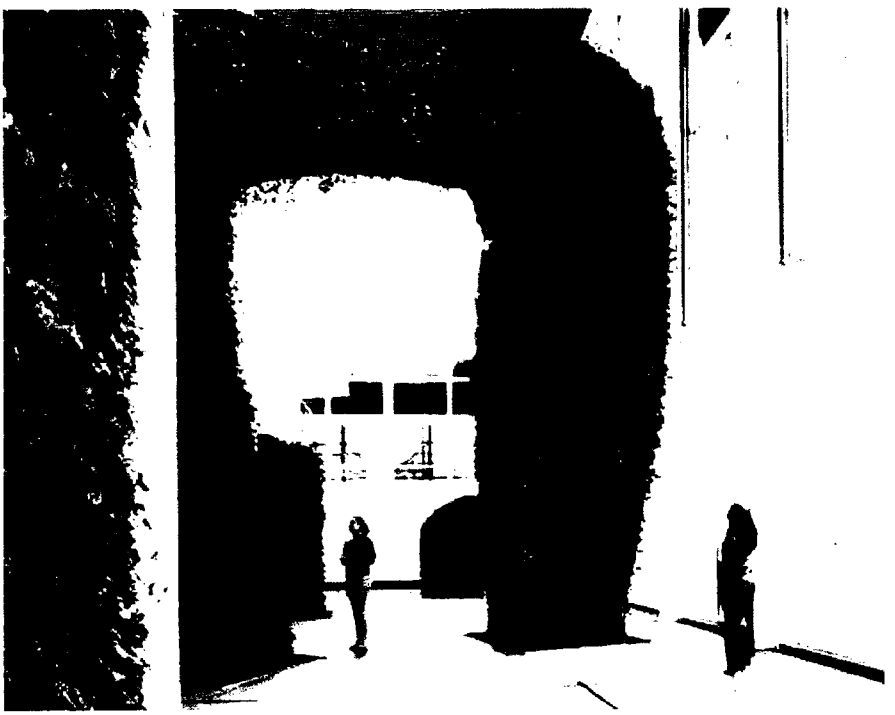

Figure 4. Living Sculptures, WRT's Urban Garden Room at One Bryant Park in NYC

2. Facsimile, the use of nature imagery and materials from natural resources. An example of 'facsimile' is the foliated sculpture by Kent Bloomer installed at the Ronald Reagan Airport terminal (Figure 5). This metaphorical representation of nature draws on affinities of plant forms.

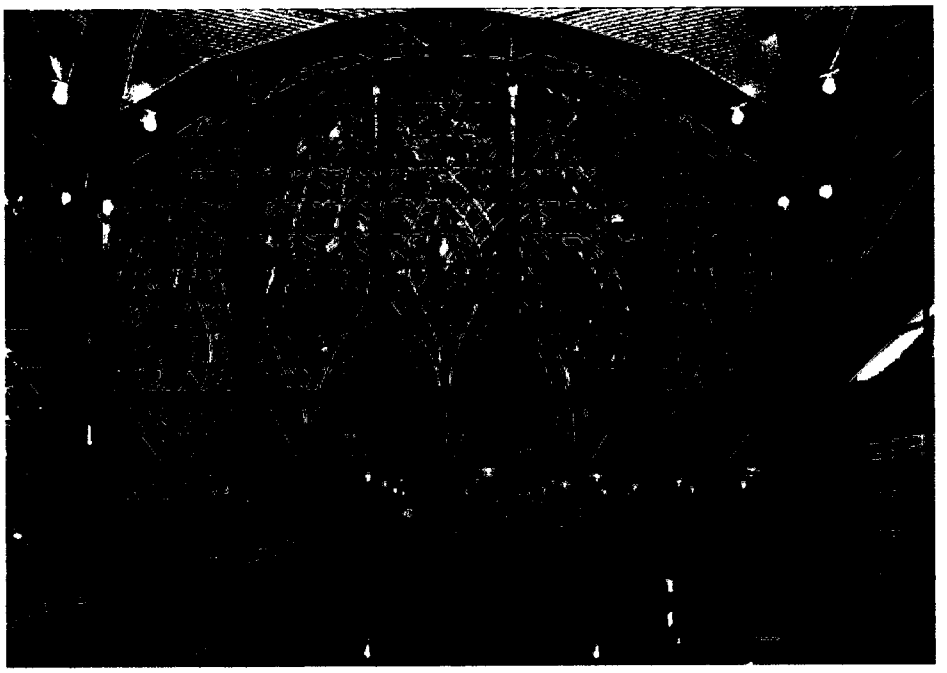

Figure 5. Kent Bloomer Studio, Ronald Reagan National Airport

3. Evocative, the use of qualities and attributes of nature in design, specific examples are sensory variability, prospect and refuge (strategic viewing conditions from a position of safety and security), serendipity, and discovered complexity. An example of 'evocative' biophilic design is the Light Forest created by Janet Rosenberg & Associates Landscape Architecture in 2006, and designed as a public terrain in Winnipeg Canada (Figure 6). The Light Forest consists of light columns that change through the seasons, and creates a feeling of a forest through the interplay of light.

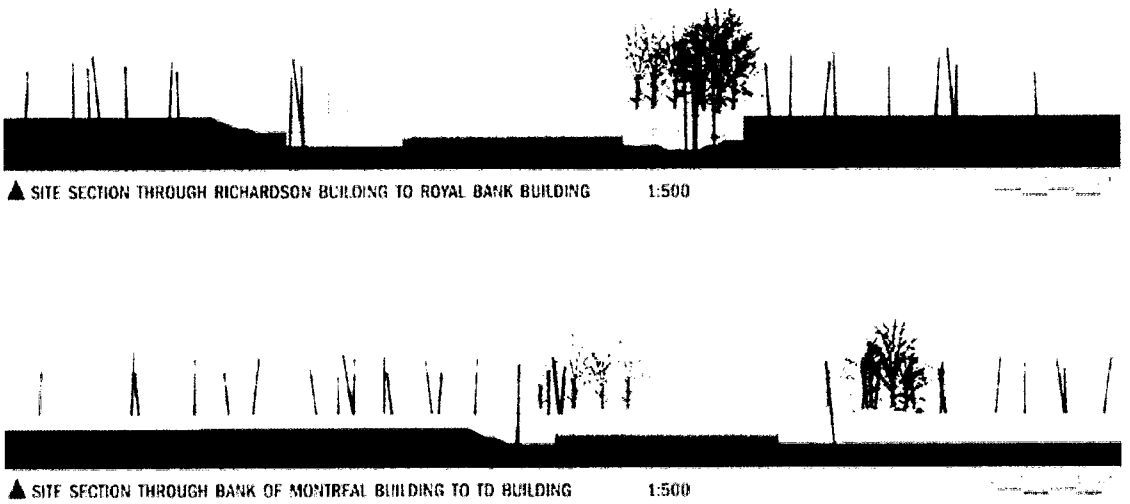

Figure 6. Janet Rosenberg & Associates Landscape Architecture, Light Forest in Winnipeg

The three approaches of biophilic design, which Heerwagen (2007) presents can be related to six biophilic design elements: environmental features, natural shapes and forms, natural patterns and processes, light and space, place based relationships, and evolved human nature relationships. These six elements and attributes are outlined below in Figure 7.

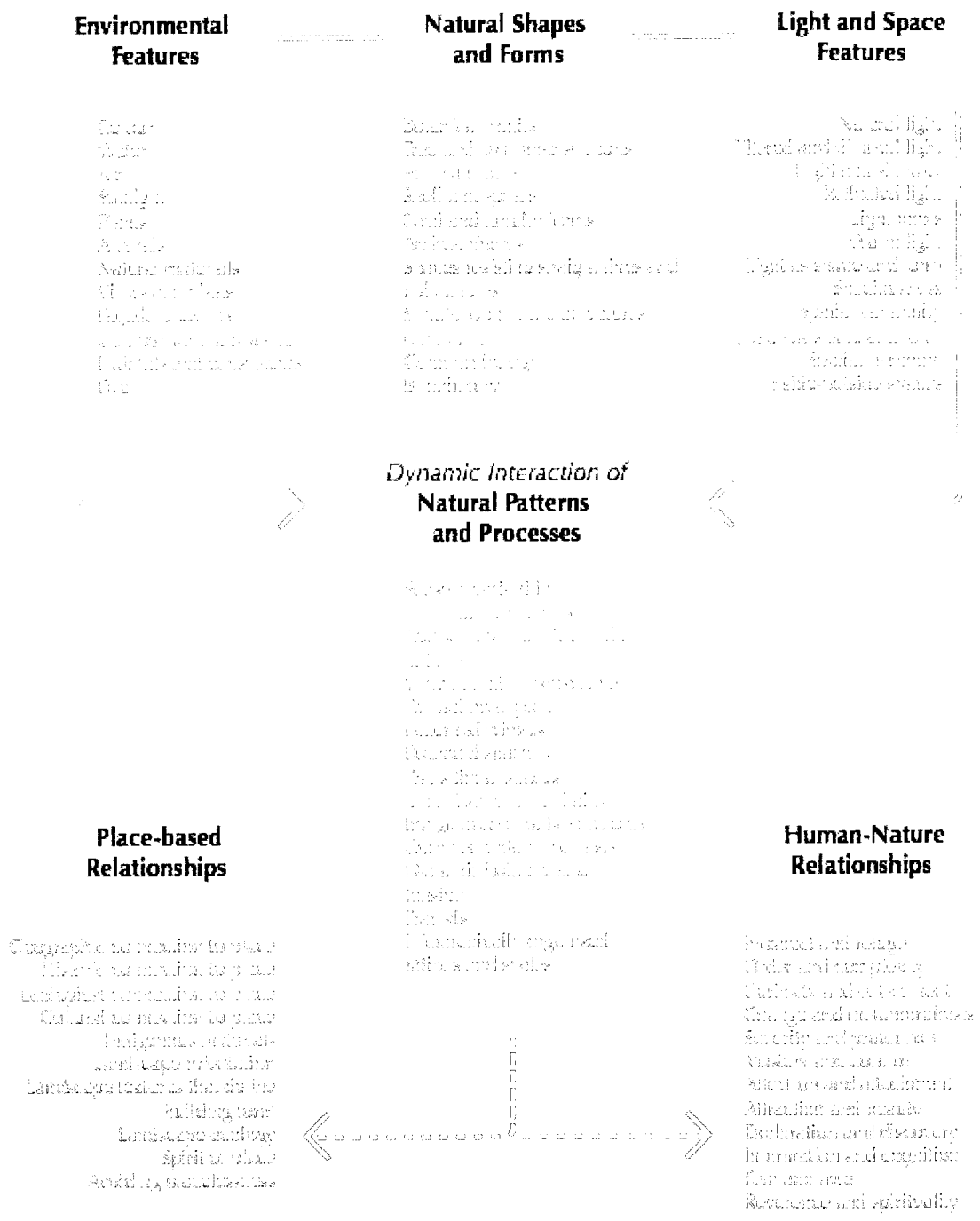

Figure 7. Elements and Attributes of Biophilic Design

(Adapted from: Biophilic Design – Stephen R. Kellert 2008 p. 15)

Natural elements and features can be incorporated into building design and spaces not only through the use of actual nature elements, but also through the use of simulated features of nature in subtle and abstracted ways. Janine Benyus (2008) explains that the biophilic design elements outlined by Kellert (2008) can be mediated by various types of technology such as structural materials, decorative elements, windows, skylights, and vegetation. The use of advanced technologies allows for further development in biophilic design.

This section established the context and the potential of real and stimulated nature with the contemporary field of biophilic design. It presented studies providing empirical evidence for the preference for views of nature, and the use of artificial nature used as an element of décor in interior environments. The present study focused on simulated nature as a decorative feature and the potential effects it can have when integrated with digital technology creating an immersive interactive experience for occupants. No studies were found that focus on this subject of interactive biophilic design.

The next section introduces and explores the integration of biophilic design with interactive digital technology, and the use of this synthesis as a dynamic, responsive decorative feature in interiors.

Responsive Aesthetic in Design

This section defines and discusses 'ubiquitous computing and intelligent environments' within the context of design as well as 'interactive installations created through digital technology'. In particular, the qualities, elements and domains of interactive experiences are addressed. Finally, the concept of 'responsive biophilic

design' is presented, and the work of three contemporary interactive designers are used as illustrative examples.

Ubiquitous computing & intelligent environments in design.

Almost twenty years ago, when personal computers were first being used on a broad scale, Mark Weiser (1991) envisioned a way that computers could blend into the environments of everyday life, which he termed "ubiquitous computing". While computing devices have undergone many changes in both size and portability over the past twenty years, at present, the common experience of computing is still mostly limited to personal devices and desktop computers (Fox & Kemp, 2009). Weiser was describing "computing without a computer", whereby "Desktop machines would largely disappear, and the tiny, cheap microprocessors that powered them would fade into the built environment" (Weiser, 1991, p. 95). Computers would integrate intimately within aspects of everyday life through the use of sensors, and, essentially, each ordinary everyday object would be a potential site for the "sensing and processing of information" (Weiser, 1991, p. 95). Weiser's concept of "ubiquitous computing" suggests numerous possibilities for improving lives through intelligent, responsive interiors. This suggestion is significant for the purpose of this project, which is to explore the positive potential for responsive installations, and investigate preferences for biophilic or non-biophilic examples. The following is an overview of the conceptual foundation for the integration of digital technology into interiors, and, after, an exploration of its positive potential for enhancing user experience.

Weiser believed that computing would be refined and integrated in such a way that the "innumerable hassles presented by personal computing would fade into history"

(1992, p. 95). The development of ubiquitous computing fueled the advancement of 'intelligent environments' developed in the mid 1990's (Fox & Kemp, 2009). Intelligent environments are defined as "... spaces in which computation is seamlessly used to enhance ordinary activity" (Fox & Kemp, 2009, p. 16). The Adaptive House project developed in the late 1990's by Michael Mozer introduced the "intelligence" of the home as that which enhances the home's capability to anticipate the needs and behaviors of the occupants by having observed them. The developed system is capable of controlling heating, ventilation, air conditioning, and interior lighting. If the activity can be anticipated, the system can carry out the actions automatically, freeing the occupants from manual control of the home. An additional consideration of the system is to conserve resources, when possible (Fox & Kemp, 2009). Donald Norman (2004) further developed a proposal to forge a new understanding for the potential of interfaces. In The Invisible Computer, Norman (1998) argued that the "difficulty and frustration we experience in using the computer are primarily artifacts of its general-purpose nature" (p. 66). He goes on to propose that the computer's functions become dispersed into a "quiet, invisible, unobtrusive" array of "networked objects scattered throughout the home" (p. 66).

Along similar lines to Weiser and Norman, Greenfield (2006) proposed that computing could be more useful if it were in more places, new kinds of places, and functioning on new scales. The European Union's Information Society Technologies Program Advisory Group (ISTAG) further expands on Weiser, Norman, and Greenfield's thinking in a vision statement presented in 1999 (Ahola, 2001). The ISTAG used the term "intelligent ambience" to describe a vision where "people will be surrounded by

intelligent and intuitive interfaces embedded in everyday objects around us and an environment recognizing and responding to the presence of individuals in an invisible way" (Ahola, 2001). In order to achieve a better understanding of the role of technology as an element of design, Dunne explains that we must dematerialize technology as a subject of study by depriving the apparent physical material (2005). Dunne is describing 'design without an object', an argument first put forward in the 1980s by the design group Kunstflug (Dunne, 2005). The concept of dematerialization, "... is that values and functions can completely shift from hardware to software, from three to two dimensions..." ultimately removing the object, and focusing on experience (Dunne, 2005). Peter Weibel (1994) explains that a form of dematerialization is "intelligent ambience", which arises from a shifting importance from technology to its intelligence, and applying this intelligence within an environment (Weibel, 1994). As a field of research, ubiquitous computing does this, using dematerialization as a way of making computer interfaces invisible, placing them in everyday objects and surroundings (Weibel, 1994). Dunne is especially captured by the work of architect Toyo Ito, as a good example for the aesthetic possibilities of this sort of dematerialization.

Dunne (2005) gives the example of Ito's exhibit Dreams Room (1992), at the Victoria and Albert Museum, London, shown in 1992 (See Figure 8 below). The room consisted of projections of real-time sounds and images from around Tokyo onto every surface in the room. Essentially, Ito created on an intimate scale what one only ordinarily experiences on an architectural scale. More importantly, with the Dreams Room (1992), Ito created an aesthetic that communicates the immaterial sensuality of the new technological environment, through creating a sensory experience for the user. With this

new perspective, future generations of designers might operate with entirely different assumptions about technology and aesthetics.

Figure 8. Toyo Ito: Dreams Room (1992)

The examples in this section demonstrate that it is possible to integrate technology seamlessly into our interior environments by imbuing objects and spaces with digital behaviors without revealing the technology behind them. The integration of biophilic design elements with digital technology further presents the potential for ubiquitous computing to perform like nature, responding and interacting with the occupants in a dynamic and enhanced way, rather than referencing nature through static decorative features. The following section discusses the potential of interactive installations and how responsive digital technology may enhance the user experience.

Interactive installations created with digital technology.

Interactive art installations create a dialogue between the installation and the participant. The participant has agency, or the ability, to act upon the installation, and is invited to do so, while the interactive installation can respond with a range of possible responses (Peacock, 2001). A study introduced by Duncan, Finley, and Gonzales in 2008 at the 27th Conference on Human Factors in Computing Systems, reveals that users enjoy experiences more when they are able to interact with the system. Their study presented empirical evidence that examined interactive and non-interactive modes in the same installation. A total of 71 pairs of users participated in the study, 34 pairs were exposed to the interactive installation, and 37 pairs were exposed to the non-interactive version of the same installation. Duncan, Finley, and Gonzales (2008) conducted interviews following the study, where participants were asked to rate their experience on a scale and found that the users enjoyed the experience more when they were able to interact with the system.

Rogala (2000), a professor of Interactive Media at the Pratt Institute states, "Interactive art depends on a variety of technologies that alter our experience of everyday life, as well as artistic expression, behavior, and practice" (2000, p. 1). Interactive installations generally are computer-based and frequently use sensors that are able to detect movement, changes in temperature, sound, light intensity, and pressure etc., which the designer has programmed in order to generate responses based on participant interaction (Fox & Kemp, 2009). Alan Peacock (2001) describes 'the interactive' to mean "experiences mediated by, and including, computer systems that take in physical world actions, and give out display in visual, sonic, and haptic sensory domains, singly or in

combination" (Peacock, 2001, p. 1). Digital technologies represent the possibility to create innovative interactive experiences with our environments (Fox & Kemp, 2009). When created by designers, interior designers and architects, interactive installations are commonly called 'responsive environments', a term that was introduced by Lucy Bullivant in 2006, to mean "...spaces that interact with the people that use them" (p. 6).

Responsive environments belong to an interdisciplinary field combining specialized interests of designers, interior designers, artists, and architects. There is a growing trend whereby designers and interactive designers are collaborating with electronic artists in order to create interactive experiences (Beesley, 2010). The interactive piece titled, Hylozoic Ground (2010), created by the Canadian architect and sculptor Philip Beesley is an excellent example of this interdisciplinary approach to responsive environments (see Figure 9).

Philip Beesley works collaboratively with interdisciplinary teams of specialists including: artists, designers, scientists, architects, and engineers who work towards the creation of, what he calls "experimental spaces" (Beesley, 2010). Hylozoic Ground, (Figure 9) is an immersive interactive environment that reacts to the movement of the participants within it, "... suggesting a more empathetic relationship between architecture and people" through the use of sensors and Arduino microcontrollers (Beesley, 2010, p. 4). The dynamic and interactive installation responds to participatory presence and touch through subtle movements (Beesley, 2010). The installation is thought to be the next-generation of artificial intelligence that combines synthetic biology and interactive technology, creating an interior environment that responds to participation in an animated way (Beesley, 2010).

Figure 9. Philip Beesly, Hylozoic Ground (2010)

Fox and Kemp believe "clear communication between participants and the environment fosters emotional attachment, which in turn enhances the spatial experience" (Fox & Kemp, 2009, p. 156). As participants have the opportunity to manipulate interactive experiences, they also have the ability to create new types of connections with each other through the commonality of a shared interactive experience (Fox & Kemp, 2009). Peacock (2001) elaborates on Fox and Kemp's discussion of the enhanced spatial experience by introducing the 'Qualities' of the interactive experience in his paper titled, 'Towards an Aesthetic of the Interactive'. He describes 'the Interactive' as possessing 'Qualities', which bring together elements of visual, sonic, and haptic sensations and actions, aspects of play, puzzlement, reward, concentration, anticipation, critical engagement, and feelings of dialogue, that when integrated together constitute a 'Texture' of the interactive as received experience (Peacock, 2001, p. 2). The concept of redundancy (predictability) and entropy (uncertainty) involved in interactive artworks

were introduced at the Creativity and Consumption Conference at the University of Bedfordshire in 2000. He further explains that "art works and entertainment artifacts have a tendency to the entropic, there is delight in the unexpected" (Peacock, 2001, p. 3).

Peacock (2001) additionally introduces the notion of 'Domains', which both identify and isolate characteristics of the interactive. The first domain is 'engagement' that is where the user stands, both literarily and metaphorically, in relation to the place of interaction. At a physical level, how they relate to the devices of interactivity, the hardware components, which respond to their movements, actions, voices, and how empowered they are in determining the outcomes of their actions. Peacock (2001) calls the second domain 'cursality', which is concerned with the density of choices and flow of events in an interactive work. Aspects of 'cursality' include repetition, looping, the significance of the repeated parts, the possibility of understanding the whole and having a complete grasp of all the parts and how they relate to one another (Peacock, 2001). These 'Domains' are implicit in the interactive work and in its construction of meanings. The domains resonate in the work to form a whole. Peacock explains, "The interactive is a powerful way of conveying meaning and values as the visual and sonic aspects of the work, and in its texture and forms is richly connotative and metaphorical" (Peacock, 2001, p. 8). This statement is relevant to combing biophilic design with responsive technology.

It follows that interactive installation-based work can be enhanced by digital technologies to create effective technology mediated biophilic experiences. Multi-dimensional dynamic interactions are in themselves somewhat biophilic (receiving and reacting to information) and can be adapted from the human experience of nature

primarily at a sensory level. This section presents the interactive experience as one that is capable of enhancing the user experience in interior environments. Additionally, this section demonstrates the potential to introduce dynamic interactive elements to the previously presented literature on static visual representations of biophilic elements. The following section presents and explores the concept of responsive biophilic installations.

Responsive biophilic design.

Developments in digital technology allow for new possibilities in collaboration with biophilic design. This section discusses the concept of responsive biophilic design with reference to three contemporary designers, who practice responsive biophilic design as an innovative aesthetic feature in interiors.

Simon Heijdens, Daniel Brown and Daan Roosegaarde are examples of contemporary interactive designers whose work draws inspiration from biophilic elements, ubiquitous computing and interactive technology. Since the concept of responsive biophilic design is interdisciplinary, it makes sense that topics outlined in this literature review, such as, the use of nature as a decorative element, biophilia, biophilic design, and interactivity can be found in their work. The 'qualities' and 'domains' of the interactive experience, introduced by Peacock (2001), engage the participant within the responsive biophilic experience, which is mediated through the use of interactive technology. Considering the surmised benefits of biophilic design, previously outlined, additional research is needed about the integration of interactive technology to understand the effects of biophilic design elements.

In Heijden's piece titled, Tree (2005), (see Figure 10 below) we see a digital life-sized tree projected onto the wall surface within an interior space. Its branches move

either slightly or intensely, in direct relation to the measured wind that passes the facade of the building in which it is projected. When participants walk by and engage, through subtle movements, with the projected tree, it mimics nature and lets its leaves fall to the ground upon which the participant is standing. The participant is able to kick at the leaves below their feet like real leaves; no sound is created by the installation as a response to this action. The result is not simply a reminder of nature; rather nature itself is integrated, by technology, into a new aesthetic (Heijdens, 2005). Heijdens uses biophilic design elements with interactive technology to create a digital facsimile of nature in interiors.

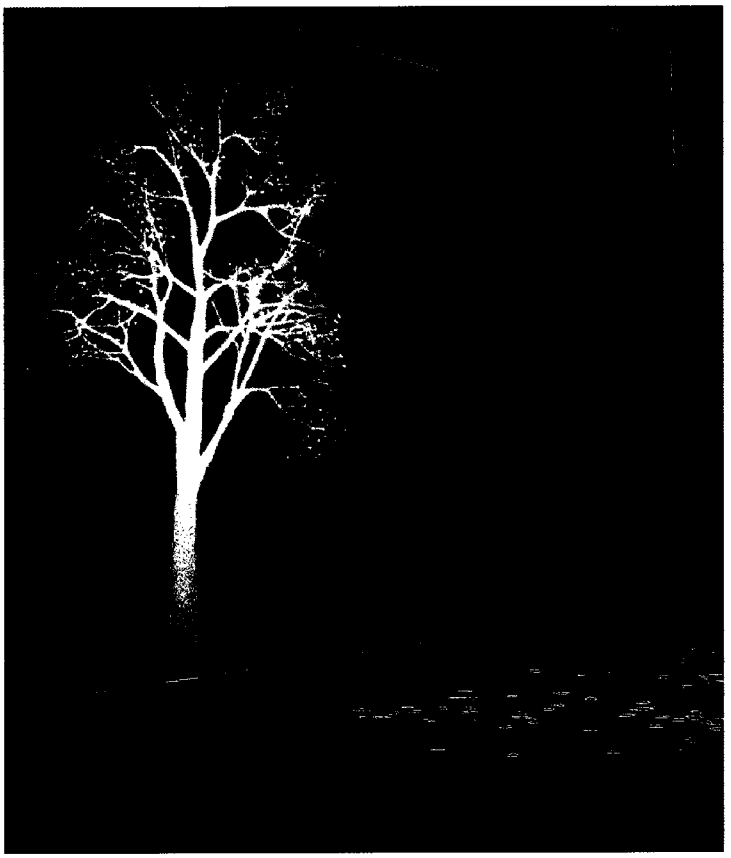

Figure 10. Tree, Simon Heijdens (2005)

Daniel Brown's series titled, On Growth and Form (2009) (see Figure 11 below) is a series of evolving digital animations, which are presented as large immersive room

sized digital projections. The interactive piece is motion sensitive, and the floral animations evolve through subtle movements mimicking natural growth patterns when participants are present and the animations dissolve when no one is there. The design critic Alice Rawsthorn states, "Brown's animations go against the grain of web-based and digitally generated images. Rather than creating action, he creates a complete sensory environment for us to inhabit" (Rawsthorn, 2005). Brown blends elements of biophilic design with technology in order to create organic moving animations from inanimate code. Rawsthorn further explains "These synthetic life forms seem to possess the life-force or 'breath of life' that animates all organic beings" (Rawsthorn, 2005).

Figure 11. On Growth and Form, Daniel Brown (2009)

Daan Roosegaarde's piece Dune (see Figure 12 below) is referred to as an 'interactive landscape', which responds to the presence, noise, subtle and active movement performed by participants (Fox & Kemp, 2009, p. 169). Roosegaarde describes the piece as a "hybrid of nature and technology" that "functions as a platform on which the relationship between visitor and the existing architecture is enhanced (Fox & Kemp, 2009). The piece is usually placed in corridors and is created from large amounts of fibers that light up and create responsive noises according to the sounds, and motion of participants. The more engaged the participants are with the interactive components, the more the installation responds. Again, Roosegaarde utilizes biophilic design in collaboration with digital technology, creating an environment enriched with responsive biophilic elements.

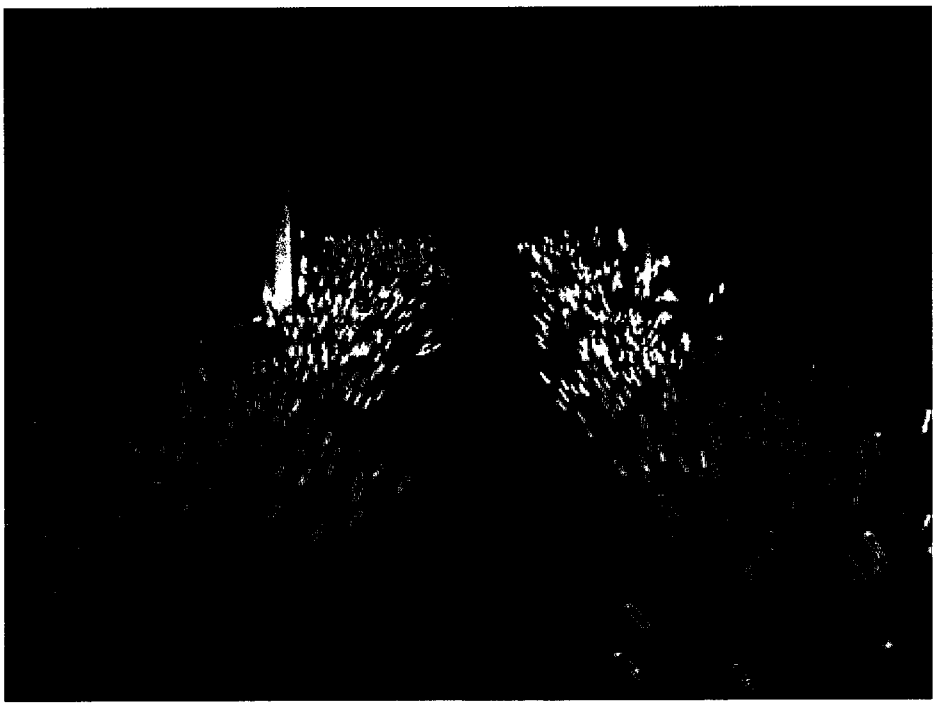

Figure 12. Dune, Daan Roosegaarde (2007)

These three interactive installations are capable of introducing nature into everyday environments, through technology that mimics nature, thus creating a biophilic

responsive environment for users. These designers simulate and represent natural imagery, patterns, and processes through technology within their work. By their cunning mimicry of nature, these designs by Heijdens, Brown, and Roosegaarde seem to appeal to human desire. The functionalist aspect, which may contribute to well-being in Heijdens, Brown, and Roosegaarde's work, is more subtle and nuanced. With such sensory experiences, there may be a range of benefits. Viewers might find interest, inspiration and enchantment through the interactive components of the pieces. This work represents a reconstitution of the general publics' assumptions about the purpose of technology, and about the limits of sensory interaction, that will result in pleasant enhanced experiences through the use of biophilic design. The examples provided within this section, suggest some clear benefits for responsive decorative features, such as: familiarity derived from integrating natural elements into interiors; designing for improved well being; and enhanced everyday experiences through interactive design.

This literature review discussed theory surrounding interactive experiences mediated through digital technology (Rogala, 2000, Fox & Kemp, 2009, Peacock, 2001, Bullivant, 2006). There has, additionally, been much theorizing and research done on the human attraction to nature and natural imagery in interior environments, also outlined in this literature review. (Wilson, 1984, Kellert & Wilson 1993, Kellert et al. 2008). At this point in the research document it appears that interactive artworks are also capable of enhancing the user experience, yet empirical evidence is lacking in the area of large-scale interactive installations, and biophilic interactive-installation based work.

Further empirical investigation and research within the area of responsive biophilic design is needed to clearly understand the benefits and possible applications of

interactive decorative elements in everyday environments. This study compared viewers' reactions to responsive biophilic and to responsive non-biophilic installations. Specifically this study examines if viewers prefer installations with biophilic design elements to those without biophilic design. It is predicted that viewers' will prefer interactive experiences mediated through responsive biophilic installations, when compared to interactive experiences that do not employ biophilic design elements. This prediction is based on the literature reviewed.

The primary aim of this study was to provide empirical evidence about responsive biophilic installation-based design through exploratory research. An additional goal of this study was to enable comparison of non-biophilic and installations incorporating biophilic design elements.

A qualitative research method was used to investigate specific creative works within the contemporary field of dynamic interactive installations that incorporate biophilic design elements. The research bridges the two disciplines of psychology and design with the goal to establish a deeper understanding into the potential of large-scale interactive biophilic installations. This collaboration across disciplines was carried out in order to establish empirical evidence through the use of a qualitative method looking at how participants respond to- and interact with dynamic interactive installations that incorporate biophilic design elements and non-biophilic design elements. The interdisciplinary collaboration between disciplines was additionally conducted to build credible evidence for the growing fields of biophilic design and interactive digital technology. As previously mentioned, biophilic design has emerged as an interdisciplinary field in the last ten years, and has just begun to be popularized through

its contribution to sustainable design (Heerwagen, 2007). This research contributes to the field of biophilic design by providing empirical evidence concerning the preferences for, and potential effects of, biophilic design human well-being. Additionally, it presents the integration of digital technology with biophilic design elements as a contemporary, interdisciplinary and credible practice for designers and, ultimately, their clients, and the users of the interactive installations.

Preliminary Study

Introduction

The purpose of the preliminary study was twofold. Phase 1, was designed to select the four installations to be used in the formal study by assessing common interactive features and behaviors amongst the interactive installations within the DECODE exhibition at the Victoria and Albert Museum, London, England. Phase 2, tested the observational protocols for each of the four interactive installations with a view to refining behaviors that had been defined a priori. Preferences were assessed by the amount of time spent at each installation and by participants' interactive behaviors.

Study Setting

The setting for this study was the Digital Design Sensations (DECODE) exhibition at the Victoria and Albert Museum in London, UK. DECODE, which looks at three current themes in digital design: Code, Interactivity, and Network.

> Code shows how computer code – whether bespoke and tailored, or hacked and shared – has become a new design tool. Interactivity presents works that respond to our physical presence. Networks charts or reworks the traces we leave behind (Decode V&A exhibition manual, 2010, p. 2).

This study focused specifically at the 'Interactivity' portion of the exhibition. The works displayed in that section responded to movement, tracking the presence of the participant and incorporating this interaction back into the work; the pieces often incorporated

reflections of the viewer. "The pieces are immersive and the lines between design, interaction, play and performance are deliberately blurred" (Decode V&A exhibition manual, 2010, p. 2).

Method

Participants. Some 20 participants selected at random were unobtrusively observed (N = 5/installation).

Design. In Phase 1, the installations were observed to select those that would best fit within the biophilic and non-biophilic categories. The purpose of Phase 2 was to ensure that the installations selected would evoke a range of participant behaviors.

Materials. An initial observational protocol was prepared prior to attending the DECODE exhibition to guide the initial observations. It listed a range of possible behaviors defined a priori, with a view to update these as needed during the observations. The behaviors were listed in rows, allowing the researcher to note the frequency of occurrence of each behavior during an observation. A clean observation protocol was used for each observation (See Appendix 1). A total of six interactive exhibits (3 biophilic and 3 non-biophilic) were considered for the formal study. Prior to the preliminary study, the various interactive installations in the exhibition had been scrutinized. The three interactive installations that integrated responsive biophilic design elements were: Dune by Daan Roosegaarde, Tree by Simon Heijdens, and On Growth and Form by Daniel Brown. The interactive installations in the preliminary study that did not integrate responsive biophilic elements were: Weave Mirror by Daniel Rozin, Body Paint by Mehmet Akten, and Flow by Daan Roosegaarde. Observations were recorded using the preliminary observation protocol (see Appendix 1).

Procedure. Some 20 observations were made of randomly selected visitors at each target installation. This preliminary study was completed in a single day. I was positioned so that the relevant installation could be readily and unobtrusively observed, and waited for participants to interact with the target installation. Participants were observed one at a time, and notes were taken in the preliminary observation protocol. Once the desired number of observations had been completed for each installation, I continued to the next target interactive installation until 20 observations had been completed for each of the four installations.

Results

Six interactive exhibits were considered (3 biophilic and 3 non-biophilic) as possible candidates for the formal study. The DECODE exhibition consisted of 28 exhibits (Interactivity, Code, Network), and a total of 11 interactive installations were included in the entire 'Interactivity' portion of the exhibition. The selection was based on the common interactive features of the installations and the participants' common interactive behaviors. Two interactive installations incorporating responsive biophilic design elements were: Dune, by, Daan Roosegaarde, Tree, by Simon Heijdens. The piece entitled, On Growth and Form, by Daniel Brown, was not used in the formal study because it was located at the entrance of the exhibition directly beside the admission desk, and because it incorporated only a very limited set of interactive features. Therefore, participants did not interact with the installation as actively as with the other exhibits. Also, the interactive features were subtler in comparison to the other installations. The interactive non-biophilic installations selected were: Weave Mirror, by Daniel Rozin, and Body Paint, by Mehmet Akten. The piece titled Flow, by Daan

Roosegaarde was not included in the formal study because it was in a separate location in the museum, too far removed from the exhibition. Therefore, the flow of visitors would have been minimal in comparison to the other installations.

Four interactive installations with similar interactive features were selected. These comprised a set of four similar interactive features, which allowed the installations to be compared to one another. These features were (1) movement, (2) sound, (3) evolving patterns, and (4) reflecting components (mirroring the reflection of the participant). 'Movement' was described as a dynamic physical and/or visual change occurring in the installation as a function of participatory interaction. 'Sound' was described as noise, emitted by the installation as a result of participatory interaction. 'Evolving patterns' were defined as repetitive visual pattern that appeared in response to participatory interaction. An example of an evolving pattern would be flickering lights, which light up in a looping sequence in response to participation. 'Reflecting components' refers to a mirror reflection of the participant, as a function of participants' interaction with the installation. The four installations were all capable of emitting movement, and evolving patterns, the two non-biophilic installations could develop reflections of the visitor, and one of the installations emitted sound.

The participants' verbal and non-verbal behaviors emitted in response to each interactive exhibit considered for study were observed. Some seven common interactive verbal behaviors were noted: (1) makes comment about installation to self, (2) makes noises to activate the installation, (3) makes a comment about the installation to someone in the same group, (4) makes a comment about the installation to someone in another group, (5) compares two installations, (6) compares installation to something else, and (7)

makes other various noises. Four common interactive non-verbal behaviors were also noted, namely (1) incidental movement (subtly moving toward the installation, and moving away from the installation), and intended movement (interacting with the installation in a deliberate and physical manner), (2) taking pictures and videos of the installation, (3) examining the installation, and (4) reading about the installation.

The sequence in which the exhibits were observed was determined by their placement in the exhibition. The first piece observed, noted by '1' in Figure 13 below, was Dune, as it lined the entrance corridor. The second piece, labeled '2' in the Figure was Tree, the third (3) was Weave Mirror, and the fourth exhibit (4) was Body Paint. Figure 13 below shows the floor plan with the layout of the observed installations in the 'Interactivity' section of the exhibition. The awkward location of the 'exit' should be noted, as it seemed to disrupt the flow of people within the exhibition as a whole.

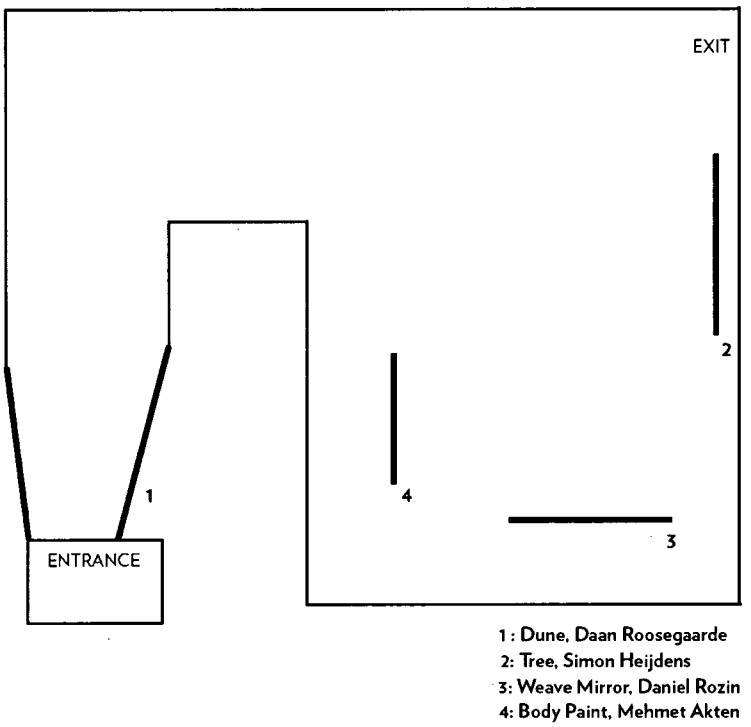

Figure 13. Partial Floor Plan of the DECODE Exhibition (Interactive Installations)

This section presents the four selected exhibits and discusses the interactive features involved in the installations as well as the possible behavioral interactions these evoked.

The interactive installation Dune, by Daan Roosegaarde (2007), shown in Figure 14 below, is composed of hundreds of long reed-like rods, which react in response to visitors' incidental/intended movement and sounds. It may be found at http://www.lumieredurham.co.uk/guide/detail/dune/. The installation references nature in a non-realistic way, this piece is located at the exhibition entrance, and it lines both sides of the entrance corridor. It is a combination of natural themes and technology. The rods resemble natural reeds through their scale, individual form, and physical arrangement. These design elements can be considered biophilic design features as they reference environmental features, natural shapes and forms, and natural patterns. Participants walk through the installation, activating the reeds through their presence. The response of the reeds is not natural, as the tip of each reed is capable of lighting up, flickering, and making a subtle chirping sound in response to participant interaction. The participatory interaction needed to activate the piece varies from the subtleness of participant presence to physical touching and movement through waving arms within and over the reed groupings. The more intense the participant's movements are, the more actively the piece responds through a high frequency in light, flickering light, and sound. It is not instantly clear to the participant how their interaction is contributing to those dynamic changes; this understanding is established through participants' exploratory behavior such as, touching, arm waving, running arms through the reeds, and making noise in order to activate the installation.

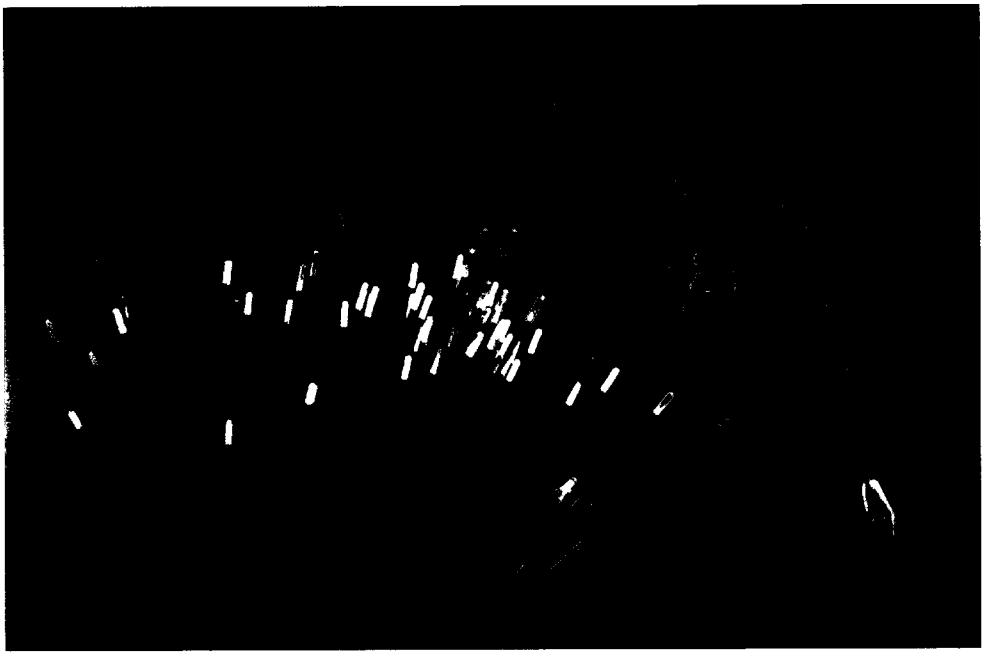

Figure 14. Dune, by Daan Roosegaarde (2007)

The installation entitled Tree, by Simon Heijdens (2005) and shown in Figure 15 below, is a projected digital installation that brings a realistic representation of nature and natural processes, like falling leaves and weather patterns, indoors as interactive elements. The piece is composed of a life-sized silhouette projection of a tree composed of light; the projected tree begins full of leaves at dawn, and moves along with the actual wind outdoors, which is measured by sensors on the exterior of the building. In this way, the piece continuously evolves with the changing weather patterns outdoors. This piece is considered to employ biophilic design elements as it uses a realistic scale, imagery and processes representative of prototypical trees found in our everyday environments. These design elements can be considered biophilic design features as they reference environmental features, natural shapes and forms, and natural patterns. The piece is not instantly responsive; it can be explored and realized through incidental participatory interaction (subtly moving toward the installation, and moving away from the

installation), and intended participatory interactions (interacting with the installation in a deliberate and physical manner). Each time a participant is present, a leaf appears to break off a branch and falls to the ground of the interior environment. The participant can move the fallen leaves by walking through them, patting them with their feet, and kicking them. The more the participant interacts with the ground the more leaves fall from the branches; this creates an interactive pile of leaves below the projected tree.

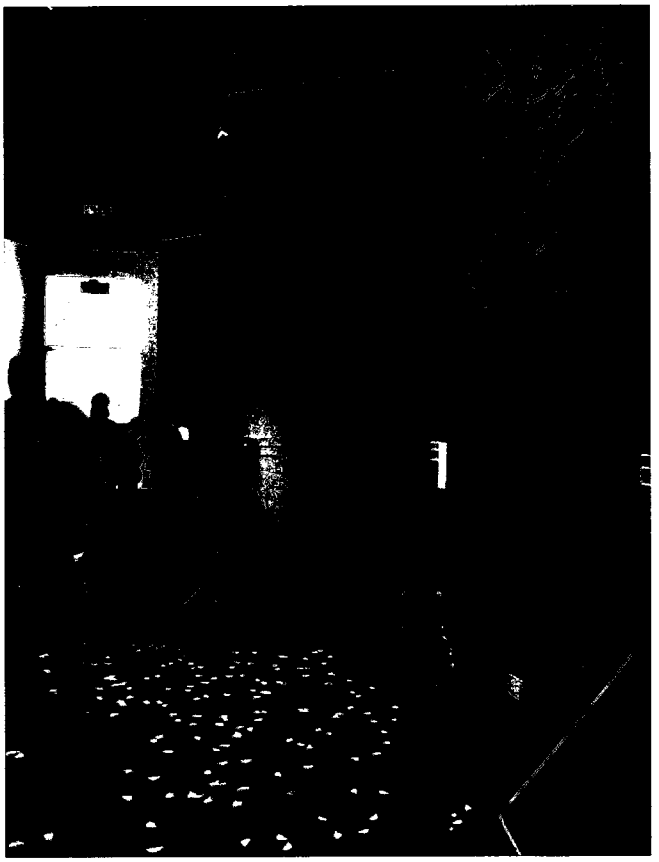

Figure 15. Tree, by Simon Heijdens (2005)

The interactive piece titled, Weave Mirror, by Daniel Rozin (2007), shown in Figure 16 below, involves a screen designed to respond to the presence of a participant. The screen evolves and creates a pixilated reflection of the participant when situated in front of the responsive screen. The technology used by Rozin is integrated in a seamless

way, and not visible to the viewer when interacting with the piece. The technological components are exposed behind the screen. However, visitors can go behind it and observe how it works. The piece encourages exploration and play by responding instantly to human presence and interaction. It has a strong element of surprise as a visitor discovers the various elements it involves. The participants can recognize themselves in the pixilated reflection provided by the piece; they are able to alter their reflection through movement, which can vary from subtle to more intended movement. The screen constantly evolves and adjusts to reveal the reflection of the participant situated in front of it.

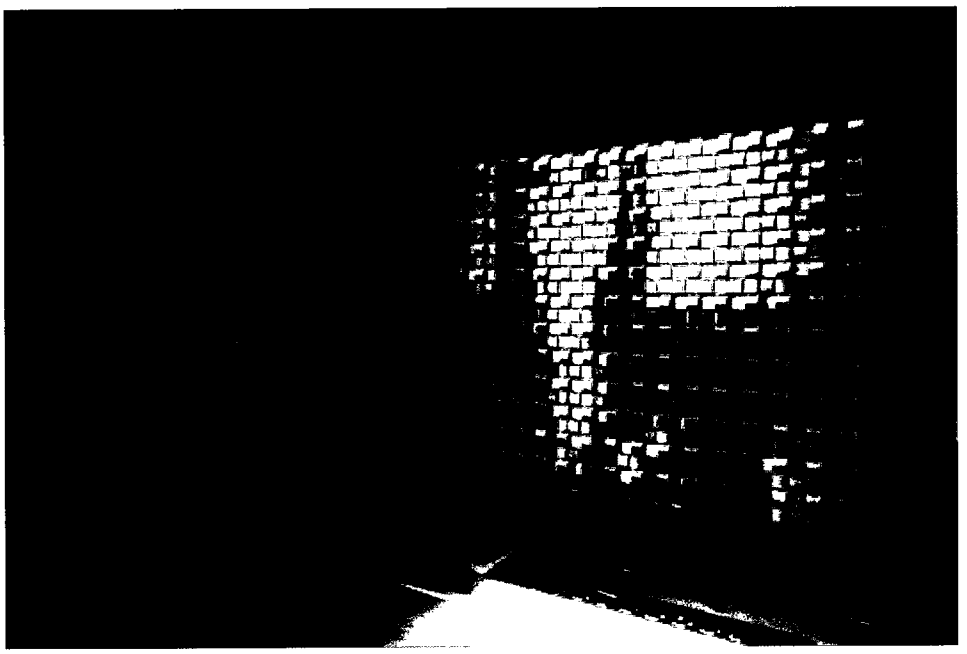

Figure 16. Weave Mirror, by Daniel Rozin (2007)

The piece entitled Body Paint, by Mehmet Akten (2009), shown in Figure 17 below, is composed of a large responsive screen that is activated through participatory incidental and intended movement. The installation enables participants to paint on a virtual canvas with their body through movement. The piece transforms gestures into

visual compositions and patterns. The participation needed is incidental or intended movement. These actions cause a visual representation of paint to appear on the screen. Hidden in the simplicity are layers of subtle details, like different aspects of motion, size, speed, colour intensity, acceleration, and curvature which all have an effect on the outcome. The possible movements are: a stroke, splashes, drips, and spirals. It is up to the visitors to discover these through exploration. The participant is instantly able to see how their participation affects the visual outcome of the piece. Participation is reflected in the piece, enabling the visitor to see their reflection through various types of abstract paint patterns and through their reflected shadow on the screen. The more frequent the participation, the more the piece responds resulting in various paint patterns created through participants' motions.

Figure 17. Body Paint, by Mehmet Akten (2009)

Observational Recordings

Table 1 below shows the possible behaviors that each installation was capable of emitting, indicated by an 'X'. As can be seen, all four selected installations were capable of emitting movement, and evolving patterns, whereas only the two non-biophilic installations could emit reflections of the visitor, and only one of the biophilic installations emitted sound.

Table 1. *Observable installation behavior*

Behavior	Tree – Biophilic	Dune – Biophilic	Weave Mirror – Non Biophilic	Body Paint – Non Biophilic
Movement	X	X	X	X
Sound		X		
Evolving patterns	X	X	X	X
Reflecting			X	X

Table 2 shows the observable participant behaviors for each installation and indicates the number of participants observed who displayed each of the behaviors (N = 5/installation). As can be seen in the Table, there was more non-verbal activity compared to verbal activity both in terms of interactions with the installations and in terms of interactions with other visitors. The behavioral patterns were quite similar amongst the four installations. Across the four installations, participants were responding to all the interactive components that the installations were capable of emitting.

Table 2. *Observable and observed participant behaviors*

Non-verbal behaviors	Tree – Biophilic	Dune – Biophilic	Weave Mirror – Non Biophilic	Body Paint – Non Biophilic
Incidental movement	5	5	5	5
Intended movement	3	4	2	4
Takes a picture/video	2	1	3	3
Examines the installation	1	1	2	1
Reads about the	2	1	1	2

installation				
Verbal behaviors				
Makes comment about exhibit: To self	1		1	1
Makes comment about exhibit: To someone in same group	2	1	2	3
Makes comment about exhibit: To someone in other group				1
Compares 2 exhibits			1	
Compares installation to something else	1	1	1	
Laughing/smiling etc. while interacting with the installation	4	3	4	5

Revisions made to the observation protocol as a consequence of the preliminary study. Several non-verbal behaviors were added. For example, participants often touched the installations while interacting with it. Before beginning the preliminary study, my research on the designers and their work indicated that the basic interactive features and the behaviors to which the pieces would respond. The initial intent was to interview the four designers to obtain further detail about the installations. However, conflicting schedules on the part of the designers did not allow these interviews to occur. This initial research gave rise to the preliminary observation protocol (Appendix 1). During the observations it became clear that slightly different protocols would be needed for each installation. No observational behaviors were removed from the protocol used in the preliminary study. I did note that various incidental and intended movement possibilities were slightly different for each interactive installation. The intended movement possibilities the biophilic installation Dune facilitated was: moves around the space,

waves arms at the installation and runs arms through the installation. The intended movement options of the biophilic installation Tree allow was: moves around the space, waves arms at installation, interacts with ground, and sits down within installation. The intended movement possibilities the non-biophilic installation Weave Mirror facilitated was: moves around the space, waves arms, and make other various hand gestures. Intended movement possibilities that the non-biophilic installation Body Paint enable was: moves around the space, waves arms, make other various hand gestures, and jumps / kicks at installation. The following changes were made to the original protocol, and the additional behaviors can be found in Table 3. These behaviors were included in the formal observational protocols (See Appendix 2).

Table 3. *Additional Participant Behaviors*

Interactive Installation	Additional Behaviors
Dune	Move through the installation
	Move back through the installation
	Move around the space
	Touch the installation
	Run their arms through the reeds
	Activate the piece through sound
Tree	Moves around the space
	Sits down within the installation
	Touches the installation
Weave Mirror	Moves around the space
	Makes various hand gestures
	Touches the installation
Body Paint	Move around the space
	Make various hand gestures
	Jump / kick etc. at installation
	Touch the installation

Formal Study

Introduction

The purpose of the formal study was to assess whether first time visitors prefer interactive installations with biophilic features or with features that do not employ biophilic design elements. The study involved two phases: in Phase 1, viewers' responses to the two types of installations were observed unobtrusively. The frequency of behaviors performed was recorded using the revised observation protocol, and the length of time they spent interacting and viewing each type of installation was measured. In Phase 2, a semi-structured interview was conducted, asking another sample of viewers' questions about their experience with the exhibition.

Method

Participants. In Phase 1, a total of 120 visitors were unobtrusively observed while inspecting one of the four installations (N = 30 for each installation) selected from the preliminary study. In Phase 2, some 30 participants were interviewed for approximately 15 minutes each in individual sessions. They were recruited at the Victoria and Albert Museum as well as from personal contacts. Participants were not paid for their time.

Design. In Phase 1 participants were observed, one at a time, throughout their encounter with the target installations in the 'Interactivity' section of the exhibition (See Appendix 1). Data were collected from 30 visitors, selected at random, at one installation before proceeding to the next, until 30 observations had been collected for each of the four installations. In Phase 2, a different group of participants were interviewed regarding their experience within the 'Interactivity' section of the exhibition (See Appendix 5).

Museum guests, who had viewed the exhibition were approached and asked about their experience within the DECODE exhibition. The principal investigator was situated at the exit of the exhibition, and approached possible participants, as they were about to leave the exhibition.

Materials. Four interactive installations comprising two employing responsive biophilic features and two that do not were selected for observation in the preliminary study. The refined observation protocols were also used. The semi-structured interview comprised seven questions about the participant's interactive experience with the exhibition (Appendix 5).

Procedure. Some 30 observations were made of randomly selected visitors at each target installation. Following the observational sessions, a different group of participants were told of the nature of the study and asked to sign an Informed Consent form before answering the questions in the structured interview (Appendix 3). Upon completion of the interview, participants were debriefed and thanked for their time (Appendix 4)

Results and Discussion

Observational Data

The observation data are arranged into seven categories based on participants' interactions with the installations: (1) amount of time interacting with an installation, (2) documenting experience, (3) educating / further informing, (4) creating collective relationships, (5) enhanced experience, (6) verbal associations, (7) creating / performing. These seven categories are defined below in Table 4.

Table 4. *Observational Categories and Definitions*

Observational Categories	Definition
Amount of time interacting with an installation	Participant interaction time calculated in seconds amongst the four age groups observed.
Documenting experience	Participants took pictures and/or video recordings when interacting with the installations.
Educating / further informing	Participants read the provided description while interacting. Participants touched the installation while interacting. Participants curiously explore how the installation functions.
Creating collective relationships	Participants connected with other participants verbally while interacting with the installations.
Enhanced experience	Participants smiled, laughed and/or chuckled while interacting with the installations.
Verbal associations	Participants verbally referenced real occurrences while interacting with the installations.
Creating / performing	Participants formed incidental and intended movements while interacting with the installations.

The time participants spent at each installation was first calculated. This is followed by a discussion of the instance in which participants were found documenting

their interactive experience. A discussion of the participants' desire to further inform themselves and explore the interactive components of the installation is presented. Collective relationships formed amongst participants while interacting with the installations is additionally discussed. Verbal associations made by the participants in reference to interactive installations is presented. A discussion on creating and performing behavior resulting in a joyful enhanced experience is presented and discussed.

Duration at interactive installation / age group.

Figure 18 below presents the number of observed participants in each of four age groups. The numbers vary because participants were randomly selected, and because different participants were observed at each installation.

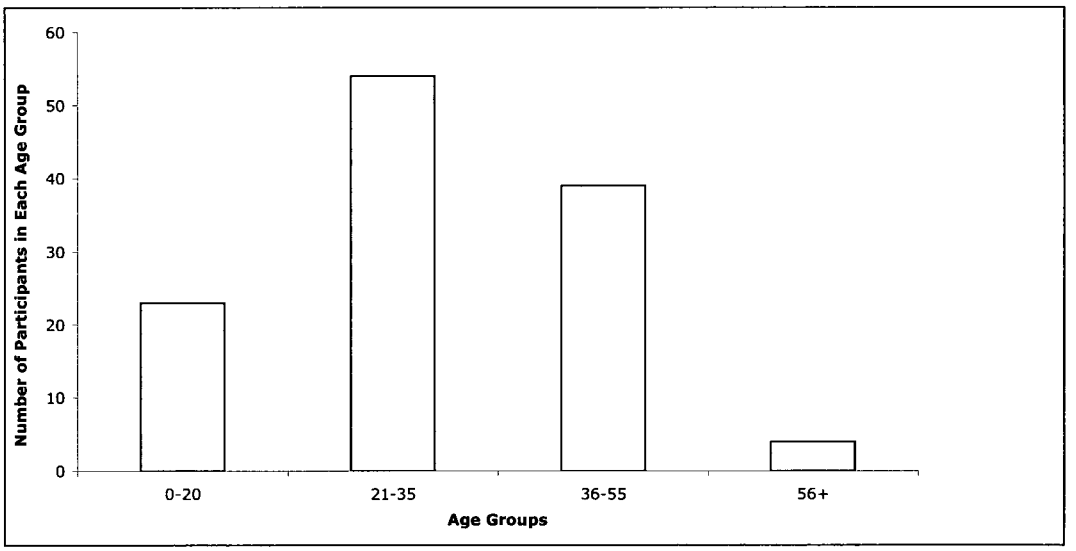

Figure 18. Number of participants in each of four age groups

The majority of the participant's ages fell within the middle age groups (21-35, 36-55), while the fewest participants were found in the youngest (0-20) and oldest age group (56+).

Figure 19 below displays the number of participants observed at each of the four interactive installations. Unequal distributions of ages were found among the four interactive installations. Most participants' fell within the middle age groups observed (21-35, 36-55) at all four installations. The fewest number of participants were in the oldest age group (56+) in which no participants were observed interacting with the installation entitled, Body Paint. The number of participants in the youngest age group (0-20) is similar in both the non-biophilic installations, while the number of participants differs in both biophilic installations.

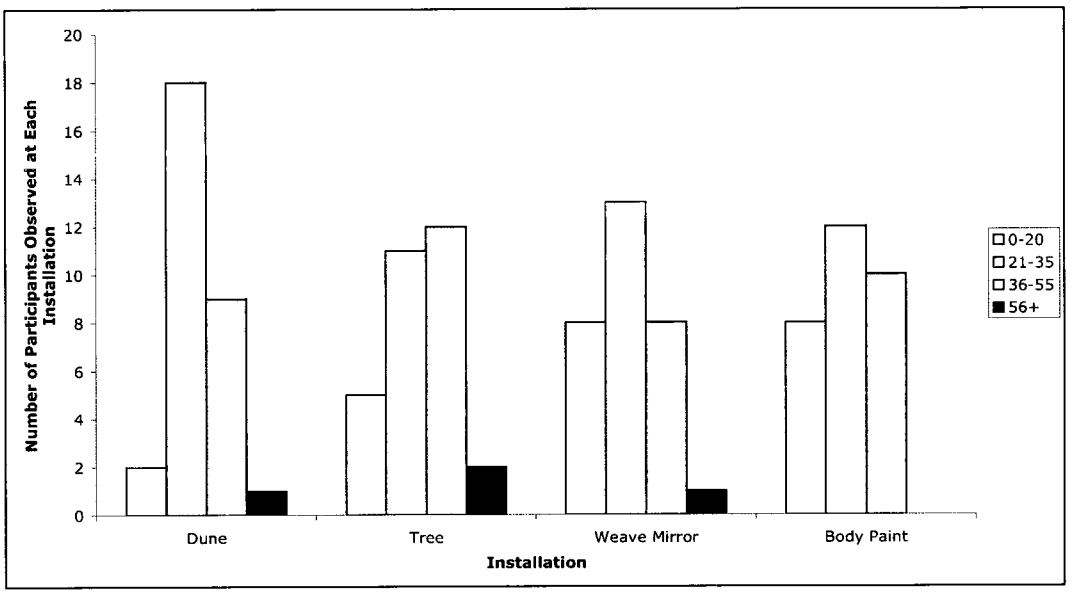

Figure 19. Number of Participants Observed at Each Installation

Figure 20 below presents the average time (in seconds) observed participants spent interacting with the biophilic interactive installations (56 s), compared to the non-biophilic interactive installations (34 s). This may suggest that they were more engaged with installations that involved biophilic elements. A one-way ANOVA was conducted comparing the interactive biophilic installations to the interactive non-biophilic installations. The analysis revealed that the average duration for biophilic (M = 55.60,

SD = 31.27) was significantly higher than the non-biophilic (M = 33.27, SD = 25.92), F (1, 119) = 18.14, p < .001.

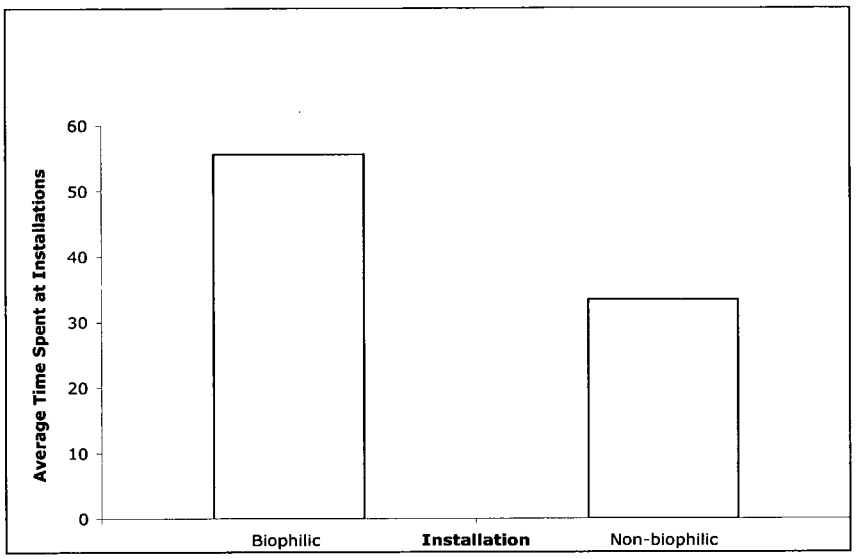

Figure 20. Average Time Spent at Biophilic and Non-Biophilic Installations

Figure 21 below presents the average time participants spent at each of the installations. Although more time was spent interacting with the biophilic installations than the non-biophilic installation, the average time varied considerably from one installation to the next. It is important to point out the difference between the two biophilic installations as the participants spent more time interacting with the biophilic installation, Tree, when compared to the other biophilic installation, Dune. Participants spent the most time interacting with the biophilic installation Tree (70 s), followed by the non-biophilic installation Body Paint (47 s), then by the biophilic installation Dune (N = 41 s), and participants spent the least amount of time interacting with the non-biophilic installation Weave Mirror (N = 20 s). A one-way ANOVA was conducted to determine if the participants' response times were significantly different. The results showed that the amount of time spent interacting with the installations differed significantly, F (3, 119) =

19.92, $p < .001$. A Tukey Post Hoc comparison showed that the average duration in the non-biophilic installation Weave Mirror was significantly lower, and that the average duration in the biophilic installation, Tree was significantly higher than each of the other three groups, all at the $p < .01$level. The biophilic installation, Dune and non-biophilic installation Body Paint were both higher than the non-biophilic installation Weave Mirror ($p < .05$); both were also lower than the non-biophilic installation Body Paint ($p < .05$), but these two did not differ significantly from each other ($p > .05$).

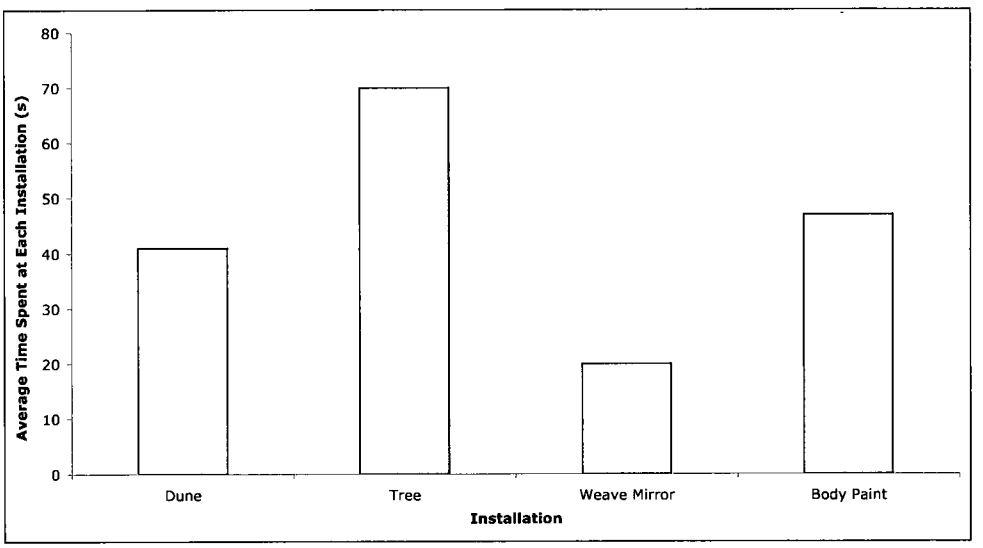

Figure 21. Average Time Spent at Each Installation

Figure 22, below shows the average amount of time each age group spent interacting across all the installations. Participants in the youngest age group (0-20) spent the least amount of time interacting with the installations (M = 24 sec), followed by the participants in the 21-35 age group (M = 37 sec), then by the participants in the 36-55 age group (M = 59 sec), and finally, the participants in the 56+ age group spent the most time interacting with the installations (M = 94 sec), especially with the biophilic installation, Tree. As mentioned earlier, no participants in the oldest age group were observed interacting with the Body Paint installation. Taking all the four age groups together,

participants spent the most time interacting with the biophilic installation Tree. Due to the large differences in the group sizes formal statistical comparisons between condition (biophilic/non-biophilic) as a function of age could not be conducted. However, the dataplot in Figure 22 reveals the average amount of time participants spent across the four installations.

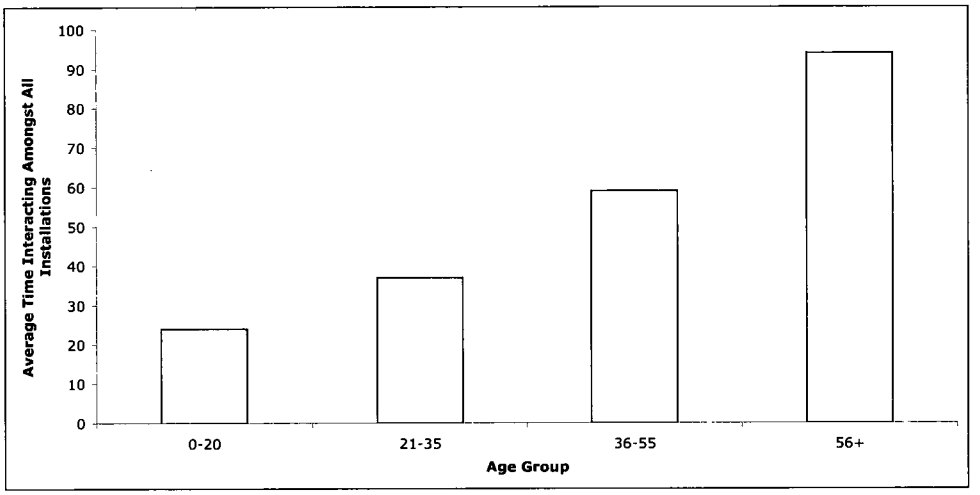

Figure 22. Average Interaction Time Across the Installations

Figure 23 shows the average amount of time participants in each of the four age groups spent at each installation. Normally it would be expected that the first installation (Dune) in the exhibition would attract the viewers' attention, and ultimately they would engage with the installation longer than the subsequent ones, this did not occur in this study. However, there was no such primacy effect in the present data. This can be explained by the participants being unfamiliar with interactive installations. The installation Dune was located at the entrance of the exhibition, beside the admission desk; participants possibly felt uncomfortable interacting with the installation in the view of awaiting exhibition guests. Participants were also possibly unaware which pieces were interactive in the exhibition.

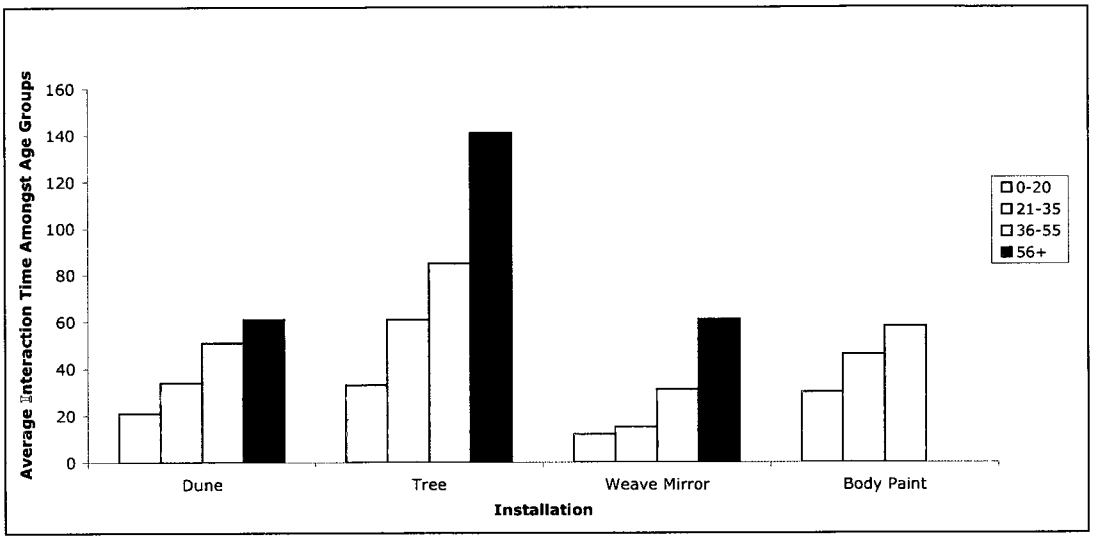

Figure 23. Average Interaction Time Amongst Age Groups

Documenting experience, educating / further informing.

Table 5 shows that more participants who interacted with the non-biophilic installations documented their experience by taking pictures or videos (N = 46) much more often than viewers observed interacting with the biophilic installations (N = 22). In both non-biophilic exhibits, participants were able to see their own reflection within the work, and the installations responded immediately to the participants' interaction. Participants who took pictures of their reflection in the non-biophilic installations apparently created mementos of their experience.

Table 5. *Documenting Experience, Educating / Further Informing*

Behavior	Dune	Tree	Weave Mirror	Body Paint
Takes pictures / videos of installation	8	14	23	23
Reads the provided description	22	26	15	14
Touches the installation	19	21	1	3
Examines piece (curiously explores how it works)	5	12	18	11

Table 5 also shows that participants were more inclined to read the descriptions of biophilic (N = 48) than of non-biophilic (N = 29) installations, suggesting that they were more interested in the biophilic installations. The participants' age did not play a significant role in encouraging them to read the description. A possible reason for this could be that the functions of the biophilic installations were less immediately clear to the participants and that they therefore needed either to be explored through interaction or to read the description of these. This time spent reading was included in the time spent at each installation; this could partly explain why participants spent longer at the biophilic installation, Tree compared to the non-biophilic installations. Evidently, this inspired participants' curiosity the most. By contrast, the interactive elements were more immediately responsive and clear to the participants when interacting with the non-biophilic installations.

Table 5 additionally shows that more participants touched the biophilic more often (N = 40) than the non-biophilic (N = 4) installations. Both non-biophilic interactive installations were flat screen based installations, which apparently did not encourage participants to touch the components. By contrast, participants interacted with the Tree piece by touching the life-sized tree truck projected on one of the exhibition walls. The arrangement of Dune along the exhibition's entrance corridor encouraged participants to touch the responsive elements while interacting. The long rods extended from the ground and reached the arm level of participants. The rods referenced reed-like forms found in natural settings through their scale; this element encouraged participants to interact intimately with the installation through touch.

The findings displayed in Table 5 also show that participants interacting with non-biophilic (N = 29) installations examined and explored how the instillations functioned a similar way slightly more often when compared to the biophilic installations (N = 27). The reflecting components (mirroring the reflection of the participant) found in both non-biophilic installations, or a novelty effect may explain this curiosity. They explored the functionality of the piece, mainly by walking behind the screen, closely approaching the screen based installations, and looking for the projecting elements involved in the exhibits. Participants weren't just interested in their own reflection, which does cast doubt on the interpretation of why more participants took videos/pictures of their reflections when interacting with the non-biophilic installations. Participants examined the Tree installation by looking for where the image was projected, and examined the Dune installation by looking closely at the material and how the installation was attached to the ground. When looking at the installations individually in Table 5, it is evident that fewer participants examined the installation Dune, when compared to the other three installations in the study. As speculated earlier, one reason for this could be the fact that the installation was located at the entrance to the exhibition.

Creating collective relationships.

Collective relationships were defined by participants connecting verbally with another participant while interacting with the installations. The findings show that participants in groups make more comments to members of the same group when interacting with non-biophilic installations (N = 32) than with biophilic installations (N = 20). Grouped participants can be defined as more than one participant who visited the exhibition together. Some 20 participants in groups interacted with the Weave Mirror

(non-biophilic) of whom 16 made comments to members of the same group. A total of 18 grouped participants were observed interacting with the Body Paint (non-biophilic) installation, of whom 16 made comments to members in the same group. Similarly, some 16 grouped participants interacted with the Tree (biophilic) installation; they all made comments to members of their own group. Finally, some 17 participants in groups interacted with the installation entitled Dune (biophilic), but only 4 of them made comments to members in the same group while interacting. Participants may have made fewer comments while interacting with the Dune installation because of its location, which was directly at the entrance of the exhibition and within view of the registration desk. Participants were thus just beginning to discover the pieces in the exhibition and may have had no firm expectations yet as well as possibly being shy with regards to their own interactive behavior. Once they saw how other visitors were interacting with the installations, they may have felt less inhibited, becoming eager to explore the installations through interaction. Additionally, the installation Dune was not immediately responsive to participation, and explorative behavior was needed from the participant in order for them to detect how the installation was responding to them. Many visitors may thus have missed the fact that the installation was, in fact, interactive.

These results show that interactive installations can encourage and foster shared experiences amongst participants, specifically the non-biophilic installations. The installations encouraged participants to connect and be playful with other participants, helping and showing each other how to interact with the exhibits.

Few participants who visited the exhibition alone commented to someone in a group (biophilic N = 4; non-biophilic N = 4). None of the single participants (0/13)

observed interacting with the Dune (biophilic) installation made comments to others. By contrast, the (4/14) single participants observed interacting with the Tree (biophilic) installation all made comments to other participants. Only (1/10) participant observed interacting with the Weave Mirror (non-biophilic), made a comment to another participant, and (3/12) participants who were observed interacting with the installation, Body Paint (non-biophilic), made comments to participants in another group.

These results therefore provide some evidence that interactive installations can promote social connections between strangers through shared experience. Although this did not occur very often in any of the installations, it is unusual for lone participants to talk to others in a museum setting.

Enhanced experience.

Findings for the fourth category concerning enhanced experience reveal that participants interacting with biophilic and non-biophilic interactive installations were joyful during their interactions. Joy was determined by observing participants who smiled, laughed, and chuckled while interacting with the four installations. These data shows that interactive components in installations enhance experience, encouraging participants to exhibit behaviors not normally expected in a museum.

Findings in this category additionally show that participants interacting with both the biophilic installations (N = 26) and non-biophilic interactive installations (N = 25) made comments to themselves. Examples of comments made while participants interacted with the installations are: “Ohhhh, wow”, “Cool”, “Ahhhh”. When looking at the interactive installations individually it should be noted that a total of 7 participants made comments to themselves when interacting with the biophilic installation Dune,

whereas a total of 19 participants made comments to themselves while interacting with the Tree installation. When looking at the non-biophilic installations, a total of 12 participants made comments to themselves when interacting with the Weave Mirror installation, and 13 participants made comments to themselves when interacting with the Body Paint installation.

Verbal associations.

Verbal associations were defined as participants verbally referencing real occurrences while interacting with the interactive installations. More participants made verbal associations when interacting with the biophilic installations (N = 13) than with the non-biophilic installations (N = 9). These results show that interactive installations that reference natural features that exist in our environments encourage participants to form associations to these features. This notion is particularly true when looking at the interactive Tree installation, which references nature in a realistic way. An example of the verbal associations made by participants when interacting with the Dune (2/13) installation: "It's like long grass", and with the Tree (11/13) installation: "It's like kicking a real pile of leaves, it's blowing like a tree outside". Examples of the verbal associations made by participants interacting with the Weave Mirror installation: "It's like a mirror, that responds", and with the Body Paint installation: "It's like painting like Jackson Pollock". Participants made fewer verbal associations when interacting with the non-biophilic installations. Perhaps these novel non-biophilic installations just didn't remind participants of anything in particular, whereas it takes less imagination to reference realistic representations of nature to real nature.

Creating / performing.

The sixth category, (creating / performing) involves two sections (incidental and intended movement). The frequencies of these incidental and intended movements were observed and calculated for each of the four installations, and can be found in Appendix 3. The incidental movement possibilities for the biophilic and non-biophilic installations facilitated similar incidental movements, namely moving towards or away from the installation. The arrangement of the biophilic installation Dune forced participants to move through the installation, allowing them also to move back through the installation.

Participants made the most frequent incidental movements when interacting with the biophilic installations, specifically with the installation, Dune. Dune does, however, facilitate more incidental movements compared to the other 3 observed installations. The installation lined the entrance corridor, which forced participants to enter into the installation, and ultimately led participants into the rest of the exhibition. The arrangement of the other 3 installations did not facilitate this incidental movement.

Participants made the most frequent intended movements when interacting with the non-biophilic installations, specifically with the installation, Body Paint. Body Paint does however facilitate more incidental movements compared to the other 3 observed installations.

The findings from these observations show that the interactive features in the installations encourage exploratory play and performance in the participant; the effects of their interactions are clear and visible in the exhibit. The participant discovers that they are capable of contributing to the outcome of the installation through their interactions.

This element promotes incidental and intended movements, as the installations respond to participant.

In summary, it was observed that participants amongst all observed age groups spent more time interacting with the biophilic responsive installations, specifically the Tree installation, when compared to the non-biophilic ones. It was observed that as the participants age increased so did the length of time they spent interacting with the interactive installations. It was also observed that the installations encouraged participants to document their experience while interacting, specifically the non-biophilic installations. Also, it was observed that the interactive installations influenced participants to read the provided descriptions and also touch the installations while interacting, specifically the biophilic installations. Both biophilic and non-biophilic interactive installations also created curiosity in the participants as they were observed exploring how the installations functioned. It was recognized that the installations fostered shared and joyful experiences amongst participants, as it was observed that participants verbally connected with others throughout their interactive experiences. Additionally, the interactive installations encouraged verbal associations of references and memories, which were observed. Lastly, it was observed that participants formed incidental and intended movement in response to the interactive components of both the biophilic and non-biophilic installations.

Structured interview data.

The structured interviews were conducted after completing the observations. Interview results were arranged into four categories. One concerned the participant's preferred interactive installation, why they liked it the most and how it made them feel,

and the second, their least preferred installation. The third category explored the type of installations people would prefer for everyday applications. The fourth category referred to participants' general comments towards the exhibition as a whole. Participants were randomly selected for the semi-structured interview sessions, the age groups participating in the study where not controlled. The distribution of participants in the four age groups is shown in Table 6 below. However, it should be noted that the number of interviewees in the two oldest groups was approximately the same number as in the two youngest groups when added together.

Table 6. *Number of Interviewees in Each of the Four Age Groups*

0-20	21-35	36-55	56+
2	14	9	5

Most preferred interactive installation.

The findings reveal that interviewees amongst all four age groups preferred the non-biophilic interactive installations (N = 19), compared to the biophilic interactive installations (N = 11). When looking at the participants as a whole, the data show that the non-biophilic installation Weave Mirror was the most preferred (N = 12), followed by the biophilic installation titled Tree (N = 10), additionally (N = 7) preferred the non-biophilic installation Body Paint, and (N = 1) preferred the biophilic installation titled Dune. This lack of interest in the installation Dune may be due to the placement of the installation at the entrance of the exhibition, which may have contributed to a lack of visitor expectations, and participatory shyness. The entrance location of this installation was not sensible as Dune relies on exploratory behavior. Participants possibly would have interacted with the installation more if it were located towards the middle or end of the exhibition where the other 3 installations were located.

The findings for the preferred installations for each of the four age groups reveal that all 16 people falling into the younger age groups (0-20, 21-35) preferred the non-biophilic interactive installations, whereas 11 of the 14 participants falling into the two older groups (36-55, 56+) preferred biophilic interactive installations. This is consistent with the findings from the observational study, where the younger participants (0-20, 21-35) were more engaged with the non-biophilic installations, while the older participants (36-55, 56+) were more engaged with the biophilic installations.

The participants in the younger age groups specifically preferred the non-biophilic installation entitled Weave Mirror. They explained that the installation was immediately engaging, aesthetically pleasing, and that they enjoyed the exposed responsive components. Participants in the younger age groups (0-20, 21-35) preferred interactive experiences that establish an immediate understanding and clarity to how they are affecting and contributing to the overall installation. One participant in said: "I really liked the movement, how the whole piece would move and change according to my movements. It was beautiful and aesthetically pleasing to me. I loved how interactive the piece was, and how immediate it was, it instantly responded to me." Another participant said: "I thought the exposed mechanism components were really intriguing, I liked being able to see how it worked at the back of the piece, it definitely was an added value, an element of surprise. I'm just a lover of things that aren't bright and kind of in your face, things that aren't garish. I found this piece to be quite subtle and elegant." The younger age groups are more immersed in digital technology and are thus generally familiar with communications, media, and digital technologies. They may therefore have different expectations of the digital technology in the interactive work than the older people. They

prefer the installations that display their reflection, respond immediately to their interactions, and clearly understand how they are contributing to the installation.

Participants in the older age groups (36-55, 56+) preferred biophilic interactive installations when choosing from the four installations, especially the Tree. They explained that they enjoyed the imagery, the use of real occurrences in nature, the responsive elements, and juxtaposed components. For example, as one participant said, "It was like there was a real tree in the exhibition, I loved the link to the exterior weather patterns, the subtle movement in the branches and the kind of randomness it has with the falling leaves. That aspect really appealed to me, I guess the realness opposed to the artificial. I felt kind of consumed by it, totally drawn into the imagery." Another participant explained, "It was an impression of nature, I liked how nature is translated through the use of computer technology manipulations. It's interesting to see how designers use digital computer technology in a way to create pieces representational of organic life. This digital technology is used as a tool to create something that appears to be quite organic to the audience. The contrast and tension that is created when these two themes meet is quite interesting to me. I mean it's technology based in there, it's so nice to see something that reflects nature."

When participants were asked how they felt while interacting with their preferred installation, a typical response for both non-biophilic installations was that it was 'playful', whereas words like 'calm' and 'inspired' were used more for the Tree.

Least preferred interactive installation.

When asked about the least liked installation, nine of the 30 participants chose the Dune. Another eight chose the Body Paint, followed by seven who chose the Tree, and

the remaining six participants liked the Weave Mirror the least. Data for each of the four age groups reveal that (N = 11/16) of the younger participants least preferred the biophilic interactive installations, whereas (N = 9/14) of the older participants least preferred non-biophilic interactive installations.

When the participants in the two youngest age groups were asked why they least preferred the biophilic installations, they explained that the biophilic interactive installations were not immediately responsive to their interactions. They felt that the pieces were too subtle, and they didn't clearly understand how they themselves were contributing to the installations. When referencing the biophilic installation, Dune, one participant explained, "I found that I didn't get an instant response from the piece, I had to move around quite a bit to get a response from it, I really had to work at it." Another participant recalled the Tree installations and said, "It was because I wasn't really aware how it was responding to my interaction, or if it even did, where with the others I was immediately aware of how my interaction with it affected it, and knew how the pieces were responding to me. A possible explanation for this finding could be that participants from the two youngest age groups are from generations accustomed to 'instant gratification'. These participants are part of the Generation Y and Z, which are often referred to as 'digital natives' (Prensky, 2001). Many individuals of this generation have been born completely within mass technology and have had a life-time use of media technologies and communications such as the World Wide Web, instant messaging, text messaging, mobile phones, MP3 players, and YouTube (Prensky, 2001).

The two older age groups said they least preferred non-biophilic installations because they found the non-biophilic installations too aggressive, that they became un-

engaging over time, and that they lacked depth. One participant said, "I think it was just too in your face, it was too immediate, I got bored quickly and I just wasn't engaged in the piece. It seemed more suitable for children, but it did get you moving." Another participant explained, "The colors put me off a bit, they were too bright, I found it all a bit too messy for me, I didn't like it very much, the piece almost seemed to demand interactions."

When participants were asked how they felt while interacting with their least preferred installation, they typically did not know what to respond for both biophilic. When challenged, they used words like 'confused', 'not challenged', 'under-whelmed', and 'unengaged'.

Preferred interactive installations for everyday applications.

When asked about everyday applications of the installations, the findings revealed that the majority (23/30) of participants chose the biophilic installations. This is interesting as the majority of participants said they preferred the non-biophilic pieces, when asked which installations they prefer within the exhibition context.

The youngest participants falling in the (0-20) age group saw the non-biophilic interactive installations as the most applicable to everyday environments. The other age groups, taken together, saw the biophilic installations as the most applicable to everyday environments compared to the non-biophilic installations. The results vary when looking specifically at which biophilic interactive installation participants saw as applicable to everyday settings; (6/30) chose the installation Dune, while (17/30) chose the installation Tree.

Responses covered specific environments where the installations could be integrated (public, domestic, and institutional environments), and also related to a variety of individuals who could benefit from these interactive installations (the mature demographic, people with disabilities, children). The majority of participants believed that the interactive installations could be applicable and beneficial if applied to public environments. One participant said, "I think they would work best in public areas, this could distract people from their daily routine and allow them to enjoy a different kind of experience. I noticed people were smiling and laughing while experiencing the pieces, the exhibition had such a joyful atmosphere." Participants also suggested everyday interior environments, as settings where interactive installations could be integrated. One participant revealed: "I'm an artist and I create interactive spaces for people with disabilities, so in fact I work with interactive technology quite a lot, so of course, I could, yes absolutely! In all interiors, in all environments, people with disabilities live in these god awful dull sensory environments, which have little meaning in them, and something much more creative would just be wonderful, and would be perfect to enhance their day to day environments. I think a lot of people could benefit from these pieces integrated into their personal environments, like their homes and public areas, like their day centers. I work with people with all sorts of disabilities, especially learning disabilities, particularly autism and mental health disabilities, and also physical disabilities. I can imagine them really enjoying these pieces it's something joyful, and aesthetically beautiful that they can be a part of. I think the pieces have the possibility to really help people".

Several participants additionally suggested that the interactive installations could be applicable and advantageous to institutional environments. One of these participants said, "I think all of these interactive pieces would work best in a doctor's office, or hospital waiting room, those places can be boring and stressful while you're waiting, so these sorts of pieces could affect them while they wait. I think this would make patients more cheerful and remove stress, maybe improve their mood. I guess it would take the patients mind off of the current situation and engage people in the work."

Participants' general comments towards the exhibition.

Participants provided descriptive answers when communicating their general comments towards the exhibition as a whole. Participants discussed digital and interactive design focusing on the large-scale installations specifically involved in the interview.

Participants spoke about the interactively based installations integrated within the context of the V&A museum, which usually houses static decorative arts and design pieces. One participant explained, "I found it interesting that digital technology was brought into a decorative art museum, this show really represents our digital generation and how digital technology is becoming a common medium in creative practices like design, and art. It's using digital technology and manipulating it in an organic manner, representing itself in forms of various materials, forms, patterns, colors, imagery, basically it's digital technology as decoration." Participants also spoke about their experience at the exhibition as a new and exciting experience. One participant said, "The interactive pieces were very interesting and engaging to me. It was a very new and exciting responsive experience mediated through the digital technology. It was like

something I had never seen before." Participants additionally spoke about digital technology as a contemporary medium used in decorative art and design. A participant said, "This exhibition really showed the capabilities of this generation. Digital technology is such a part of their daily lives, it is intuitional for them to use and create with it. I think it's also a new way of looking at decorative art, it's moving, it's vibrant, emotional, and lively, very of the moment." Participants explained that the interactive installations in the exhibition promoted collective social relationships, play amongst the participants, and encouraged a joyful experience. One participant said, "It was really great how it brought people together, I guess perfect strangers were brought together, people were helping each other and laughing together, the exhibition really allowed participants to connect and share an experience together through images, activities and interactions, in that sense it was really special."

General Discussion

Overview of Main Findings

The following section provides an overview of the main findings from the above results.

The apparent relationship between viewing time and age shows that participants, on average, spent longer interacting with the biophilic than with the non-biophilic interactive installations. This suggests that participants were more engaged with installations that involved biophilic elements. This notion supports the initial assumption of this thesis, which predicted a preference for biophilic interactive installation based work when compared to non-biophilic interactive installations.

Data also revealed that younger participants spent less time at all the installations, with a monotonic increase in age and viewing time. That is, the older the participant was, the longer they spent looking/interacting with the installation. As the interviews were only conducted at the end of the exhibition, viewing times were not available for that group of participants. A relationship was, however, evident between the preferred interactive installation and age in the structured interview data.

Responses in the semi-structured interviews did match what other participants did as noted in the observational sessions. The interview findings showed that, on average, more than one half of the participants preferred non-biophilic interactive installations when compared to biophilic interactive installations. As with the observations, participants in the younger age groups predominantly preferred the non-biophilic interactive installations, while the older participants preferred the biophilic interactive installations. However, the sample size was not balanced for age in the observational

sessions and semi-structured interviews: more young than older people participated in the study, which skewed the research findings.

Findings from the semi-structured interviews show that participants could imagine biophilic installations integrated into everyday environments more than non-biophilic. This finding is interesting as most participants in all the age groups said they preferred non-biophilic installations within the exhibition context. Therefore participants prefer to see biophilic installations integrated in everyday environments when compared to non-biophilic installations despite the preference of the younger participants for the non-biophilic installations in the exhibition per se. This suggests that the preferences of those participants varied as a function of context: in the longer term, biophilic installations were preferred by this audience, whereas in the immediate context, the fascination with the non-biophilic installations were seen to be more interesting. Therefore when installing permanent installations, these should be biophilic.

Findings from the observations and interviews show that the older participating age groups said that they preferred biophilic interactive installations and were additionally engaged with the work for longer periods of time when compared to the non-biophilic interactive installations. Older participants said they felt calm while interacting with the biophilic interactive installation entitled, Tree. Younger participants said they felt playful while interacting with the non-biophilic interactive installations. Non-biophilic installations could be integrated into environments where individuals would benefit from an increased level of stimulation created by dynamic novel components, resulting in physical, and social activity performed by the participants. Examples of these

environments are: mundane public spaces, daily waiting periods, childcare facilities, rehabilitative spaces, special events, and exhibition settings.

Findings from observations show that the non-biophilic installations involved in this study promote imaginative exploration amongst the participants. Participants become experimental as they have the ability to interact with the installation, connect with other participants, or just watch others participating. The interactive experience can change depending on how a group of users participate, whereby the rules are learned and are completely dynamic and evolving. Participants verbally connected with other participants when interacting with both the biophilic and non-biophilic installations, specifically when interacting with Tree and Body Paint. Clear communication between users and the installation appears to foster at least some social engagement. As users are able to manipulate their experience through interaction, they can also create new types of connections with each other. This indicates that the nature of the interaction should be considered when designing for specific purposes. For example: environments in which people would benefit from collegial relations such as travel terminals, and waiting rooms, may make use of socially engaging interaction.

Findings from the interviews revealed that participants believed that it was very innovative to use the world's largest decorative arts museum as the venue for a contemporary exhibition full of dynamic and digital pieces. These findings also reveal that participants see digital technology as a contemporary medium used in decorative art and design. Findings for the interviews show that participants thought the work encouraged social connections, and also supported a joyful feeling in the participants interacting with both the biophilic and non-biophilic installations. This indicates that

interactive installations of any sort (biophilic or non-biophilic) would be well received in contemporary interiors, especially where it is important to convey a message of being progressive and innovative.

Implications and Contributions of the Study

This exploratory research revealed the potential benefits of interactive installations that employ biophilic design elements. Through the use of research methods consisting of ethological observations and semi-structured interviews, it was apparent that interactive installations enhance experiences through interactive components promoting curiosity, physical activity, social interaction, and joy in the participants. These findings show that older people enjoy the biophilic interactive installations, and younger people enjoy non-biophilic interactive installations in the short term, and that all would enjoy biophilic installations in more permanent environments. The study therefore sheds light on specific environments that are addressed at the end of this section, which could benefit from non-biophilic and biophilic interactive installations.

The findings support the research on biophilic design and dynamic interactive installations previously reviewed in the literature. The findings from this study are practically driven and have the possibility of being applied to interiors with the goal to enhance environments through the use of interactive biophilic design specific to the user. Age and preference for biophilic or non-biophilic interactive installations is a contributing element to the existing theory surrounding the two types of installations presented. Age was not a consideration in the literature reviewed, therefore presenting future opportunities in this area of research.

Empirical research appears scarce on the interaction with new media technologies that would influence the design of interior spaces. Findings from this study contribute to this area and reveal specific variables: age, and the appropriateness of biophilic and non-biophilic interactive installations for different environments. Research findings support the literature review research on interactive installations created with digital technology; interactive components have the potential to enhance experiences through novel and biophilic elements.

Through the research method it was apparent that interactive installations enhance experiences through interactive components promoting curiosity, physical activity, social interaction, and joy in the participants.

Limitations of the Study

There are several limitations that need to be acknowledged and addressed regarding the present study. The first concerns the distribution of the participants' ages. Age was not an initial consideration for the study. The participants were selected at random, making it impossible to control for age. Therefore, the number of representatives in each of the four age groups observed and interviewed was unequal. However, the results suggest that the participants' age may play an important role both in terms of preference, and in terms of time spent interacting with biophilic and non-biophilic interactive installations. Per chance, the majority of participants fell within the 21-35 age group, which is also the researcher's age group. The researcher may inadvertently have been somewhat biased towards this particular age group, as it is easier to approach someone in the same age group. For these reasons, age should be controlled for in a future study of this kind.

Limitations to two of the questions asked in the structured interview became evident following the study. Two questions were included in the structured interview, which may have subtly encouraged the respondent to answer these in a particular way. These questions were asking the participants how they felt while interacting with their preferred and least preferred interactive installation, but rather than allowing participants to voice their feelings freely, lists of five feelings were provided as options to choose from. An option of 'other' was provided in the provided list of feelings; several participants chose this an option when the feeling specific to their experience was not listed, participants were probed to specify how they felt. An additional limitation was the lack of interview questions with regards to the participant's overall exhibition expectations, total time frame at the exhibition, and general knowledge of the exhibition prior to their attendance.

The exhibition design, specifically the layout of the exhibition in the interactivity section, was another limitation to the study, although this was beyond the control of the researcher. The installations were arranged relatively close to each other within the contained exhibition space. The responsive components in the interactive installations were highly stimulating and encouraged interest and activity in the participants. The layout also encouraged large numbers of viewers to gather around the individual installations. This aspect made it challenging to conduct the observational sessions and to accurately to observe the incidental and intended behaviors formed by the participants in response.

The selection of the biophilic installation Dune was an additional limitation to the study. The location of this installation at the entrance of the exhibition was not initially

recognized as a potential problem when selecting the interactive installations for the study. The participants were shy at the outset of going through the exhibition, possibly unaware that components of the installation were interactive and/or possibly uncomfortable with the interactive components considering the location of the installation beside the administration desk. This might have affected the results in an undesirable way, as the two interactive biophilic installations yielded varying results. This limitation did however reveal that the arrangement of the installations could contribute to the organization of viewer circulation patterns in exhibition settings. This is particularly evident when looking at the arrangement of Dune. This biophilic installation lined the entrance corridor, which drew the viewers into the center of the exhibition.

Future Research

The findings as well as the limitations of this study bring forth interesting possible avenues for future research. Future studies could benefit from a larger sample size, a controlled distribution of age amongst, and an equal amount of years amongst the four participating age groups in both the observational sessions, and semi-structured interviews.

The use of the same thirty participants throughout the observation and structured interviews could also strengthen the findings and ensure that the data from the observational sessions and structured interviews correspond. However, it would be difficult to be inconspicuous if the researcher were to follow participants throughout the exhibition and then interview them. A solution could be to use four researchers instead, with one researcher placed at each interactive installation for the observational sessions, that way the researcher could observe participants unobtrusively.

Future studies could benefit from the use of participants with varying cultural backgrounds. In this study, the researcher did not take note of the participants' cultural background in either the observational and/or interview sessions. A comparative study looking at how individuals from various cultural backgrounds react and interact with responsive installations would be beneficial. It would also be interesting to look at how different cultures respond to interactive experiences involving biophilic design elements.

The approaches, elements and attributes (p. 24 – 27) introduced biophilic design variables for designers to consider for future work possibilities with the integration of interactive installation-based design.

Need for Interdisciplinary Collaboration

There is a need for interdisciplinary collaboration when discussing the concept of responsive biophilic design, which draws from several fields: biophilic design, environmental psychology, and interactive technology. The approaches, elements, and attributes of biophilic design, and the empirical studies on the relation between nature and well-being, along with digital technology and sensors previously discussed in the literature review establish and contribute to the concept of responsive biophilic design.

There is an additional need for interdisciplinary collaboration when producing empirical studies similar to this one. The interdisciplinary approach to this research study contributes to the field of biophilic design through the use of a qualitative method. It explores variables and considerations for designers of interior spaces and provides credible empirical evidence, which strengthens the field of biophilic design.

Creative endeavours in interactive installation design are inherently interdisciplinary (Peacock, 2001). Large-scale interactive installations require

interdisciplinary teams of specialists from various disciplines to collaborate in the pursuit of developing and applying them.

Interactive installations that are developed for interior environments are in a sense frameworks to encourage and elicit the interactions between people and between people and the interior space (Fox & Kemp, 2009). The growing development of digital technology has made the expansion of interactive work on a large-scale possible, but content, curatorial, and design intentions need to be effectively synthesized. Means of obtaining interactive input, articulating responsive output, manufacturing and fabrication, and social, psychological, and cultural considerations are all areas that interdisciplinary teams working on interactive projects could engage (Bullivant, 2006).

Interactive installations that fall within the categories of biophilic or non-biophilic are appropriate to specific users and environments. Both biophilic and non-biophilic interactive installations could benefit from the collaboration of, interaction designers, interior designers, architects, and environmental psychologists. Additionally, biophilic responsive installations would benefit from horticultural therapists, and sustainable consultants. The non-biophilic responsive installations could benefit from the consultation of motion graphic designers, material specialists etc. Professionals, specific to the users needs should additionally be involved.

Specialists from specific disciplines are needed depending on the desired outcomes of the interactive installations. The contextualized setting and identified users for a specific project affect the disciplines that are also needed. The findings from the semi-structured interviews show that participants thought that the interactive installations could be beneficial to the mature demographic, people with disabilities, children and

could be used to purely enhance everyday experiences through interactivity. Inclusive design should be a consideration for interdisciplinary collaboration when developing interactive installations. Fox and Kemp (2009) explain that there are numerous healing, nurturing, and rehabilitative opportunities for interactive installation based design with respect to both the mature demographic and people with disabilities; they don't however present empirical evidence in support of these claims. Further empirical investigation should be conducted within the area of large-scale interactive installation-based work involving specialists from various disciplines. Fox and Kemp explain that the last several years have marked a change in the way society thinks of the mature generation and people with disabilities (Fox & Kemp, 2009). In short, general expectations and demands have grown with respect to these populations, additionally there are growing economic advantages as the mature population increases. Specialists in the areas of gerontology, rehabilitation, and childcare should be involved and consulted, specific to the users needs throughout the design process and integration of the interactive installations into the specific setting.

Suggestions for Designers

Previously outlined opportunities for interdisciplinary collaboration can be summarized into guidelines for interior designers, as the majority of benefiting environments are based in interiors, and involve how the users experience the interior setting. Ideally, interior designers would develop and lead the interdisciplinary teams, and seek specialist consultation for the development and application of these installations. Interdisciplinary collaboration amongst specialists specific to the desired outcome, the environment and users should be consulted throughout the design process. Designers

should carefully consider evaluating and predicting user needs when developing interactive installations.

Responsive biophilic installations, which realistically mimic nature, should be considered for older participants. Participants preferred realistic representations of nature, and not abstract references to nature. More participants made comments referencing nature while interacting with installations that represented nature in a realistic way. Responsive biophilic installations should be integrated into environments, which are able to facilitate participatory interactions in subtle and active ways over an extended duration of time. Interior designers should consider the specific environments that would support and benefit the integration of interactive biophilic installations resulting in a calming effect. These environments are: healthcare settings, waiting rooms, office workspaces, elderly care facilities, rehabilitative spaces, and domestic living interiors.

Non-biophilic interactive installations that employ dynamic novel elements and encourage a level of surprise in the participant should be considered for a younger audience, and an audience that has a short duration of time for the interaction. These installations should be integrated into environments that support active and playful participation. Evolving dynamic elements should be considered as these changing components and ultimately encourage novel experiences for participants. These suggested environments are: mundane public spaces, daily waiting periods, childcare facilities, rehabilitative spaces, special events, and exhibition settings.

Interactive features in both the biophilic and non-biophilic installations facilitated certain participant behaviours, for example, intended and incidental movement, touch, sound etc. Designers can use this knowledge to encourage viewers to behave certain ways

in certain environments. Examples of these environments are: rehabilitative spaces, educational environments, performing dance studios, and communal areas. Further research is needed in this area, specifically looking at the sensory and physical responses of the participant and if these responses become more dynamic while the participant is interacting with responsive installations.

The placement and location of the interactive installations encouraged viewers to move through the exhibition space in a particular way. The placement/location of the installation Dune is a specific example of this. The installation, Dune lined the entrance corridor to the exhibition, which led participants through the hall and into the main exhibition. Designers can use interactive installations to influence the movement and flow of people through interior environments.

References

Ahola, J. (2001). *Ambient Intelligence.* Retrieved from http://www.ercim.eu/publication/Ercim_News/enw47/intro.html

Akten, M. (2009). *Body Paint.* Retrieved from http://www.memo.tv/

Anusas, M. (2006). *Attachments to nature: Design and eco-emotion.* In M. Karlsson (Ed.), 5th Conference on Design and Emotion. Gothenburg. Sweden.

Anusas, M. (2006). Experiences of Ecological Emotion. *Engage newsletter*, 12-20.

Appleton, J. (1975). *Perspectives on Landscape Aesthetics: The Experience of Landscape.* Chichester and New York: John Wiley.

Beesley, P. (2010). *Hylozoic Ground: Liminal Responsive Architecture.* Riverside Architectural Press.

Benyus, J.M. (1998). *Biomimmicry: Innovation Inspired by Nature.* Grand Rapids, MI: Zondervan Publishing House.

Benyus, J.M. (2008). A Good Place to Settle: Biomimicry, Biophila, and the Return to Nature's Inspiration to Architecture. In Kellert, S. R., Heerwagen, J., & Mador, M. (Eds). *Biophilic Design.* Hoboken, N.J.: Wiley.

Bergdoll, B. (2007). *Nature Design: From Inspiration to Innovation.* Switzerland: Lars Publishers.

Bishop, C. (2005). *Installation Art.* New York: Routledge.

Bloomer, K. (2000). *The Nature of Ornament.* New York: Thomson-Shore Inc.

Botton, A. (2006). *The Architecture of Happiness.* New York: Pantheon Books.

Breidbach, O. (2007). *Rene Binet: From Nature to Form.* New York: Prestel Publishing.

Brown, D. (2009). *On Growth and Form.* Retrieved from http://www.danielbrowns.com/

Bullivant, L. (2006). *Responsive Environments: Architecture, Art and Design.* London: V&A Publications.

Darley, G., Philippa, L. (1986). *Dictionary of Ornament.* New York: Pantheon.

DeKort, Y., Meijnders, A., Sponselee, A., Ijsselsteijn. What's Wrong with Virtual Trees? Restoring from Stress in a Mediated Environment. *Journal of Environmental Psychology*, 26, 309-320.

Duncan, S., Finley, T., Gonzales, A. (2008). *Interactive Art: Effects on User Identity & User Satisfaction.* New York: Cornell University.

Dunne, A. (2005). *Hertzian Tales: Electronic Products, Aesthetic Experience and Critical Design.* (Online Version). London: RCA Research Publications.

Dunne, A. (2005). Architects in Cyberspace: Fields and Thresholds. *Architectural Design*, 188, 61-65.

Field, T. (1998). The Effect of Indoor Foliage Plants on Health and Discomfort Symptoms Among Office Workers. *Indoor and Built Environment*, 7, 204-222.

Flannery, M. (2005). Jellyfish on the Ceiling and Deer in the Den: The Biology of Interior Decoration. *Leonardo*, 38, 239-244.

Fox, M., Kemp, M. (2009). *Interactive Architecture.* New York: Princeton Architectural Press.

Fromm, E. (1964). Our Way of Life Makes Us Miserable. *The Saturday Evening Post*, 237 (8), 1-4.

Fromm, E. (1965). *Socialist Humanism: An International Symposium.* New York: Doubleday.

Gibbs, J. (2005). *Interior Design.* London: Laurence King Publishing Ltd.

Grady, J. (1955). Nature and the Art Nouveau. *The Art Bulletin*, 37 (3), 187-192.

Green, W., & Jordan, P., (2002). *Pleasure with Products: Beyond Usability.* New York: Taylor & Francis Inc.

Greenfield, A. (2006). *Everyware: The Dawning Age of Ubiquitous Computing.* Berkeley, CA: New Riders.

Hawken, A., Lovins, H., Lovins, B. (1999). *Natural Capitalism: The Next Industrial Revolution.* London: Earthscan.

Heerwagen, J., (2007). Biophilia and Design: Handout for Portland Lectures. Retrieved from http://www.aiaportland.com/downloads/Biophilia%20Portland%20handout%208-27-%0907.pdf

Heerwagen, J., (2001). Bio-Inspired Design: What Can We Learn from Nature? *BioInspire*, 15 (3), 1-9.

Heerwagen, J., Kellert, S., & Mador, M. (2008). *Biophilic Design.* NJ, USA: John Wiley & Sons, Inc.

Heerwagen, J., & Orians, G. (1986). Adaptations to Windowlessness: A Study of the use of Visual Décor in Windowed and Windowedless Offices. *Environment and Behavior*, 18, 623 - 639.

Heerwagen, J., & Orians, G. (1992). Evolved Responses to Landscapes. The Adapted Mind: *Evolutionary Psychology*, 555-579.

Heijdens, S. (2005). *Tree*. Retrieved from http://www.simonheijdens.com/.

Henry, A. (2001). *Kant's Theory of Taste: A Reading of the Critique of Aesthetic Judgment*. UK: Cambridge University Press.

Honour, H., Fleming, J. (1977). *Dictionary of Decorative Arts*. New York: Harper and Row.

Ingold, T. (2000). The Perception of the Environment: Essays in Livelihood, Dwelling and Skill. London: Rothledge.

Jordan, K., Randall P., & Jordan K. (1977). *Multi Media: From Wagner to Virtual Reality*. New York: Norton and Company.

Joye, Y. (2007). Architectural Lessons from Environmental Psychology: The Case of Biophilic Architecture. *Review of General Psychology*, 11, 305-328.

Kahn, P. (1999). *The Human Relationship with Nature: Development and Culture*. Cambridge, MA: MIT Press.

Kaplan, R. (1993). The Role of Nature in the Context of the Workplace. *Landscape and Urban Planning*, 26, 193-201.

Kaplan, R., & Kaplan, S. (1989). *The Experience of Nature: A Psychological Perspective*. Cambridge: Cambridge University Press.

Kaplan, S. (1987). Aesthetics, Affect and Cognition. *Environment and Behavior*, 19, 3-32.

Kellert, S. (1997). *The Value of Life: Biological Diversity and Human Society*. Washington: Shearwater Books.

Kellert, S. (2005). *Building for Life: Designing and Understanding the Human-Nature Connection*. Washington: Island Press.

Kellert, S., Wilson, E. (1993). *The Biophilia Hypothesis.* Washington: Island Press.

Kellert, S.R. & Heerwagen, J.H. (2008) Preface. In Kellert, S. R., Heerwagen, J., & Mador, M. (Eds.). *Biophilic design: The theory, science, and practice of bringing buildings to life.* Hoboken, N.J.: Wiley.

Lechner, A. (2006). Can Workplace Design Enhance Creativity and Adaptation to Change?. New York: Stern School of Business New York University.

Ludden, G. (2006). Surprise and Emotion. Presented at the 6th International Conference on Design & Emotion. Hong Kong.

Miller, H. (2005). Design for Well-being: Towards an Aesthetic of the Interactive. *Digital Creativity*, Nottingham Trent University, 12 (4), 237-246.

Milton, K. (2002). *Loving Nature: Towards Ecology of Emotion.* London: Rothledge.

Moresco, J (2009). *Building Green Homes.* Revreived From http://gigaom.com/cleantech/building-green-homes-breaks-into-the-mainstream-in-northern-cali/

Nakamura, R., Fujii, E. (1992). A Comparative Study of the Characteristics of the Electroencephalogram when Observing a Hedge and a Concrete Block Fence. *Journal of The Japanese Institute of Landscape Architects,* 55: 139-144.

Naylor, G. (1998). *William Morris: Designs and Writings.* New York: Cartwell Books Inc.

Norman, D. (2004). *Emotional Design: Why We Love (Or Hate) Everyday Things.* New York: Basic Books.

Norman, D. (1998). *The Invisible Computer: Why Good Products Can Fail, The Personal Computer is so Complex, and Information Appliances are the Solution.* Massachusetts: MIT Press, Cambridge.

O'Neill, M. (2007). Rhetorics of Display: Arts and Crafts and Art Nouveau at Turin Exhibition of 1902. *Journal of Design History*, Oxford University Press, 20 (3), 205-225.

Orr, D. W. (2006). *Design on the edge: The making of a high-performance building.* Cambridge, MA.: MIT Press.

Peacock, A. (2001). Towards an Aesthetic of 'the Interactive'. *Digital Creativity.* 12 (4), 237-246.

Physick, J., (1982). *The Victoria and Albert Museum: The History of its Building.* Oxford: Phaidon.

Picard, R. (1997). *Affective Computing.* Cambridge, MA: MIT Press.

Roosegaarde, D. (2007). *Dune.* Retrieved from http://www.studioroosegaarde.net/

Rosenberg, J. (2006). *Light Forest.* Retrieved from http://www.jrala.ca/

Rozin, D. (2007). *Weave Mirror.* Retrieved from http://www.smoothware.com/danny/

Prensky, M. (2001). Digital Natives, Digital Immigrants. *MCB University Press.* 9, 5.

Purcell, T., Peron, E., & Berto, R. (2001). Why do preferences differ between scene types? *Environmental and Behavior*, 33, 93-106.

Rawsthorn, A. (2005). *Daniel Brown. Unthinkable Essays,* Retrieved from http://www.ngca.co.uk/docs/Daniel-Brown.pdf

Rogala, M. (2000). Towards a Theory of Interactive Art Experience. *Interactive Media Design.* 1-5.

Saveri, A. (2003). The Household Horizon: A Guide to Technology and Daily Life in 2012. Institute for the Future. Retrieved from http://www.iftf.org/

Schifferstein, H. (2005). *Sensing the Senses: Multimodal Research with Applications in Product Design.* Holland: Delft University of Technology.

Sole-Smith, V. (2008). Nature on the Threshold. *The New York Times*, 7 September 2006. Retrieved from http://virginiasolesmith.com/PDF/nature.pdf

Turkle, S. (2003). Evocative Objects: Things we think with. Cambridge, MA: MIT Press.

Ulrich, R. (1980). Effects of Interior Design on Wellness: Theory and Recent Scientific Research. *Research Report Series,* 9, 55.

Ulrich, R. (1980). Benefits of passive experiences with plants. *The Longwood Program Seminars: University of Delaware and Longwood Botanic Gardens.* 12, 26-31.

Ulrich, R. (1981). Natural versus urban scenes: Some psycho physiological effects. *Environment and Behavior*, 13, 523-556.

Ulrich, R., Simons, R., Losito, B., Fiorito, E., Miles, M., and Zelson, M. (1991). Stress Recovery During Exposure to Natural and Urban Environments. *Journal of Environmental Psychology,* 11, 201-230.

Ulrich, R. (1984). View Through a Window may Influence Recovery from Surgery. *Science.* 224, 42-421.

Victoria and Albert Museum. (2010). Decode: Digital Design Sensations (Exhibition Manual).

Weibel, P. (1994). (In German). Wie in einem Spiegel. Der spekulative Satz als Metapher. Artic. *A Journal for Art and Philosophy*, 2, 38-42.

Weiser, M. (1999). The Computer for the 21st Century in Scientific American. Retrieved from http://nano.xerox.com/hypertext/weiser/SciAmDraft

Wilson, E. (1984). *Biophilia: The Human Bond with Other Species*. Cambridge, MA: Harvard University Press.

Wingfield, R. (2003). *Responsive Textiles*. Retrieved from http://loop.ph/bin/view/Loop/WebHome

WRT. (2009). *Living Sculptures.* Retrieved from http://www.wrtdesign.com/

Appendices

Appendix 1 Observation Protocol: Preliminary Study

Observational protocol.

Observation # _____, B1 & B2 = biophilic 1 and 2; N1 & N2 = non-biophilic 1 and 2,

Group = G; Single subject = S, Gender= M or F, Approximate age # _____.

For example: Observation # __1__, B1, G, Approximate age # __25__.

Observational Protocol (example included):

Start time: 10:14AM		
Behavior	Frequency	Comments
Non-verbal Moves towards exhibit Moves away from exhibit Waves arms at exhibit Etc. (list behaviors associated with interactions with each exhibit) Etc.		
Verbal		
Makes comment about exhibit:		
To self		Wow – I really like that
To someone in same group		Hey, Lisa – don't you think….
To someone in other group		
Compares 2 exhibits		Oh, even better than the one with the tree over there
Talks to self		
LOL/chuckles		
Etc.		
End time: 10:21AM		

Appendix 2 Observation Protocol: Formal Study

Observation protocol.

Observation #:

Piece: Daan Roosegaarde (Biophilic 1 - Dune)

Single / Group:

Gender:

Approximate age:

Observational Grid:

Start time:		
Behavior	Frequency	Comments
Non-verbal		
Moves through the installation		
Moves back through the installation		
Moves around the space		
Touches installation		
Waves arms at installation		
Runs arms through installation		
Takes pictures / videos of installation		
Examines piece (curiously explores how it works)		
Reads about the piece		
Verbal		
Makes comment about installation:		
To self		
Makes noises in order to activate the installation		
To someone in same group		
To someone in an other group		
Compares two installations		

Compares piece to something else (i.e. Memory etc.)		
Makes other various noises (i.e. Laughter etc.)		
End time:		

Observation #:

Piece: Simon Heijdens (Biophilic 2 - Tree)

Single / Group:

Gender:

Approximate age:

Observational Grid:

Start time:		
Behavior	Frequency	Comments
Non-verbal		
Moves towards the installation		
Moves away from the installation		
Moves around the space		
Waves arms at exhibit		
Interacts with the ground		
Sits down within installation		
Touches installation		
Takes pictures / videos of installation		
Examines piece (curiously explores how it works)		
Reads about the piece		
Verbal		
Makes comment about installation:		
To self		
To someone in the same group		
To someone in an other group		
Compares two installations		
Compares piece to something		

else (i.e. Memory etc.) Makes other various noises (i.e. Laughter etc.)		
End time:		

Observation #:

Piece: Daniel Rozin (Non-Biophilic 3 – Weave Mirror)

Single / Group:

Gender:

Approximate age:

Observational Grid:

Start time:		
Behavior	Frequency	Comments
Non-verbal		
Moves towards the installation		
Moves away from the installation		
Moves around the space		
Waves arms at installation (Moving upper body)		
Makes various hand gestures at the installation		
Touches installation		
Takes pictures / videos of installation		
Examines piece (curiously explores how it works)		
Reads about the piece		
Verbal		
Makes comment about installation:		
To self		
To someone in same group		
To someone in an other group		
Compares two installations		
Compares piece to something		

else (i.e. Memory etc.) Makes other various noises (i.e. Laughter etc.)		
End time:		

Observation #:

Piece: Mehmet Akten (Non-Biophilic 4 – Body Paint)

Single / Group:

Gender:

Approximate age:

Observational Grid:

Start time:		
Behavior	Frequency	Comments
Non-verbal		
Moves towards the installation		
Moves away from the installation		
Moves around the space		
Waves arms at installation (Moving upper body)		
Makes various hand gestures at the installation		
Jumps / kicks etc. at installation (Moving lower body)		
Touches installation		
Takes pictures / videos of installation		
Examines piece (curiously explores how it works)		
Reads about the piece		
Verbal		
Makes comment about installation:		
To self		
Compares two installations		

Compares piece to something else (i.e. Memory etc.) Makes other various noises (i.e. Laughter etc.)
End time:

Appendix 3 Creating / Performing: Results

Frequency of behavior.

Incidental Movements	Dune	Tree	Weave Mirror	Body Paint
Moves towards the installation	30	30	30	30
Moves away from the installation	30	30	30	30
Moves through the installation	30			
Moves back through the installation	30			
Intended Movements	**Dune**	**Tree**	**Weave Mirror**	**Body Paint**
Moves around the space	16	30	29	30
Waves arms at installation (Moving upper body)	13	14	22	27
Makes various hand gestures at the installation / Runs arms through installation	18		12	19
Jumps / kicks etc. at installation (Moving lower body)				17
Touches installation				
Interacts with the ground		30		
Sits down within installation		1		