**Bringing the Outside In:
Creating Artificial Lighting to Improve People's Psychological Wellbeing by Evoking Biophilic Response Through Aesthetics and the Sun's Biological Benefits**

by

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Bringing the Outside In:
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ABSTRACT

More than 50% of the world is now living in an urban environment and 90% of those people's time is spent indoors with artificial surroundings. There are many ways these artificial surroundings can be manipulated to mimic the countless beneficial qualities of earth's natural environments through technology and aesthetics. This document explores how earth's organic forms can be merged into artificial lighting that simulates the sun and moon. Each prototype was created through biomimetic implementation of the sun and moon's colour temperature to biologically keep a person's circadian rhythm in sync while representing the presence of a psychological biophilic response through aesthetics.

Keywords: Circadian rhythm, biomimicry, biophilia, at-home lighting, medical lighting, light therapy, nature design, interactive lighting, sleep technology, electroluminescent, nature technology, LED, health and wellness, quality of life, indoor environment

Many thanks to Ishan Sharma for taking the time to contribute his knowledge and skills to my prototype creation

And to my advisor, Nick Puckett, for all his patience

For my parents.

Without their guidance and support, none of this would have been possible.

Metzger for the thousands of hours by my side

As well, to all the friends and family that listened to my crazy ideas even if they didn't know what I meant

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CHAPTER 1. INTRODUCTION

Technology has enabled a vast amount of change, both positively and negatively, including travel, communication, medical advancements and the constant environmental manipulation from organic to artificial. Since the invention of electrical lighting in the late 1800's, artificial light in houses has aided people to see at night as well as work later hours by keeping them awake. At-home electrical lighting clearly has many benefits that have improved the world in multiple ways. However, many have yet to recognize the health concerns of this lighting. Indoor lighting usually remains at a constant colour temperature and brightness throughout the day (sometimes getting brighter in the evenings). Only three percent of earths surface is protected or used as parks, while more than 95 percent has been manipulated directly by humans either through being ploughed, paved or disrupted in another way (Gullone 2000). Not only has this 3 percent of earths surface become a designated "nature zone", but these areas are also frequented often. In Canada and USA more children and adults visit zoos than attend major professional sporting events combined (Gullone 2000; P. H. Kahn 1999). Desired views are habitually considered to be landscapes that highlight earth's natural elements. People travel long distances just to walk across the seashore, and will pay large sums of money to purchase properties that have what is considered a desired view, such as the oceanfront. "Humans lived in nature for 5 million years. We were made to fit a natural environment...When we are exposed to nature, our bodies go back to how they should be" (Louv 2011a). Our bodies have come accustomed to the earth's natural environment and cycles and have evolved biologically and genetically to it for our health and benefit. Nearly all of our modern habits with lighting are the complete opposite of what our biological makeup is pre-adapted to. At night, we turn on more light thus increasing brightness when dimmer lit environments should be occurring. Some sleep with lights on, or have bright light coming through their windows from living in a busy urban city. Yet, if blinds are drawn to create darkness while sleeping, then the mornings are also dark and do not let in adequate lighting to reset ones circadian rhythm. Today, 54 per cent of the world's population live in a city, estimated to increase to 66 per cent by 2050 (United Nations 2014). There is a "…blind assumption that the human species has an unlimited capacity to adapt to the environment, no matter how far removed it is from that in which we evolved" (Gullone 2000). The traditional ways humans have experienced nature is vanishing. In some countries it has completely vanished and turned into hobbies, trips or vacations such as camping. Richard Louv introduced the term *Nature-Deficit-Disorder* in 2005 in his book entitled *Last Child in the Woods*, which is used to describe the growing gap between humans and nature. Human's relationship with the outdoors, or lack of, influences our daily life in many ways. Richard Louv also coined the term *The Nature*

Principle, which is a fusion of theories and trends proving well-known ancient truths that the natural world is fundamental to human health, spirit, well-being and survival. This principle focuses on powers natural elements have on our intelligence and senses, both physical and psychological (Louv 2011b). With this principle in mind he states that "Utilizing both technology and nature experience will increase our intelligence, creative thinking, and productivity, giving birth to the hybrid mind" (Louv 2011b, 5).

Biomimicry combines technology with biological research to create synthetic biology both in form and function, while biophilia is both a design style and a hypothesis stating that incorporating actual vegetation, mimicked forms of vegetation or representations of vegetation induce psychological wellbeing. The growing aesthetic trend within each driver that focuses on shape and form is popular because of the psychological want for organic, natural stimuli that is activated through genetic determinism. Integrating multiple sensors into pre-existing everyday objects will give the subconscious feeling that the object is organic, or will completely remove the thought of it being there entirely. Current technology is capable and readily available for making interactive technology and has been for a few years now. "Unfortunately, the changes are not always positive and much of the technology we use is clunky, unfriendly, unnatural, culturally biased, and difficult to use. As a result, several aspects of daily life are becoming increasingly complex and demanding" (Nakashima, Aghajan, and Augusto

2009, 349). Natural interaction is a key element to successful interactive designs, without this approach to smart environments and devices there is no reason to make them interactive.

OBJECTIVE

Through studying natural interaction for smart environments, biophilia, biomimicry, biological rhythms and light therapy, the purpose of my thesis research is to merge psychological and biological benefits from technology and the physical organic world to create at-home smart lighting devices. Each object addresses the following research questions:

1. How can wellness devices be designed to ensure they are used daily?
2. How can biophilic responses occur from the aesthetics on light technology?
3. How can the concept of light therapy be used at home for improved wellness?

The result of this research involved the creation of two prototypes that implement biomimicry through colour temperature simulation of the sun and the moon to biologically sync your circadian rhythm while also eliciting a biophilic response with aesthetics. By documenting the creation evolution of these objects, accompanied with medical and theoretical research, I hope to educate and stimulate interest on not only circadian rhythms but also other ways technology can subconsciously induce positive benefits through various applications of biology and ecology.

FINAL CREATIONS

The designs that I have developed demonstrate two separate approaches at-home lighting and visual can positively affect people's circadian rhythms and psychological well-being. The two final prototypes are entitled with Lugandan words, Musana and Mwezi, meaning sunshine and moon.

1. **Musana** is a set of wall mounted light strips visually designed to resemble the structure of an acacia tree and the form of twisted grass. It is intended to replace every artificial light at home to properly sync the users circadian rhythm through various colour changes. This lighting piece first goes through a sunrise phase then stays daylight colour balanced all day until it is the appropriate time for a sunset. By simulating the numerous colour temperatures of sunlight, this installation can trigger various biological functions responsible for overall mood, sleep and energy production, otherwise known as circadian rhythm.
2. **Mwezi** is an interactive floor intended for at-home use that replicates the moons colour temperature at night when walked on. This prototype helps keep users circadian rhythm in the proper stage when waking up in the middle of the night and right before sleep. The moon

is a similar kelvin temperature to a sunset. This colour temperature tells the circadian rhythm it is time to sleep and will then prepare the body through a set of biological changes including promoting melatonin release or, in this case, keep melatonin levels high.

DOCUMENT OUTLINE

The first section of this document describes my creative process and research methods that I undertook to form my final prototypes. Research through design is a diverse process, and because of this, two methods were integrated into my process to formally help with documentation and synthesis of research.

The second chapter is the Literature Research, which played a fundamental role in the conceptualization of my prototypes. This section provides a scientific foundation on circadian rhythms and theoretical design topics such as biomimicry, biophilia and smart environments. The knowledge gained in this section provided an in-depth understanding of each topic, therefore the ability to implement the benefits of each. The vital details of each literature topic were brought together to create prototypes that are all-encompassing wellness devices.

In the Prototype Evolution chapter of this document initial creation ideas are first presented, followed by a description of two preliminary iterations that were abandoned, a summary of why these were abandoned, discussions with industry professional's, visual and functional inspiration, then material research and lastly a detailed description of each final prototypes process. The iterations included at the beginning of this chapter are ones that I began to create and then for various reasons changed direction and abandoned the ideas. Visual and material research led me to the discovery of many unique materials, lighting products and biophilic designs that inspired me to create in innovative ways I may not have otherwise attempted. The last segment of my Prototype Process details the process of my final prototypes. Brief explanations of the prototypes chosen names and their functions are explained first, then early prototype conceptualization is rationalized and user testing for Musana and Mwezi is illuminated. After this, each individual prototype is divided into sections. Included in the sections are:

1. An introduction explaining inspiration that led to the final idea
2. Creation results and challenges, divided into stages
3. A detailed description of the final prototype outcome

In the conclusion of this document I reaffirm how the two prototypes I completed validate an all-encompassing biomimetic at-home wellness device and represent a grounded theory of bringing the outside in. Followed by a personal reflection and key challenges during creation are stated. Then this section, and the entire document, concludes with suggestions for future research and add-ons that have arisen during the process of this project.

CHAPTER 2. CREATIVE PROCESS AND RESEARCH METHODS

My thesis exploration involved the combination of two different research methods. The two methods used are grounded theory and the engineering design process. Each method was selectively used at idiosyncratic times during my research process when they would supply the most value to development; neither was used for the entire process. The engineering design process requires identifying a specific problem, whereas grounded research is a good method to use when there is no specific problem or research question identified at the start.

GROUNDED THEORY

I started my exploration through grounded theory. "Grounded theory depends on a "discovery model" of theory generation that focuses on discovering patterns that identify problems and connections between these patterns and motivates the researcher to raise questions about the phenomenon in the natural field"(Aldiabat and Le Navenec 2011, 1071). Rather than beginning with a hypothesis, the first step in grounded theory research is data collection through a variety of methods. After data collection, key points are then extracted and grouped together when similar concepts are found (Barnett 2012). My three research questions that are previously stated under Objectives were created with the help of the discovery model. The preliminary core themes of artificial light, interactive design, organic aesthetics of earth and wellness were identified based on personal interest before gathering data. Without preliminary interests identified, data research would have been endless and connections would have taken an extremely long time. After gathering visual and literary data through discussions and personal research, I linked together similar patterns and problems and discovered my fundamental topic of light therapy/circadian rhythms. The discovery model of theory generation was used in preliminary stages to find and combine research topics with similar patterns to light therapy/circadian rhythms. Using this method to initiate my research allowed me to discover and group together my final topics that may not have otherwise been found or used in combination. From these groupings I was able to form coherent and personally appealing research questions to undertake. Not only did this approach help to produce research questions, but it also led to the implementation of additional theories and benefits beyond only light therapy that made the prototypes more complex and beneficial.

Integrating the core theme of circadian rhythms/light therapy required an in-depth understanding of circadian rhythms and the technical requirements for light therapy. The engineering design method is primarily focused on information-rich technological knowledge and exploring ways to incorporate them into the users needs (Radcliffe 2013). Due to the topic of my investigation relying on specific technical requirements and scientific understanding, my second research method is the engineering design method.

ENGINEERING DESIGN PROCESS

"Engineering design is a recursive activity that results in artifacts – physical or virtual" (Radcliffe 2013, 8). In David Radcliffe's chapter entitled *Multiple Perspectives on Engineering Design"*, he discusses a few key strategies in engineering design to make the most of potential opportunities. Each strategy involves constant adaption or the desire to seek new or better ways to do things. Further stated in the chapter are the three measures of success for this process: clarity, simplicity and safety. Staying adaptable during projects and seeking for new or better ways does not mean that you should incorporate every way into the design. If the design suffers or becomes unclear by adding newly discovered technology, then that technology is not appropriate. Keeping the final prototypes simple and clear was very important during my creation process because I did not want to take away from the functional light benefits, or take away from the chance of biophilic responses.

Technological knowledge must be regularly researched during creation with the engineering design method, which then leads to constant technology changes, reevaluation and modifications. During the process of this research project many changes were applied and tested before coming to the final prototypes. These changes were primarily made from product and technology research in the field. A lot of background research was conducted to specify requirements needed before a thorough prototype solution was made.

Grouping together the benefits of aesthetic and interaction design with the technical requirements necessary to trigger ones circadian rhythm with light turned into my final two prototypes through the use of both grounded theory and the engineering design method at various times throughout.

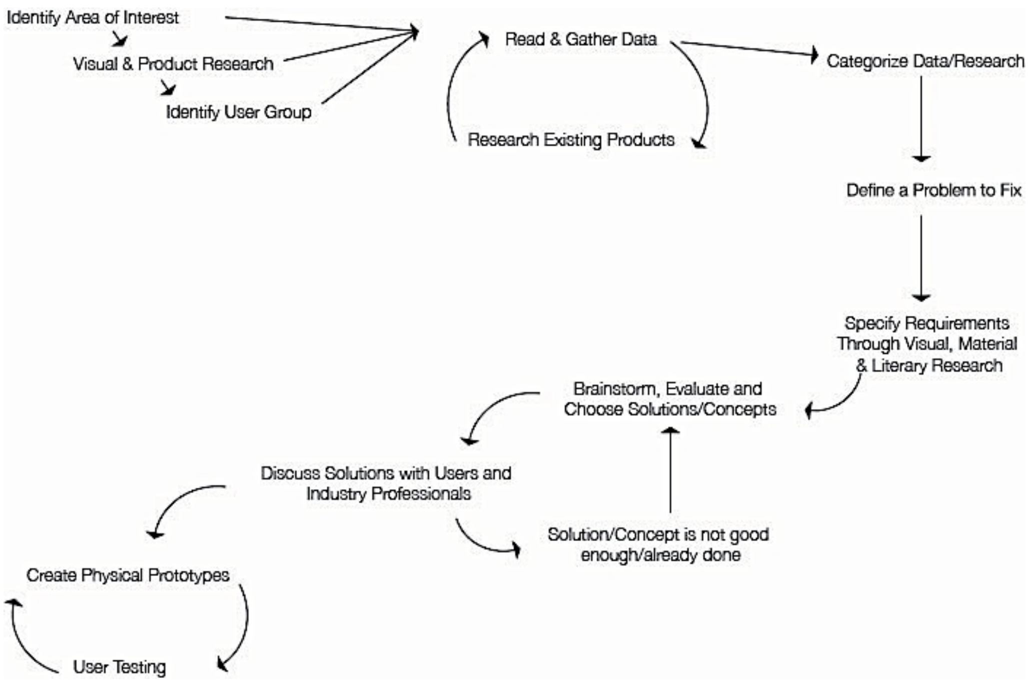


Figure 1, My Creative Process

CREATIVE PROCESS

Figure 1 shows my creative process and how both methods cycle into the overall schematic. Through visual, material, creation and literature research I used grounded theory to identify codes, systematically group similarities and then identify a specific area of interest and theories to be used. Once the general area of interest and problem was defined, background literature and product research was conducted that reflects both methods at this stage. Grounded theory was used here to reach the next engineering design method stage by helping analyze all research and group them together coherently to specify requirements. Once a final collection of categories and technical requirements was created, an initial concept/solution was formed. The concept was further refined through user testing and a constant evaluation of technology that could better serve my idea.

The final prototypes I have created came from combining grounded theory's discovery model and analyzing techniques to create the literature foundation, followed by using the engineering design method steps to shape the technical purpose. Using each method when needed, allowed me to combine many different formulas to come up with an ideal solution while also giving me the freedom to use my own natural methods. Adding these elements to my pre-existing thought process allowed me to analyze and theorize in a more efficient manner. Not only did these methods input new organization and process techniques, it also made the design process easier to reflect and document. “Design is learned by doing and reflecting. It is not formulaic; it is an art rather than a science” (Radcliffe 2013, 8).

CHAPTER 3. LITERATURE RESEARCH

There are many technological advances that have benefited human’s daily life and hygiene that in turn improved health and life expectancy. Although each technological advance has created safer, healthier and easier lives for humans, fundamental human needs that are only provided through specific outdoors qualities have been neglected. This chapter synthesizes literature research used to form an all-encompassing at-home wellness device driven by the concept of light therapy.

Biomimicry is the term used when an aspect of the natural world in form and/or function is mimicked. I start this chapter by explaining biomimicry because the two succeeding literature topics, circadian rhythms and biophilia use biomimicry to improve human’s psychological and biological health. Knowing the basic knowledge and wording used with biomimicry and its three applications will help to understand the rest of the document as it transpires. The function of a physical prototype is not the only way it provides value; materials, operation and visual design also need to be thought of. Biophilia and smart environments are lastly explained to understand the reasoning behind both prototypes aesthetic and interaction.

Both of these played a secondary role to the creation of my prototypes to ensure every aspect integrated provoked a positive response.

BIOMIMICRY

In 1997, Janine Benyus, amongst many others had the realization that humans not only have lost touch with the outdoors but have been able to create many ground-breaking inventions simply by studying the earth's vast ecosystems and coined the term *Biomimicry*. This term refers to an amalgamation of science, engineer and design practices that use earth's ecology and biology for inspiration to solve problems in various fields (Goss 2009; Nguyen 2006; Volstad and Boks 2012). The literal translation of biomimicry means "imitation of life" derived from a combination of two Greek roots; "bio", meaning life and "mimikos", meaning imitation. The earth's ecosystem has proven itself a successful system through adaptation and evolution over the course of 3.8 billion years (Goss 2009). Many ecosystems that have formed over billions of years can be studied to generate new solutions for today's problems and find solutions that generally outperform pre-existing man-made ones. Three well-known inventions that use biomimicry are; exploring termite mounds to create passive cooling in buildings, studying cockleburs to create Velcro and self-cleaning materials such as windows and paint inspired by the hydrophobic surface of the lotus leaf. There are two main approaches to biomimicry, the reductive view, which can be used through three applications and holistic view (Volstad and Boks 2012).

REDUCTIVE APPROACH

Reductive biomimicry can help solve a specific problem in fields such as engineering, design and science but does not guarantee or strive to yield any environmentally sustainable solution. The reductive view is a way that designers and engineers transfer biological technologies into their designs, also known as practices of biotech and bioengineering. This form solely focuses on the imitation of particular organisms or biological processes. This is the most used form of biomimicry, and usually does not have a goal to create sustainability. Reductive biomimicry is often confused as holistic biomimicry because subconsciously the design is assumed to be less ecologically damaging based on aesthetic and/or function. The reductive view is usually found in three main applications being material, structure and form, or a combination of these.

APPLICATION 1 – MATERIAL

A material application of biomimicry is the synthetic creation of a material that replicates a living material. An example of this is the creation of artificial nacre. Nacre is found on the underside of red abalone shells and is twice as tough as high-tech ceramics. The layering of hard and elastic combinations gives nacre its remarkable strength and toughness.

APPLICATION 2 – STRUCTURE/MECHANICS/DYNAMICS

The second application is mimicking the structure, mechanics or dynamics by directly simulating an organism or living system's function. This is mainly used for developing products in engineering or art fields through a systematic study of natural sciences. An American design firm, IDEO created a self-sealing valve from studying the movement of the tricuspid of a heart valve. The bottle will only let water out when it is squeezed and then automatically closes. This has created a quick and easy way to drink water during activities.

APPLICATION 3 – SHAPE AND FORM

The third application uses organic forms and/or shapes found within living systems to enhance the products aesthetic appeal. This application is usually found in fields with a strong art/design component such as industrial or architectural design. Antoni Gaudi was a Spanish architect from Reus that was heavily influenced by nature. The use of biomimicry is represented in many of his buildings shape and form. As seen in Figure 2, the Sagrada Familia staircase was clearly influenced by the shape of a snail. Although application 3 does involve mimicking the shape and form of living structures, it is not always the intent to make the visual inspiration obvious. For example, a shape and form that mimics nature could mean that a car is designed in a similar shape to an aerodynamic beak.

HOLISTIC APPROACH

The holistic approach to biomimicry is also known as the “eco-design” oriented approach because it is seen as becoming “…versed in life-cycle planning that considers each step in the product design process, starting with the extraction of raw materials and ending with renewal or reuse of the manufactures product” (Volstad and Boks 2012, 192). The holistic view of biomimicry is a more in depth imitation and incorporates the three reductive applications while also achieving ecological sustainability with products that do not harm the environment in their production, use or decay. This level involves thinking about the entire process in which living systems manage through consideration of every detail from creation to decay as part of an entire system.

An expansion on the mass of new information in the natural science fields has been growing the appeal, availability and popularity of biomimicry. Fragmentary knowledge of biology (such as the sequencing of genomes) double every five years (Goss 2009). Powerful scopes and satellites are now able to provide striking new visuals and observations that in the past were unimaginable. This new magnified imagery is able to offer graphic presentation of molecular structures and other complex structures that have yet to be explored. These exciting developments have helped many biologists, medical doctors, engineers and designers alike to solve major problems simply by turning to pre-existing solutions within the earth’s ecosystems.

Figure 2 Spiral Staircase in the Sagrada Familia by Antoni Gaudi, retrieved from http://commons.wikimedia.org/wiki/File:Sagrada_Familia_Spiral_Staircase_2_(5839764546).jpg

CIRCADIAN RHYTHM

The sun is necessary to provide life for all living organisms; it depicts where specific plants will grow or die and sets each organism's daily cycle. Humans also need the sun, not only because the sun provides vegetation that humans require to live, or because it provides the earth with warmth, we also rely on the sun for many internal biological functions. Without the sun, the daily internal biological changes we take for granted would be different from how they are now. The sun goes through a daily cycle from sunrise to sunset where it changes brightness and colour depending on the time of day.

The effects of artificial light can extend much further than simple visual appeal, and have a biological effect producing a positive influence on health (Riemersma-van der Lek et al. 2008), alertness (Campbell et al. 1995; Phipps-Nelson et al. 2003), well-being (Partonen and Lönnqvist 2000) and on sleep (Campbell et al. 1995; Viola et al. 2008; Santhi et al. 2005). A lot has been learned in recent decades about light and the non-visual, biological or non-image-forming (NIF) effects that it produces. A newly discovered photoreceptor, residing in the retina of the eye, partially mediates the effects of NIF (Koninklijke Philips N.V. 2014). Some NIF effects on the human body include, but are not limited to, hormone release (melatonin and cortisol), sleep quality, biological clock & phase shifting, mood & depression, alertness and visual acuity & performance (Philips, 2014). It was recently discovered that the NIF effects are mediated by melanopsin. Melanopsin is found within a photoreceptor cell type in the retina of the eye and it regulates the biological effects of light. It is most sensitive to blue light with peak sensitivity at 480 nm (McClung 2007; Santhi et al. 2012). When light is perceived with the eyes (ocular light), the light reaches these melanopsin-containing photoreceptor cells and a complex chemical reaction occurs. This reaction produces electrical impulses that get sent through multiple nerve pathways to our biological clock, which in turn strongly mediates the circadian rhythm (Johnsson 2008).

The word circadian derives from latin words circa, meaning around, and dies, meaning one day (Quera Salva and Dr. Sarah Hartley 2012). A circadian rhythm is an internal biological rhythm that can be found in almost all living beings from prokaryotes to higher organisms (Johnsson 2008). This rhythm is linked to the organism's natural surroundings by environmental signals or cues that set their biological clock, then triggering the circadian rhythm. These environmental signals/cues are referred to as zeitgebers. The most potent zeitgeber is light for all organisms (Quera Salva and Dr. Sarah Hartley 2012). Human's biological clocks are situated in the suprachiasmatic nucleus (SCN), located in the anterior hypothalamus. The rhythm of the SCN orchestrates the rhythm of other biological processes. "The overall circadian system of man is thus a complicated structure where the SCN has been described as a "conductor of the circadian orchestra" (Johnsson 2008, 63).

Since light signals from the retina are fed to the SCN, light is thus affecting the cells in the SCN. The cells in the SCN govern the circadian clock functions. Our internal biological clock controls our circadian rhythm, which gets synced under natural conditions to the earth's 24-hour light/dark rotational cycle. The average cycle in humans is about 24.3 hours (Czeisler et al. 1999), which is slightly slower than the natural light-dark cycle. Without being reset daily, even this small difference in hours would create an irregular circadian rhythm. The internal rhythm will adapt the cycle to the light regime of the sun, therefore, representing a 24-hour rhythm. A circadian rhythm is still present without light and because it is not precisely 24 hours, circadian rhythms can venture off if not exposed appropriately to zeitgebers. This cycle irregularity can be compared with jetlag when a person has not yet set their rhythm to the new time/light change causing fatigue, headache and reduced daily well-being (Johnsson 2008).

Since light regulates the phase shifting of the biological clocks, light then also influences processes, which get regulated by the clock (i.e. energy levels and hormones). Our natural hormone levels, body temperature, attention, cognition and sleepiness all contribute to our natural biorhythm (Johnsson 2008; U. 2010; McClung 2007). Each of these has a designated relationship with the natural light/dark cycle. The circadian rhythm controls a large variety of bodily processes, including the production of important sleep/wake hormones essential for a healthy sleeping pattern. The two main hormones that regulate between activity and rest are cortisol (often referred to as the "stress hormone") and melatonin (the "sleep-promoting hormone"). Cortisol levels naturally peak in the morning preparing the body for the day's activities. While cortisol levels rise, melatonin decreases and the opposite occurs at night. Melatonin levels naturally rise in the evening when it becomes dark (McClung 2007; Santhi et al. 2012; Phipps-Nelson et al. 2003), enabling an easy, quick and natural sleep. Exposure to bright light in the morning resets the biological clock, which then triggers when melatonin will be released that evening, thus allowing for sleep to take place naturally (Quera Salva and Dr. Sarah Hartley 2012). A normal functioning biological clock is very sensitive to light input, because of this light treatment can be used to restore the proper timing of body rhythms. Regular exposure to light is beneficial for ones health because it synchronizes the inner circadian system to maintain biochemical and physiological order in the body (U. 2010). When the wake time is earlier, sleep will also come earlier and vice versa, this is known as the homeostatic process. The homeostatic process is simply the internal clock accumulating the need for sleep by counting how long you have been awake. The homeostatic process feeds into the circadian rhythm which is controlled by the SCN and under normal conditions will confine sleep to the night time in humans due to biological clocks being so sensitive to light input (U. 2010). This is why melatonin may still be released at its normal time at night, due to light change, even if a person wakes later in the day. Disrupting this symbiotic balance will disrupt the natural circadian rhythm leading to negative effects on the quality of sleep and consequently hindering the ability to optimally perform each day (Quera Salva and Dr. Sarah Hartley 2012; U. 2010). Many accidents arise due to improperly adapted circadian rhythms that can easily be adjusted by using adequate lighting. Disturbances that are induced through improper light exposure can occur due to shift-work or travelling to a different time zone. Shift-workers that have night shifts are operating their biorhythms solely with the homeostatic process. The circadian rhythm may then get confused when exposed to morning light if the person has already been awake for a full cycle according to their homeostatic process. Since light has a much stronger synchronizing effect on the circadian system, light can then be used for adjusting the internal clock to the shift workers schedule, creating a stronger rhythm and leaving less chance for actual sunlight to confuse the cycle.

LIGHT THERAPY

As the sun changes colour and brightness throughout the day, so do humans biology. Geographically, further north has less sun during the winter months. Biologically this has affected about four to six percent of humans with what is called Seasonal Affective Disorder (SAD) (American Family Physician 2000). SAD is a recurrent mood disorder that is characterized by a recurring pattern of remission and onset linked with seasons (Flory, Ametepe, and Bowers 2010). This disorder has been linked to delayed circadian rhythms (Flory, Ametepe, and Bowers 2010; Miller 2005; Kurlansik and Ibay 2012) and was first treated with anti-depressant medications. The symptoms of SAD are similar to clinical depression; symptoms include lethargy, disturbed sleep, overeating, difficulty concentrating and social problems (Kurlansik and Ibay 2012). A person is only diagnosed with SAD if their symptoms are incapacitating, however, there is also another 20 percent of people with a milder version that is known as the winter blues. There are many people during the winter in cold and sunless cities that have similar symptoms to SAD due to a delayed circadian rhythm, but a much milder version than those with the winter blues. This mildly delayed rhythm can also be prevalent during the summer months when people stay indoors with artificial lighting for elongated periods of time.

Since SAD is mainly due to a delayed circadian rhythm, people have begun to use what is called light therapy as a natural, unobtrusive alternative to alleviate their symptoms. The circadian rhythm needs to be "reset" each morning for the proper internal biological processes to happen at appropriate times throughout the day. Studies have shown that the human circadian rhythm is particularly sensitive to morning sun, or artificial light spectrums in the short wavelength portion because it is more effective in suppressing melatonin concentration than longer wavelengths of light (Gordijn, 'T Mannetje, and Meesters 2012). Short wavelength of light is perceived as blue to the human eye, and the longer wavelengths are red.

Morning high density light therapy is a proven non-pharmacological way to suppress and release melatonin by triggering the circadian rhythm to a specific phase (Kurlansik and Ibay 2012; Flory, Ametepe, and Bowers 2010; Viola et al. 2008; Gordijn, 'T Mannetje, and Meesters 2012; Terman 2007; Shirani and St Louis 2009; Santhi et al. 2012).

Research on circadian rhythms and the use of light therapy is the underlying origin to my thesis, all prototype iterations and both final prototypes. "With the widespread prevalence of artificial light in our society and its potential health consequences, there is a growing need to engineer artificial light to minimize its disruptive effect" (Santhi et al. 2012, 57). In this Journal, Santhi et al. states that the current biological knowledge that is available is sufficient to engineer these artificial lights to minimize circadian disruptions and optimize sleep-wake cycles (Santhi et al. 2012). This biological knowledge was prevalent not only in this data research but was repetitive among many readings about light therapy and circadian rhythms. Throughout my visual research of other existing products in the market place, I noticed that the current advancements in technology are at a level where it is possible to mesh both the biological and technological knowledge for circadian rhythm improvement.

Light therapy can minimize disruptive effects brought on by artificial surroundings. I took the concept of light therapy further and instead of just minimizing the damages through morning light; I engineered two installations with artificial lights that constantly cue the users circadian rhythm day and night to sync with their homeostatic process. Understanding the full role of circadian rhythms on the human body and the exact scientific details on how light therapy alters this rhythm has been the root for my thesis concepts as well as many technological decisions. Clinical trials researched gave me insight into not only the technological specifications required for light therapy including brightness, colour temperature, distance of light, duration and time of day, but also biological effects these have when altered and reasons why people choose light therapy or problems causing them to stop using it. During these regulated trials, strict routines are given to the patients that the doctors make certain are performed. These strict routines give efficacy to light therapy that is not always easy to accomplish at home. Many users view their daily light sessions as a "burden" since it needs strict regimens (Terman 2007). These regiments includes using it at the same time each morning, being a certain distance, absorbing the light a set amount of time and continuously repeat this task every day or any benefits gained may instantly go away. Dawn simulation light therapy has helped to ease this burden by providing an alternative to post-awakening bright light because it can conveniently be used while the patient sleeps. Dawn simulation draws a slow, incremental light with the maximum intensity able to be two orders of magnitude lower (Terman 2007). Understanding the basics of how light therapy needs to be used coupled with the users problem of why it does not get used was the driving design problem for my thesis.

Although my final prototypes did venture away from the user group of severe SAD patients, therefore not needing the specific light intensity, understanding the overall specifications of this therapy and how the beneficial effects scientifically work has helped with my ideation. The technological aspects of light therapy can be incorporated into everyday lighting, just on a milder scale, to improve the moods of everyone surrounding the light. Not many people are aware of these disorders, or even understand their own biological rhythm let alone know that it exists. With more than half the world spending 90% of their time in artificial environments and not fully understanding the damaging effects it can and has caused is what drove the overall passion for my thesis. Once conceptualization on a functional level began, I searched for ways to further improve artificial environments to decrease damaging effects. These damages occur while inside because humans are heavily attuned to earth's many cycles, since our bodies evolved for optimal survival in the outdoor environment. Going beyond incorporating earth's key cycles, I investigated biophilia as a way to include earth's naturally occurring aesthetics to create a positive response, known as a biophilic response.

BIOPHILIA

Edward O Wilson first presented the biophilia hypothesis in 1984 in his book entitled *Biophilia*. His hypothesis refers to the inherent emotional inclination and dependency humans have with other living things, not just for physical sustenance but also the craving for aesthetic and cognitive satisfaction (Gullone 2000; P. H. Kahn 1999; P. Kahn 1997; Kellert and Wilson 1993; Grinde and Patil 2009). Various studies and theories have been brought together to support this hypothesis including environments of evolutionary adaptation (EEA), biophobia, attention restoration theory, health benefits, and implementation methods. The hypothesis heavily relies on and embodies both biological and genetic determinism throughout all studies and research.

ENVIRONMENTS OF EVOLUTIONARY ADAPTATION

Like all species, humans have changed through evolution and adapted to live in specific environmental qualities. The term Environments of Evolutionary Adaptation (EEA) is used to denote the specific qualities a specific species, in this case humans, have evolved to live in (Grinde and Patil 2009). Deviations from the way of life for which we are genetically designed are referred to as mismatches, and the word discord is used to represent mismatches that have a negative impact i.e. they cause poor health or stress (Grinde and Patil 2009). Unlike following theories and studies, the terms EEA, discord and mismatches are not ways to explain a biophilic response or what triggers it, they are simply explained to describe the qualities humans have evolved in that trigger biophilic responses and associated terms for deviating qualities. There are many positive mismatches in modern society, such as mattresses preventing us from sleeping on the ground, not to mention modern day medicine curing what we perceive as simple infections and diseases that would have otherwise killed us in the past. Creating an exact replica of our EEA would cause detrimental health issues, and not just visual changes but also lifestyle. A relevant step towards creating an environment that closely mimics humans EEA is firstly by understanding the qualities of our evolved environment then implementing as many of these qualities as possible while avoiding discords and only keeping necessary mismatches that aid in our quality of life.

Most evolutionary accounts proclaim that humans lived on the savannas of East Africa for nearly two million years and have adapted to those surroundings. It is further believed that in the savannas, humans would congregate towards specific features of landscape for higher chances of survival such as bodies of water, plants and large open grasslands. Bodies of water provided physical necessity, acted as a perimeter of defense from enemies and attracted animals making hunting easier. Plants and flowers were largely considered a signifier for life and would not only provide food but also materials for building and medicine. Large open grasslands allowed approaching threats to be viewed from afar. Once Wilson's hypothesis began to circulate, many sociologists took interest and began studies of their own in relation to biophilia and the idea of "safety signifiers" from the savannah.

BIOPHOBIA

Prior to the hundreds of studies sparked from the idea of safety signifiers from evolution, Charles Darwin in the late 1800's, suggested the theory of humans having pre-set fears from evolution (Gullone 2000). It has been argued that stress activation is an emotion evolved as a psychological strategy to deal with threatening situations. Artificial environments with no replications of nature could subconsciously trigger stress activation as if it is threatening their well being (Grinde and Patil 2009). Artificial cues that could form this emotion include not only lack of greenery and fresh air but also lack of earth's organic materials, systems and biological triggers. A century after Darwin posed this hypothesis, Seligman continued investigation and further backed the conclusion that these developed fears are most likely because they pose a threat, or have in evolutionary history posed a threat to survival, coined biophobia (Gullone 2000). Biophobia is when organisms are pre-programmed to fear certain situations, living things, objects or environments based on instinctual levels of survival. This notion, strengthened with empirical support, provides a strong basis to the hypothesis that humans have also evolved with positive reactions to elements of living systems.

ATTENTION RESTORATIION THEORY

Many studies dealing with psychological benefits from the outdoors are typically based on theories of restorative effects. A main part of this theory suggests that the visual environment is important for stress recovery, and that stress reduction is faster in natural environments compared to urban environments (Grinde and Patil 2009). A branch of restorative effects theory is the attention restoration theory, which is a similar concept to EEA with the difference being its focus is on attention and other mental cues instead of evolution. This theory suggests that environments with aesthetics resembling living systems can restore attention and environments with perceived disturbing factors could lead to mental fatigue quicker. These perceived disturbing factors are defined as any mismatch that visually does not appear to resemble qualities of the EEA. Objects, forms and materials may impact brain processes through the subconscious, even if they are not being focused on (Grinde and Patil 2009). Therefore environments that replace these disturbing factors with objects that subconsciously appear to be living systems will lead to effortless attention and restore mental capacity. The possibility that the natural environment influences subconscious parts of the brain in ways that cannot easily be described is a reoccurring theme among biophilia's empirical evidence and amalgamation of theories. A classical example of this subconscious reaction to visuals, coupled with the concept of biophobia, is being afraid of a twig at first glance because it resembles a snake. Fear in this instance is initiated prior to any visual inspection of the twig. Simply through incorporating biophilic forms and reducing biophobic forms in an artificial environment will create an at-ease mind frame and remove any suggestions that it is an "unnatural" environment, thus potentially unsafe.

HEALTH BENEFITS

The subconscious behaviour to add natural elements into ones surroundings can also be referred to as the response to the biophilic quality of the human mind (Grinde and Patil 2009). The first hospitals in Europe considered having a garden was an essential part of the environment to aid in the healing process (Grinde and Patil 2009). Since then, the use of greenery to heal or as preventive medicine has gradually decreased due to technological and medical advancements. Considerable research on health and recovery through implementation of actual or visual representations of vegetation and desired landscapes has been carried out over the last few decades. Most research on this topic has proven that beneficial health and psychological effects can occur upon relatively brief exposures of either the actual element or visual representations (Grinde and Patil 2009; Kellert and Wilson 1993; P. H. Kahn 1999). Simply adding biophilic design touches, either living or structures, into a living space can induce positive changes on reducing stress, improving attention, mental restoration, increased longevity and self-reported overall health and wellness (Grinde and Patil 2009; P. Kahn

1997; Gullone 2000; Joye 2013) The stress reducing effect is a key element to the health benefits of biophilia, because stress is the root of many ailments including cardiovascular diseases, anxiety and depression. "Nature appears to have qualities useful for stress relief…by being consciously or unconsciously "pleasing to the eye"" (Grinde and Patil 2009, 2336).

CLINICAL TRIALS

Two clinical trials on assessing health from varying window views and one study using imagery are explained in more detail as to how the trials were conducted and recorded. Each study grouped their findings based on age, weight, gender, tobacco use and overall health prior. A study taken in a prison recorded each inmate's health care needs and compared the findings between which window view they had in their cell. Inmates whose cells looked out onto nearby farmlands or forests required less health care than those who looked out onto the concrete prison yard. A similar window view study was conducted on post-operative gall bladder patients and analyzed the recovery time of those that had a window looking into greenery vs. those that looked out onto a brick wall (Gullone 2000). The overall recovery of the patients with a green view was much faster in comparison, reflected in recovery time, less encouragement from hospital staff and a fewer need for potent painkillers (Gullone 2000; P. H. Kahn 1999). The next study was done on reducing pre-surgical patients stress levels using imagery. One of a serene view with water, one an exciting outdoor scene and the third setting was with no image at all. "Findings showed that after a relatively brief period of exposure (three to six minutes) the systolic blood pressure levels of pre-surgical patients were 10-15 points lower in the condition that involved serene nature pictures that in the other two conditions" (P. H. Kahn 1999, 13).

IMPLEMENTATION METHODS

Each previously mentioned theory and clinical trial has explained the varying positive outcomes that encompass a biophilic response such as improved attention, mental restoration, health and the varying EEA qualities to elicit these responses as well as what to avoid. There are four main strategies where human made designs can integrated these qualities to trigger a biophilic response (Joye 2013). The first strategy, and the most straightforward, is to incorporate actual vegetation into the creation. This strategy is mostly used with architectural designs through incorporating living plants inside, having many windows with desired views or creating green roofs. The second strategy is to provide organic cues in visual design by imitating EEA qualities. These imitations can be realized according to different levels of abstraction. One mode of abstraction is to copy the exact structure of a chosen EEA quality into the visual design. The second mode imitates the structure in a more stylized, abstract way. The assumption is that humans will recognize it as a natural element because of its structural similarities, which will then elicit similar biophilic responses to those of exact replicas or actual flora. Antoni Gaudi's Sagrada Familia as seen in Figure 3 is not only a great example of biomimicry, but also as an abstract form of biophilic design. The ceiling shown is not an exact replica, but the structural similarity is enough for humans to recognize both subconsciously and consciously. The third mode is an even more abstract imitation, imitating a very low level of visual features. Some theorists suggest that designs with three-dimensional fractal properties are able to trigger some biophilic responses (Joye 2013).

Figure 3, Interior of Sagrada Familia by Antoni Gaudi retrieved from http://commons.wikimedia.org/wiki/File:Sagrada_Familia_interior_1.jpg

Meticulously understanding how humans can gain a positive biophilic response in a variety of ways has led to my aesthetic decisions for both my prototypes, as well as inspiring my second to come to fruition. Through exploration of how the entire home can be manipulated to closely mimic humans EEA led to my second prototype, Mwezi. Biophilic design was chosen as my aesthetic since the functional aspects of my designs mimic a fundamental cycle of the earth that humans have evolutionally adapted to. Therefore using visual qualities of human's EEA to induce a biophilic response seemed an obvious approach. Once research was compiled on both aesthetic benefits and technological benefits within natural biology, my research moved into various input benefits to decided on the most appropriate way the devices would be operated within the environment to ensure no discords would be added. The concept of natural interaction was used for the creation of Mwezi.

NATURAL INTERACTION

Natural interaction is defined in terms of experience perceived by the user as being a genuine and/or frequent interaction. The environmental enhancement in smart environments using sensors provides the environment with the ability to act or react to the users specific interaction (Alves Lino, Salem, and Rauterberg 2010). Developing a device that reacts based off of frequent naturally occurring movements, expressions or gestures will make the environmental enhancement more commonly used. The next step is embedding technology into the environment, which is a must for immersive natural interaction to occur. Through seamless environmental integration and input as a frequently occurring movement, the technology becomes invisible to the user making their interactions a natural way of acting instead of feeling forced or fake. Integrating the concept of natural interaction into interactive technology helps to create sensor-integrated objects that can subconsciously be used. Regardless if this object is intuitive or not, the user will not want to use it if natural movement detected by the sensor does not make sense in relation to the output or location in the environment. Likewise if the output provides an overload of unnecessary information or actions, this would be considered a disturbing factor and cause mental fatigue therefore the user again will not want to use it.

Analyzing the use, location, purpose and end user that the smart technology will be placed into, will define how natural interaction should be used. Being aware of each of these aspects and placing them into appropriate context will lower the chances of technological integration hindering the environment instead of enhancing. When smart environments are appropriately used and the feeling of it being technology becomes blurred, subconsciously we view this as being reality or a natural way of being and interacting (Alves Lino, Salem, and Rauterberg 2010). This feeling coupled with seamlessly embedding all physical synthetic materials will further help to create an EEA, reduce possibilities of a biophobic response from a synthetic visual and create a pleasing mental state in accordance with the attention restoration theory. Through minimizing discords and mismatches while maximizing safety signifiers through form and material has not only ensured primary focus to the moonlight of mwezi but has also raised the chances of a biophilic response being evoked through the visual recognition of wood as the material.

By making interactive devices react to "normal" movements, will further remove any inorganic gestures humans have to perform that may trigger their subconscious in an unnatural way. Being able to make the closest resemblance to a human's EEA, while using technology, will only be possible by analyzing every aspect including interaction. There is no need to switch on or off the sunlight outdoors, so why should there be one in our homes? If we want the closest resemblance to how our genetic determinism is "pre-programmed", more than just visual resemblance and function must be considered. Mwezi and Musana are two objects that will help aid in the creation of an all-encompassing Environment of Adaptation for humans in their houses by removing all unnatural stimuli and adding visual biophilic triggers.

CHAPTER 4. PROTOTYPE EVOLUTION

CREATION RESEARCH

Converting as many EEA discords within home spaces as possible to provoke a biophilic response is an easy way to merge our genetically determined and modern wants. The chosen discord manipulated for my final prototypes and all preliminary iterations is artificial lighting. Research on circadian rhythms is a fundamental premise to all of the work I have done and biomimicry was always a central term since all creations involve mimicking a biological cycle. I have also continued to explore biophilia throughout, but the early stages only reflect basic use. On the other hand, natural interaction was only introduced in the final stages as I created Mwezi. The following sections of the document describe my initial idea, two abandoned prototypes, research on existing products and materials that assisted my final prototypes and lastly the process of creating the final prototypes and how they contribute to the overall narrative of my project.

INITIAL CREATION IDEAS

Through studying biological reasoning for why people get seasonally depressed in the wintertime because of poorly synced circadian rhythms and how/why light therapy is a viable pharmacological alternative, I gathered both technical elements as well as user problems to form initial ideas. Combining these led to the very first prototype ideas that were presented during the Encounter Colloquium. The idea was to create a set of bedroom devices to enhance all happenings, both biologically and environmentally that should occur during the sleep/wake cycle. Figure 6 illustrates a miniature of how the artificial lights can be integrated to enhance the sleep/wake cycle. Seen in the miniature prototype is a set of bedroom light devices that are all synced together and mimics the suns cycle, one on the curtain, one on the bedframe, and finally a bedside light that could also be moved around the house. The integrated lights in the curtain idea would brighten, dim and change colour balance according to where the user should be in their circadian rhythm. The bedframe would gradually go through a simulated sunrise into a high brightness low spectrum blue colour when the user wakes up to reset their circadian rhythm, mimicking the idea of light therapy. Integrating the light into the bed frame makes it much easier for people to get morning light therapy while they are still waking up and then will not have to remember to do it after they get out of bed. At night the curtain and moveable light will gradually dim and become a warmer colour to promote melatonin release and help the user fall asleep easier. The time of night that the lights will begin to dim depends on what time the user has set their wake up time to be for the next day, so they get enough sleep and also do not oversleep.

Peer feedback from these preliminary ideas was not to aim at creating a medical device for SAD. Creating this type of device would have narrowed down possible creations because there are such specific technical requirements that would have to be taken into consideration.

Figure 4 Bedroom Set

Figure 5 Foam Prototype

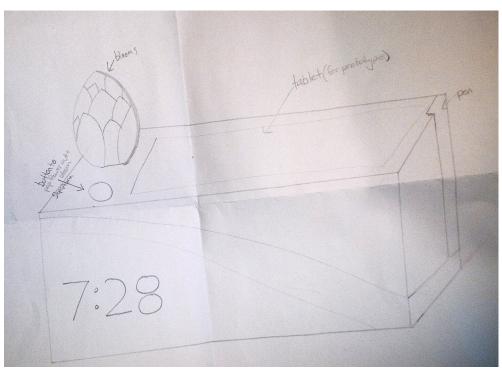


Figure 7 Bedside Device Drawing

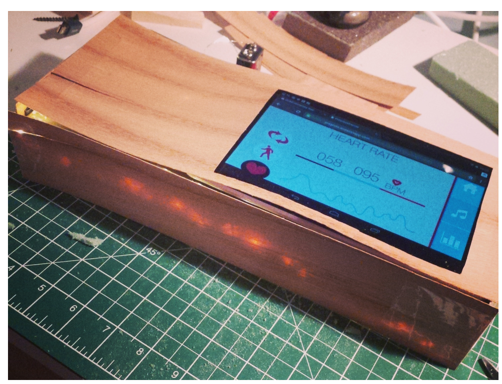


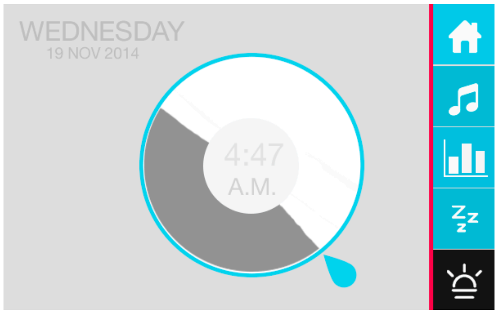
Figure 6 Bedside Device Prototype

BEDSIDE DEVICE PROTOTYPE

As I moved away from the specific needs for people with SAD, I began to focus on ways that the whole sleep cycle could be improved while also including a less intense version of morning light therapy. It is important to understand that this bedside device described below, symbiotically works with the sleeping mask that is described succeeding this section. Three main stages went into the formation of this device, the foam prototype, recreation of the visual design and tablet designs. Biophilia was beginning to be integrated on a basic level at this point.

The main prototype function was to store data tracked from the sleeping mask, and visually display the information on a screen. The first stage was a foam prototype, with an LED string and a flower made out of paper, figure 7. This prototype was used to demonstrate how the tableside light device could look like. The top part of the light, where the flower is illustrated, would be a flat interactive touch screen that would display tracked information. The user could also write on the screen to write down what is on their mind before they go to bed, which is a proven habit used to improve sleep (Sack et al. 2007).

The next stage was a reimagining of the visual design, because making a touch screen from scratch is beyond my capabilities and so in order to insert a screen (tablet), the design had to change so it would fit. I slightly altered the original aesthetic look of the foam prototype on paper at first, figure 8 and then created a physical prototype as seen in Figure 9. I created this prototype by using foam for the interior to create a frame and then coated it with wooden veneer to give the appearance that it is made out of wood. The top part of this device, where the tablet is shown, displays an interactive data set that the user can easily click through. Displayed on the tablet were alarm clock functions, music for energy and relaxation and various data. This data includes heart rate, sleep cycles and, upon waking, there are tips on how to improve future sleep, figures 10 through 15. The next round of peer presentations and feedback was the exposé. For the exposé I presented the sleeping mask and bedside device with tablet inserted.



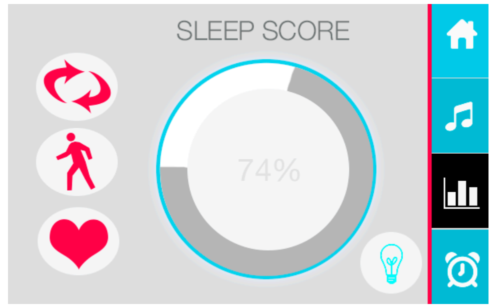
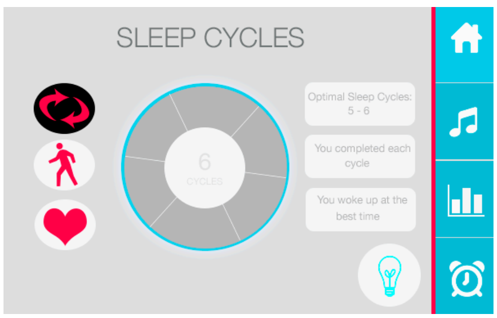


Figure 8, Bedside Device Alarm Clock

Figure 9, Bedside Device Sleep Score



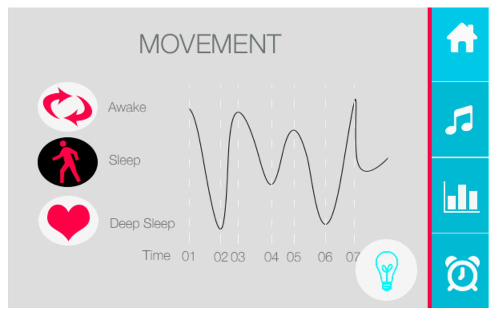
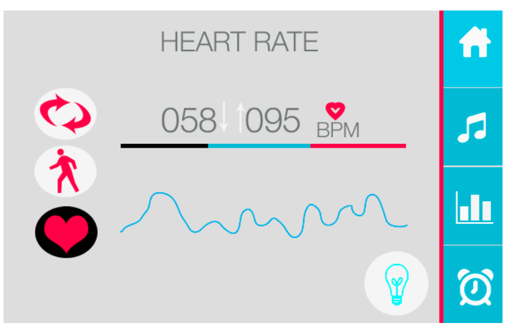


Figure 10, Bedside Device Sleep Cycle

Figure 11, Bedside Device Movement



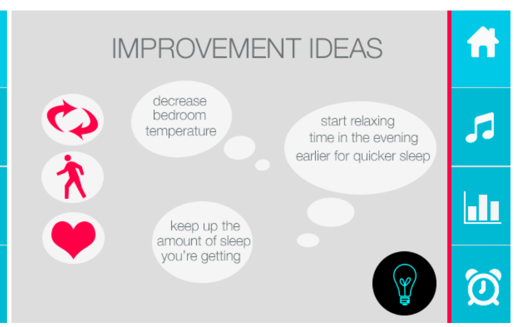


Figure 12, Bedside Device Heart Rate

Figure 13, Bedside Device Improvement

Figure 14, Sleeping Mask Prototype

SLEEPING MASK

The sleeping mask was made in parallel to the bedside device, and therefore was also conceptualized through analyzing the entire sleep/wake cycle. Together the bedside device and sleeping mask would improve circadian rhythms with light therapy and giving the user details about their sleep/how to improve it. This mask incorporated the benefits that morning sun and light therapy has for the circadian rhythm and also improve the user's sleep environment by appearing dark throughout the night. Having dark environments at night, paired with bright mornings can improve the circadian rhythm through a better sleep.

The sleeping mask was incorporated with a pulse monitor, accelerometer and LED's, figure 16. The pulse monitor and accelerometer were decided on to track the users sleep based off of product research on other sleep tracking products. Research shows that throughout the night a person completes various sets of cycles that switch between deep sleep and light sleep. During a deep sleep, it is harder to wake up, and in a light sleep it is much easier to wake up. Many products, including simple apps, track these sleep phases through either movement and/or heart rate to decipher which sleep phase a person is in, and then will trigger their programmed alarm only when it is detected that the person is in a light sleep. This idea was implemented into the sleeping mask, and instead of a noise alarm the integrated light was used to wake the user. Having an eye mask and bedside device that is automatically synchronized together is much easier for people to use, setup and understand. The sleeping mask was not only meant to deliver light therapy quickly, easily and efficiently, but would also monitor sleep cycles.

INTIAL PROTOTYPE REFLECTION

Through feedback, creation and product reviews I gained key insight that transformed these two prototype concepts and led to the final thesis outcome. While creating the bedside sleep tracking device and light up sleeping mask, I realized not only that a sleep tracking theme did not elucidate much interest, but also that there are many similar products to the bedside sleep tracking device already in the market. Additionally some of the more advanced products such as *fitbit*, *Sense/SleepPill* and *ResMed* far exceeded my technological capabilities meaning I would be making a product that would be of less value than is already available. Specific qualities that exceed my capabilities for various reasons include the size of *Fitbit* and *Sense/SleepPill* making them a very easy wearable or clip on for sleeping and *ResMed's* advanced motion sensor using bio-motion technology to wirelessly measure breathing and body movements throughout the night. After an exploration was made on one part of my initial idea, I began again with my preliminary ideas and took a different path to explore, leading me to the final prototypes.

INDUSTRY PROFESSIONAL INTERVIEWS

Two professionals provided feedback and insights that were important in the development of my final prototypes. The first professional, Dr. Roger Hall, is a consulting psychologist who works with professionals to improve their life and work performance. Through discussion with Dr. Hall about my interests on lighting and wellness was when I learned of light therapy. Prior to this discussion I was not aware of any connections between my two interests. Learning about light therapy also guided me into circadian rhythms, creating the basis of my entire thesis exploration.

During the exploration and creation of the sleeping mask and bedside device I was able to meet with Dr. Henry Moller from Praxis Holistic Health. Dr. Henry Moller is a holistic medical practitioner with extensive knowledge on the topics of sleep, circadian rhythms and various other non-SAD light therapy treatments. He was able to help me decide which direction I should take with my thesis by providing advice on what his patients would prefer and also by knowing current products out in the market. The direction suggested by him is to continue exploring how to improve people's wellbeing by using light and discontinue the element of tracking sleep. This suggestion further solidified my personal decision as previously mentioned.

VISUAL & FUNCTIONAL INSPIRATION

After the two sleep tracking prototypes were set aside and all literature research topics were analyzed, visual and functional research was undertaken for further inspiration. Creating innovative prototypes for environments was a huge driving force for me from the beginning and each visual presented in this section played a critical role in shaping and guiding me to the final two prototypes. Some products were examined in detail, whereas others were briefly understood or simply acted as visual aid to help with aesthetics. Each visual inspiration of this section briefly describes what it is and who made it and how they contribute to Musana and/or Mwezi both visually and functionally.

Glowing Places developed by *Philips Design*, and *Light Form* by *Francesca Rogers*, figure 18, are two interactive lighting installations that have inspired both my prototypes in similar ways. *Glowing Places* are plastic seats that measure the presence of both the number of people sitting and the length of time they sat for, while Light Form is a wall installation with lights that can be opened and closed. These ware two visuals that opened up my mind to more creative alternatives; both visually and functionally, on how light can be installed inside artificial environments and lent to some inspiration for both prototypes. Both installations seamlessly integrating all technical hardwire with no direct visual inspired both of my final prototype ideas. The simplicity of the gestures that is detected or needed makes these good examples of how natural interaction can be utilized into industrial designs. *Glowing places* is set in a public environment, with no obvious cues that would direct the user to assume it is interactive. Functional insight gained from both, but more so *Glowing Places*, directly relates to the interaction decision made on Mwezi. Using the aesthetic design, in this case a chair, to change states when someone performs the function of the design, sitting, is a very basic yet extremely effective way to ensure the interaction is natural. The idea of designing a well-known item to ensure interaction is natural, gave me the idea to use a floor with the interaction of walking. Although the wall is not usually interacted with by opening and closing, opening items to reveal something is. Also the concept of there being light all across the wall aided in my decision to create a wall installation instead of window only. Another visual explained, *BioWall,* was the inspiration that led me to the wall design of Musana, however *Light Form* further persuaded the direction.

The next five visual inspirations have biophilic qualities to them that acted as visual aid, and three of these visuals directly inspired specific creation processes, but none directly inspired either of my final prototypes.

Loop.pH, is a company based out of London, England that merges space, technology and living matter into a visionary experience. A lot of their work acted as an inspiration to me visually, more than just the two installations documented. Their first installation that I came across was *Kensington Archilace*, figure 19, a permanent light installation in Kensington Palace. As seen, he light installation forms into a tree. Another obvious form of light mixed with biophilia is made by *BW Architects*, a kinetic installation of LED flowers that was presented at Tribeca Film Festival in 2013. Each rod was set at different lengths to create varying movement and speed activated by the wind. Another non-abstract form of biophilia is present in *Digital Dawn* designed by Rachel Wingfield, co-director of loop.pH, figure 20. This window feature uses electroluminescent technology and conductive phosphorous printing inks that emit light to create a foliage effect. It uses light sensors to monitor the changing levels of light in the room and will “grow” depending on the dimness. The biophilic response that is provoked by this piece is through both form and function of the vines being present as well as growing. All three of these installations show how light can be made to trigger a biophilic response and show a very non-abstract form of biophilia.

The concept of Digital Dawn was an inspiration to Musana’s prototype conceptualization. The inspiration was brought on through combining the progressive lighting function with the second documented piece created by *Loop.pH, Biowall*, seen in figure 21, a hand woven three-dimensional structure that can be crafted into surfaces of any dimension and form used for plants to grow on. Visually, this wall mimics formations of bubbles, living cells and water molecules that can create a biophilic response. Both installations combined together as inspiration to the creation process of Musana due to their biophilic forms. Specifically, BioWall led to a visual wall design to elicit a biophilic response while combining the lighting technique seen in Digital Dawn of it progressively turning on.

Lastly, a custom wallpaper company called *ROLLOUT* created wallpaper that represents how actual outdoor materials (wood) can be merged with light. Although this is a wall installation it inspired an initial floor layout of Mwezi. Having light shine through wood in this way led me to the miniature floor prototype I created but did not get used in the final for various reasons, detailed in my prototype process.

Figure 15 Light Form, retrieved from Evolo, http://www.evolo.us/architecture/light-form-is-a-modular-lighting-system

Figure 16 Kensington Archilace by Loop.pH, March 2012 http://loop.ph/portfolio/kensington-archilace/

Figure 18 Digital Dawn, February 2003, by Loop.pH, http://loop.ph/twiki/bin/view/Loop/DigitalDawn

Figure 17 Biowall by Loop.pH http://open.loop.ph/bin/view/Loop/HauteGREEN

MATERIAL RESEARCH

Various materials for both of the final prototypes were used, such as wood, RGB LED strips, conductive thread, conductive tape, Velostat, EL wire, flexwood and plastic tubing. Most of these are well known, however there is a few that is not and need further explanation. Furthermore this section will detail two materials, OLED and UV lights, that were not used, but are mentioned under future steps. These materials are explained in detail regarding what they are, how they work and where/if they have been integrated into the prototypes.

Incorporating light through mimicking the sun for the final prototype was the dominant focus throughout the course of the research and creation. Since light was always going to be a crucial aspect of the creation, researching on types of light available was very important. Types of light that were used in the final prototypes are RGB LED strips and EL wire. OLED's and UV lights were also researched and will be discussed. The original window idea, light-up eye mask and the final floor prototype need a light source that is flexible, and resilient. Electroluminescent (EL) panels, wires or strips, figure 25, are comprised of a conductive phosphor material sandwiched between two transparent films. An even more flexible and resilient EL panel has been invented by *Oryon Technologies* called *ElastoLite*. This type of panel is created in a similar fashion, with slight alterations; figure 26 shows how ElastoLite panels are made. This particular type of EL panel is waterproof and similar flexibility to fabric, figure 27.

EL wire has been used in Mwezi as the only light source because it is resilient, inexpensive and provide a gentle, even illumination instead of showing varying pixels. EL wire was chosen over panels and strips for reasons related to cost, wire amount, needed area and plug-in limit on arduino shield. Each of these details is discussed in more detail in the final prototype section. Although having steady, even illumination would have aesthetically been nicer for Musana, the cons of EL greatly out weighed the pros. EL cannot can change colour and they are very dim, which are two key functions Musana is based off of. RGB LED's are used for Musana because they are flexible, bright and can change colour by being programmed with the only downfall that it illuminates in pixels instead of evenly distributed.

A relatively new form of light, organic light-emitting diode (OLED) is a combination between LED and EL, both in abilities and how it is made. OLED's are able to do all the functions of the LED strip while combining the physical benefits of EL, flat and evenly lit. This technology is not easily available to the public, nor is it easy to program. This is why OLED's are discussed in my next steps as a different material to be incorporated.

The use of UV lights is also mentioned under future steps, which was suggested by one of the interview nurses. The sun naturally gives off UV light and artificial UV light can give similar benefits. These lights can provide vitamin D, air and water purification, sterilization and help in the treatment of skin conditions such as psoriasis and vitilgo.

One of the main materials used in Mwezi is called velostat, as seen in figure 29. Velostat is a conductive, pressure-sensitive material therefore can be used instead of force sensors and also can be cut into any size. The discovery, and use, of velostat eased many issues that would have been present if regular force sensors were used for the entire area of Mwezi. Velostat is easy to connect and is the exact same as a regular analog force sensor input. Force sensors that are sold to the public for micro-controllers such as arduino, are very small in comparison and the price of one 1.5" square sensor is about six times the price of a 36" square velostat sheet. Since velostat can cover a much larger surface area at a much cheaper cost it has made wiring less chaotic, ensures none of the surface area is empty and has allowed for more freedom in the size of the final prototype.

The last interesting material found, allowed for more freedom and is used in both of the final creations, Flexwood made by Sommers, figure 30. Flexwood is extremely thin cut wood finished with either a resin or cotton backing for support. This material is used in both Musana and Mwezi to elicit a biophilic response since it is wood and also because of its thinness for the most amount of light to shine through. It is used in Musana specifically to cover the entire strip because of its versatility, which has enabled the entire design to be created and is explained in more detail under final prototype section.

Figure 19 Elastolite

Figure 20 Velostat retrieved from https://www.flickr.com/photos/adafruit/8723488129/

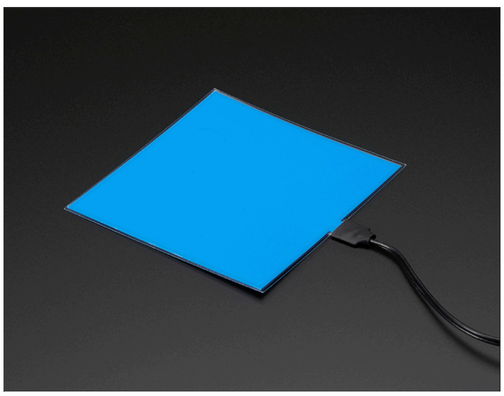


Figure 22 EL Panel retrieved from https://www.flickr.com/photos/adafruit/12777831255/

Figure 21 Flexwood

Figure 23 OLED retrieved from inhabitat flickr,
https://www.flickr.com/photos/inhabitat/10577100754/in/photolist-h7Epy7-h7FujM-6Trwge-h7E522-h7Eqcb-h7EiiU-h7FvUk-h7EpSd-h7E4wz-h7Fvkz-h7Ehhf-h7Ehgd-h7Fuoz-k5hUxS-gGEX9X-7mbWdj-qM8uWy-oTnYMo-oTnY8h-d4MApm-d4MA9h-dLUR9K-dLUR26-b9PvbD-iZrhzk-b9Pv2a-j5sk5C-cxUApN-6741Ut-j3M39D-eZd6QN-b9PvrR-5AxqWM-oXnDQj-peRT7K-oXmEnz-pcPWwY-oXn1i7-oXnEBu-oXnM1b-pezXzv-q7gBtW-kVt1Qi-dMMA6V-qE5W9W-qnHmdp-qE9Nia-b9PvhX-5fCTij-h7E3fr

FINAL PROTOTOYPE PROCESS

The final prototypes developed are titled Musana and Mwezi. The names are based off of the idea that humans evolved in the East African Savannas and are therefore genetically determined based on its qualities. The two prototypes are named from the Lugandan language, Musana meaning sunshine and Mwezi meaning moon. The wall installation, Musana, mimics sunshine and is used throughout the daytime for proper circadian rhythm functioning while the floor piece, Mwezi, mimics the moon and is used at night to keep a relaxed state for easy transitioning to and from sleep. Both prototypes benefit people who constantly need to change their sleep schedule, or on majority work inside artificial environments by turning spaces into a closer resemblance of human's environment of evolutionary adaptation through removing/hiding discords and both aesthetic and functional safety signifiers. Every added element in the biomimetic design process of Musana and Mwezi has been selectively chosen so they will induce a biophilic response, sync the circadian rhythm and make interactions natural.

USER TESTING

Once the preliminary core concept and functional ideas for both prototypes was complete, user testing began. Up until this point the prototypes were formed from research on circadian rhythms and light therapy. The main reason for testing these pieces was to learn if the users found the purpose and aesthetic appealing enough to have in their home environment. Five users were tested, two of which are registered nurses. Both of the nurses gave feedback based on professional knowledge as well as being shift-workers who constantly change their sleep schedule and disrupt their rhythm. They were able to professionally confirm that my functional design strategies made sense with the concept of light therapy, provide professional feedback for future steps and give feedback as to if they would personally use it and/or see other shift workers wanting to use it. The other three users were not shift workers or industry professionals, and therefore only provided knowledge for functional usability and aesthetic preference when needed.

A common issue brought up from these users is whether it would work for shift workers since they still go outside to travel to and from work. Based off of light therapy research, the most important time to be exposed to artificial sunlight is directly after waking up. Therefore, shift workers travel time would not have much effect. Through sunlight simulation, the internal clock will naturally adjust and shift workers will then be able to correct their sleep/wake schedules much quicker than relying on the homeostatic process solely. Secondly, a common issue with night shift workers is that they usually have higher homeostatic sleep pressure compared to day shift workers because most shift workers wake up way before they need to leave for work and go to sleep directly after their shift (Santhi et al. 2005). Musana would further alleviate this issue because it not only provides sunrise simulation but it also assists in letting the shift workers know when they should be getting tired and the time to go to bed thus alleviating homeostatic sleep pressure from occurring while at work.

The first user testing session, and the only testing on function was with a 3D animated model. This test was conducted to gain feedback on the functions and purpose after explaining the background literature concepts. During this first session, a focus was primarily placed on guaranteeing all users understood how both installations worked. Second focus was placed on confirming that each aspect of the visual design was pleasing and the users would want them in their house. These two aspects are very important to the installations because without ease of use and appealing aesthetics, people either would not want it visible or in every room of their house or would forget to use it, thus not aiding their circadian rhythm. After the first session confirmed my design plans, users were periodically asked throughout the creation for aesthetic opinions/confirmations. These opinions are discussed throughout various stages of each prototype's creation process when feedback was used.

MUSANA & MWEZI PRELIMINARY USER TESTING

The first user-testing session was a fundamental step to explain the core concepts and functions before jumping into physical creations. Figure 31 is a still image of the animated 3D model used for the first user testing session that showed Musana's and Mwezi's functions as well as general placement in a home and form without too much detail. This testing mode was used for the first testing sessions to see if the operations, biological effects and visual design were liked and valued before spending a lot of time creating something that might have to drastically change. During testing, the model was animated and showed the wall installation going through sunrise, daylight and sunset. This first stage of testing permitted the process of both prototypes to be shown together and allowed the participants to gain somewhat of an understanding for the basic structure when placed in a home. Design details were intentionally omitted to encourage users own aesthetic flow of ideas and also if they did not like the details it may have misguided their functional feedback. Very minor functional feedback was provided; all was directed to Musana such as power consumption, light layout and wanting manual overrides.

This model represents the first concept that included the idea of integrating light sensors into the window portions so that the lights arranged over the windows would turn off if adequate light was outside thus minimizing power consumption. Most of the participants questioned why the lights were placed over the window and a few were concerned about unnecessary power consumption if the lights are on in all rooms when no one is around. They understood the light sensor concept but still did not perceive enough of an added benefit to have them over a window.

The idea of having a manual override was brought up during discussion about power consumption, and also wanting them to be dimmable if it causes glare to screens. These minor issues have been conceptually implemented for a home environment and are explained in more detail in the next sections. In conclusion this test was successful and every participant expressed great interest for the overall concept and the benefits it would induce. No one had any strong disagreements that changed the concept, only suggestions for minor changes, future research and add-ons. Professional suggestions from the nurses for future applications and research was that it makes more sense in work environments, has the potential to decrease consumption of uppers such as caffeine to stay alert thus increasing health and the implementation of UV lights that were discussed in the material research section.

This testing confirmed my design strategies and led to a few suggestions for improvement including more aesthetic options, moveable light, UV light, custom controls and eliminating the light over the window. None of the users had any issues with the inclusive purpose and use of each prototype; therefore their feedback has mainly been used for future ideas and visual design preferences. The rest of the minor user-testing results are mentioned throughout both of the prototype's design processes as their feedback was used.

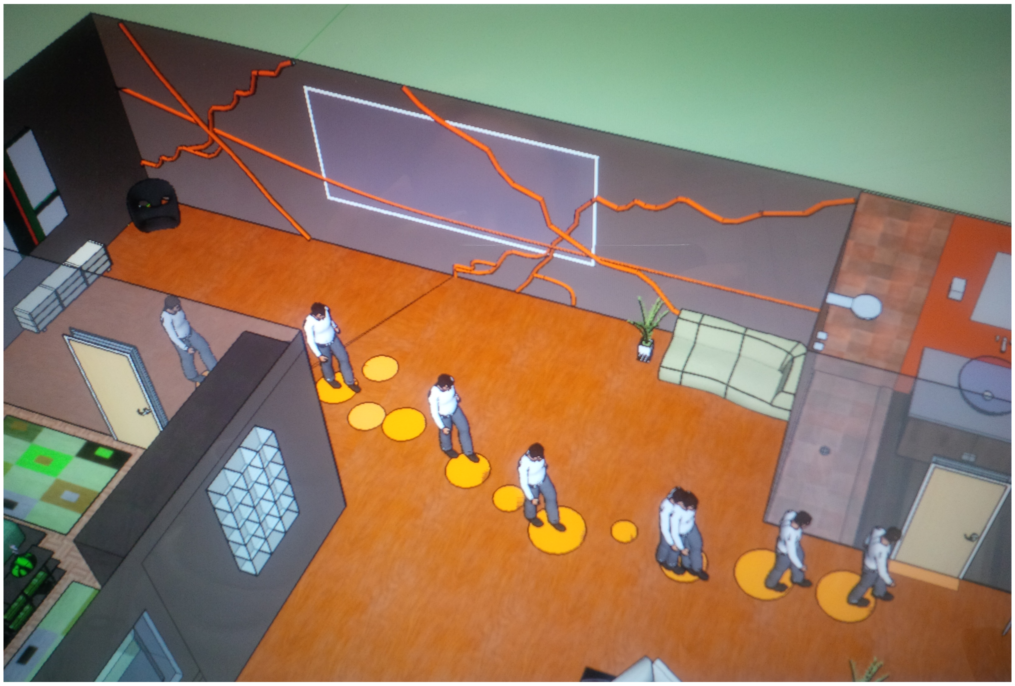


Figure 24 Animated 3D Model of Musana & Mwezi

MUSANA EARLY PROTOTYPES

Musana, meaning sunshine, is a circadian balancing artificial indoor wall light that simulates sunrise, sunset and daytime light colour cycles proven to increase energy during the day and sleepiness at night. This specific prototype exploration resulted in the creation of an artificial light installation designed for a wall. Early prototype ideas of artificial light in/over windows were formed through applying the fundamental knowledge on circadian rhythms and light therapy then later biomimicry and biophilia. Through discussions with professionals, family, friends and peers and inspiration from visual research, the final wall installation concept rooted. The concept became fully formed after an amalgamation of technical and aesthetic obstacles and user feedback. Musana's final design is created using programmed RGB LED strips, flexwood and wooden wall base structures.

Issues investigated in this preliminary stage of the process were caused because the first concepts were window based and either blocked natural sunlight or sunlight altered the artificial light. The concept that began this investigation was a curtain idea with integrated lights to mimic the sun. Changing this concept resulted after informal discussions giving me insight into what people liked and disliked coupled with visual and literature research. The core themes of circadian rhythms and light therapy were liked, while the facts that a curtain would physical block their view and natural sunlight from shining through was not. This investigation was taken on through research into visuals, primarily *BioWall* and *Digital Dawn* and biophilia.

Through focusing on ways to eliminate anything covering the window, the first idea was to create small geometric 3D objects that would be placed in the window and wall corners. This approach would overcome the issue of a curtain blocking actual sunlight, however, it would not provide adequate lighting coverage for the user to biologically notice a colour difference.

At this point, in-depth literature and visual research on biophilia began, coupled with the discovery of the organically structured installation *Biowall* and EL wall display *Digital Dawn* that were previously detailed in visual inspiration. Elements from *Biowall* led me to the first concept that sparked the final prototype, while *Digital Dawn* was a key inspiration at this stage, it did not pass on to the final prototype creation. This concept still began as a window idea, but sunlight could pass through because it would just be wires over the window, it then grew into covering part of the wall also. This installation idea was to have fake plant pots at the bottom and then EL wire along the wall in a similar form as *BioWall*. As the day progresses, the fake plants would “grow” up the wire making it progressively brighter while also changing colour temperature, this function was provoked from *Digital Dawn’s* function of “growing” light. Conceptualizing this prototype into a wall with artificially growing lights and deviating away from window ideas led to the final idea. This idea was not used because the functional aspects of it beginning dim and gradually getting brighter as the day progresses do not properly follow the concept of light therapy.

Draping artificial lights across a window and wall to mimic growing plant life for a biophilic response coupled with the light changing colour throughout the entire day based off light therapy is the first stage of the final prototype design for Musana. The issues investigated that lead up to this point such as blocking the sun, providing enough lighting and ensuring light therapy knowledge is implied are solved with this design. Since the light strips would only cover a portion of the window, the problem of blocking natural sunlight and/or view would not be present. On days that plenty of natural sunlight is present and coming through the window, a light sensor would signal for the window lights to automatically be shut off and gradually get brighter the further away from the window. In a home environment, Musana will ideally replace all artificial lights in the house and would be placed in every room. The idea reached at this stage was the same concept shown in the 3D model for preliminary user testing, figure 24. Issues that this specific prototype solved were investigated through the implementation of visual and literary research and the necessary implementation of qualities of light therapy.

MUSANA CREATION RESULTS & CHALLENGES

FIRST STAGE - LIGHTING

After the 3D model testing confirmed functional interest, the next set of investigations began through physical creation. Most testing feedback about lighting changes and/or add-ons has been placed into future steps either due to time constraints, technical barriers and/or the context of where these prototypes will be displayed. This stage did not use any user testing. Literature research was used to form the technical lighting requirements.

This first necessary step for creation involved the use of addressable RGB LED strips to test ways of simulating the sun's three cycles: sunrise, daylight and sunset. It is important to state that the lights only reflect colour change, and stay at a consistent comfortable brightness, with the option of manually dimming or turning off. Traditional light therapy is a very high intensity and if used for too long can make a person sick. So for this reason Musana is made to only reflect colour temperatures similar to light therapy. The reason addressable RGB LED strips were chosen is because they are many light in one long strip, small in both width and thickness, flexible, not very fragile, and have a wide array of programmable colours. Non-addressable RGB LED strips were not used because they are now outdated since addressable strips are available, making them hard to get and their colour range is also extremely limited.

Creating these cycles had many unexpected technological obstacles as well as slight adjustments that were needed along the way to fit the end context Musana will be shown in. This strip involves complicated libraries, and even more complicated DIY coding that caused the root for each lighting issue. The technical lighting issues were getting all lights to turn on at once, gradually fading all lights from one designated colour to the next and lastly the difference in RGB value input and LED output needed to be meticulously calibrated. Secondly, since the context of Munana is different than traditional light therapy and the final environment it will be shown in is a simulated home environment instead of an actual one, some slight unforeseen details were altered including brightness, duration of cycles and lastly what will trigger the cycles to begin.

In the process of prototyping and coding the light cycles I collaborated with an electrical engineering student, Ishan Sharma. Our work together, although for a minimal amount of time, proved to be a successful collaboration to which I attribute the majority of overcoming Musana's coding challenges.

The colour temperatures for each cycle was first gathered through light therapy research to ensure validity, then slight adjustments were made to reflect the context Musana is intended to be shown in and the technology I had access to. Simulated sunset cycles usually fade to no light, however in a home context Musana replaces all lights in the house which means the entire house would go dark whether or not the household is asleep, which is unsafe. In a home environment Musana will have a manual control and the light will never turn off on its own. A second adjustment made was having to create our own daytime cycle to gradually fade from sunrise to sunset with blue light therapy colour temperature in the middle, since all other morning and afternoon light therapy colours do not change.

The colour temperatures used for each cycle are as follows. Short wavelength blue tones around 480nm (10 000k) are ideal for morning light therapy and afternoon therapy. Dusk and dawn simulations should last 90 minutes and progress from or to 1800k and 300lux max, depending on if it's dawn or dusk (McClung 2007; Santhi et al. 2012; Terman 2007). A list of specific kelvin colour temperature ranges were then converted to RGB values for each cycle to get a start value and an end value. A photography chart on colour temperatures was used for further guidance to create appropriate ranges between each cycle, and is inserted into this document as reference to the colour scale that the sun cycles through. In this process, we realized that the RGB values inputted were not being properly outputted. This chart was also used as reference to help calibrate the light output to match each appropriate colour temperature.

With the help of Ishan Sharma, each sun cycle, sunrise, daylight and sunset, was accurately prototyped with proper colour temperatures using addressable RGB LED strips. During this process many coding challenges and areas that were previously overlooked, arose along the way that were overcome. The three functioning cycles gradually fade from sunrise to daylight to sunset with the daylight cycle obviously being the longest and sunrise and sunset lasting 90 minutes each.

SECOND STAGE – AESTHETICS & STRUCTURE

After having designed the ideal colour cycles, I began the process of aesthetic testing through biophilic qualities. The goal of this stage was to generate a biophilic response through visuals while ensuring appeal to be added in a home environment. Health studies were used for reference that a biophilic response would occur when implementing various elements. In parallel to exploring the visual form, light quality and stability of structure was a constant consideration during physical creation. When beginning this investigation the first task was addressing which safety signifiers to use, then implementing biophilic characteristics while also considering durability. Once these were concluded, lighting conditions were researched to depict ways for combining these characteristics. During this stage literature research and user testing were intertwined together. Literature research was used to develop the core aesthetic and user testing was done when decisions between designs was needed.

The dominant safety signifiers, based off the East African Savanna EEA theory, are "relatively smooth ground textures and trees that help define the depth of the scene" (P. H. Kahn 1999, 10). The most common grass and tree native to this Savanna are giant naivasha star grass and acacia trees (Webber 2002). Based off of these dominating safety signifiers, material connections and biomorphic forms and patterns were researched and created. The growing plant form across a wall was already introduced in the first user testing and so the overall form was already understood, just no specific plant reference, form details or how it would stay on the wall were yet made. Material decision and initial form inspiration and creations were made before any user testing was done. User testing during this stage was mainly used for decision between aesthetic choices or to confirm aesthetic choices made.

Flexwood was chosen because it is very flexible to wrap around the light easily, thin for light to shine through and durable. A health study further confirmed this choice. The study was of wood on walls in interior spaces that led to health benefits of decreased diastolic blood pressure and increased pulse rate (Terrapin Bright Green 2012). Upon trying both samples of the plastic backed birch and cherry, a quick and easy decision was made to go with birch. When the cherry veneer was draped over the LED strip, it drastically changed the colour of light and gave a red hue. Neither of the cotton backed flexwood samples worked appropriately because they were too thick and made the light very dim.

The final whimsical twist shape in figure 31 was decided upon through visual inspirations, research on naturally occurring light conditions, needed support and user testing. Although this lighting is already simulating naturally occurring colour change, simulating sunlight's varying intensities of light and shadow through layering light sources can help create a pleasing visual environment (Terrapin Bright Green 2012). This concept was used when creating the twisted prototype, not the basic wrapped version. Biomorphic forms and patterns investigated were symbolic ways to reference contours, patterns or textures that persist in the star grass and acacia tree. Initially two different forms were created using flexwood to surround the LED strips, figure 26, which were then shown to users to decide between the two. The top of the strip is the wood simply wrapped around, and the bottom was created through using multiple thinner strips twisted around. These twists were initially inspired from a look of a vine allowing for a more organic appearance. The branches of the Acacia tree, figure 25, were used as inspiration for how to place the lights crawling up the wall.

After creating the two designs and initial wall design was thought of, user testing was done to direct next steps. This testing concluded the preferences for the twisted form and confirmed choice of tree pattern going up the wall was a good decision. All participants preferred the twisted vine inspired mimicry because they thought it looked more organic and would prefer the design in their house. The use of a light coloured wood was also liked because it would add some aesthetic intrigue while also blending in. The growing acacia tree branch idea was confirmed and a future suggestion was to create an additional device that could be moved around. This device could either resemble a tall leafy plant or be a wall divider with the same acacia inspired root structure.

Once the general vine twists and acacia root structure were decided upon through research and further confirmed from the users, the next step investigated was how to create durability with many thin strips and securely hang it on a wall. The three focuses during this test were to ensure full coverage of the LED strips, wood strips would not lose shape and all light was visible.

Clear plastic tubes and wire, figure 27, 28 and 29, were initially tested before finalizing on the support system. The plastic tube was tested because it would provide an easy base to secure to a wall and hold together all the strips in place. This would allow the strips to be easily installed by users at-home. Two tests were done with the tubes, one with the wood and lights inside and the other with them on the outside. The plastic on the outside was not used because it created an artificial layer that took away from the organic patterns, and the second one aesthetically was not very pleasing and the plastic tubes turned out to not be as malleable as needed. The wire was then tested, and worked well, but still needed a base to secure the light onto the wall. Upon creating and testing a base, the wire no longer needed to be used. The final base used, figure 30, not only provide an easy way to nail into a wall but also reflects the light, secures the wood strips and allows for full LED strip coverage. The raised side was implemented to help cover all synthetic qualities of the LED strip by giving the wood strips another depth to be secured onto, which then allowed for additional area to get covered.

Reflective tape was added inside of these bases to help reflect the light shone inside.

Once the wooden bases were chosen, the wood twists were slightly altered to fit on the wood bases and also to further hide the artificial elements of the light on a large scale. Since the flexwood is actual wood, there is a limit to its flexibility. This limit is what made the need for certain structural implementations, yet it is also what made the final design how it now is. Slight change in the layout of the twists was implemented to give a better light effect and further covering for artificial material. Inspiration for this change came from the way grass twisted. This changed the wood strips from being tightly wrapped around into them being lightly layered on top like the final shape shown in figure 31.

The final aesthetic decisions, described next, were all initially created through literature research findings and user testing was only used for confirmation along the way, or choosing between multiple designs. There was no aesthetic user feedback that greatly altered the look of Musana.

Figure 25 Acacia Tree retrieved from Fish and Wildlife Service, photo by Gary M. Stolz http://www.bestphotos.us/photo/wo124-umbrella-thorn-acacia-tree-5911.php

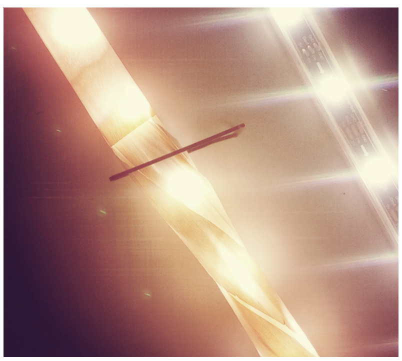


Figure 27 Musana Flexwood Twist

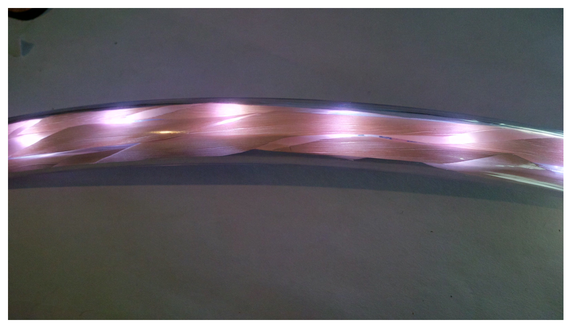


Figure 26 Musana Tube Test - Wood Inside

Figure 28 Musana Wire Test

Figure 29 Musana Tube Test – Wood Outside

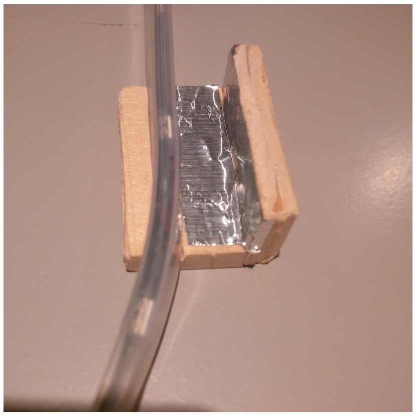


Figure 30 Musana Final Wall Base

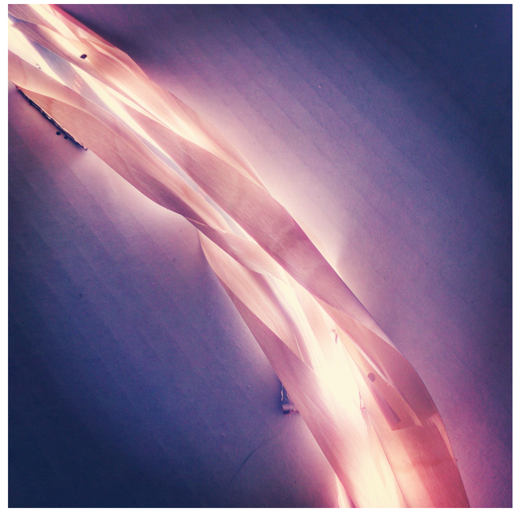


Figure 31 Musana Final Aesthetic

Figure 32 Musana Final, Lights On

MUSANA FINAL PROTOTYPE

Musana is for a home environment, however the final prototype has been designed to reflect it being shown in the thesis exhibition and because of this there are two variations; one conceptualized and one actualized. One is explained for home use, and the second is the setup for an exhibition. In a home environment, the sunrise cycle would automatically start based on the wake-up time set by the user. This is set through a simple LCD screen and individually customizable per bedroom, with the main rooms synced together to a specific time. There is a manual override to dim chosen lights when needed and save electricity when no one is using the room.

The final prototype for an exhibition space is setup in such a way to help people understand that each colour represents a very specific time of day and alters their biological state. Through encouraging interaction, it forces the user to become engaged therefore leading to subconscious understanding of each cycle instead of assuming irrelevant reasons for the light colour change. There are three large buttons on a wooden panel to the left of the wall with the lights, one yellow for sunrise, one blue for daylight and one red for sunset. To the right of each button is a simple recognizable icon attached to the panel, a sunrise icon, daytime icon and sunset icon. Two posters describing what each of these cycles do and how they biologically affect humans are placed on the wall beside the buttons. Figure 32 is the final prototype display for the show. It is a freestanding wall within the gallery space. Some parts of it are tree representations and some parts are the light.

PROTOTYPE #2 FLOOR INSTALLATION - MWEZI

Mwezi, meaning moon, is a circadian balancing indoor artificial light that simulates the moon's colour temperatures and dimness that has been proven to increase melatonin production at night (Brown 1994). Exploration of this light resulted in the prototype creation of a floor integrated with interactive artificial light. Early prototype ideas were implemented through applying the fundamental knowledge on circadian rhythms, dusk simulation light therapy, biophilia and natural interaction. Mwezi was conceptualized after Musana, with the intent to create a prototype that helps to minimize the disturbances that occur from light when a person wakes up at night. The concept was fully formed from an amalgamation of technical and aesthetic obstacles and user feedback.

Materials used in Mwezi's final design include EL wire, flexwood, Velostat, Plexiglas and wood planks.

Mwezi addresses the disturbances that occur when a person wakes up at night and needs to get out of bed and when others wake up a person turning on a light at night. The visual design was inspired by research in bioluminescence, Figure 34. Bioluminescence is the production and emission of light by a living organism. The plants at night in the movie *Avatar* are also based on the concept of bioluminescence, with the added feature of lighting up with human touch. Both of these became a large inspiration for this concept. From this, the idea of incorporating EL panels into the floor with force sensors was rooted. As illustrated in the 3D model, once someone wakes up at night and starts to walk to another room their path will be lit as they walk. When the user steps on a force sensor under the floor, the floor lights up beneath them and a few inches in front of them. In addition, well-placed strips of light illuminate where doors and/or fixed obstacles are situated. The light is colour-balanced to emit a similar Kelvin temperature colour to the moon, which is an orange/red tone (Santhi et al. 2012). This reduces, and sometimes eliminates biological disruptions caused by light when a person or their partner has to get up at night. Instead of turning on bright artificial indoor lighting that wakes them up, they instead are able to see their way simply by walking. The combination of appropriate light colour, dimness and natural interaction makes the transition from unplanned waking at night and going back to sleep much easier and quicker. The colour temperature combined with the dimness of the light helps to maintain a resting state circadian rhythm, therefore reducing the initiation of biological processes that occur when one wakes up. Mwezi is designed to not only keep the user in the appropriate biological state, but also eliminates the search for obstacles and light switches. This reduces the number of decisions the person has to make, allowing users to stay as rested as possible for easy transition back to sleep.

This was the concept discussed with participants during the first 3D testing session. All testers quickly understood and appreciated the benefits of dim moonlight coupled with natural interaction when he or she briefly gets up at night. User testing done for Mwezi after the initial testing discussed was to only during preliminary stages to confirm layout and listen to any issues they had with the current layout to fix for the final.

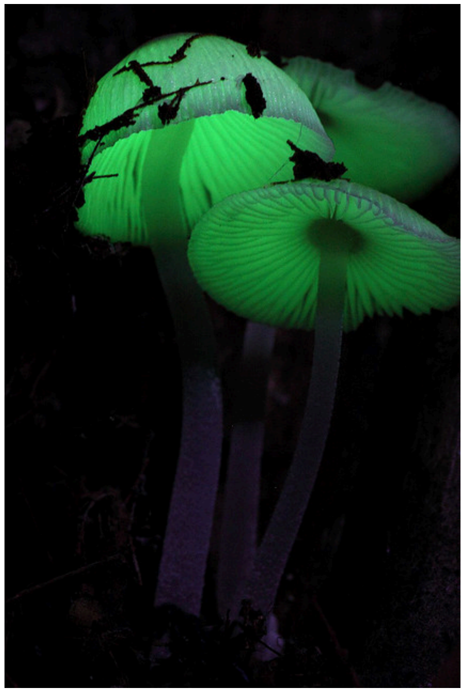


Figure 33 Bioluminescent Magic Mycena Mushrooms, photo taken by Angus Veitch, https://www.flickr.com/photos/gusveitch/4424617758/in/album-72157623556574136/

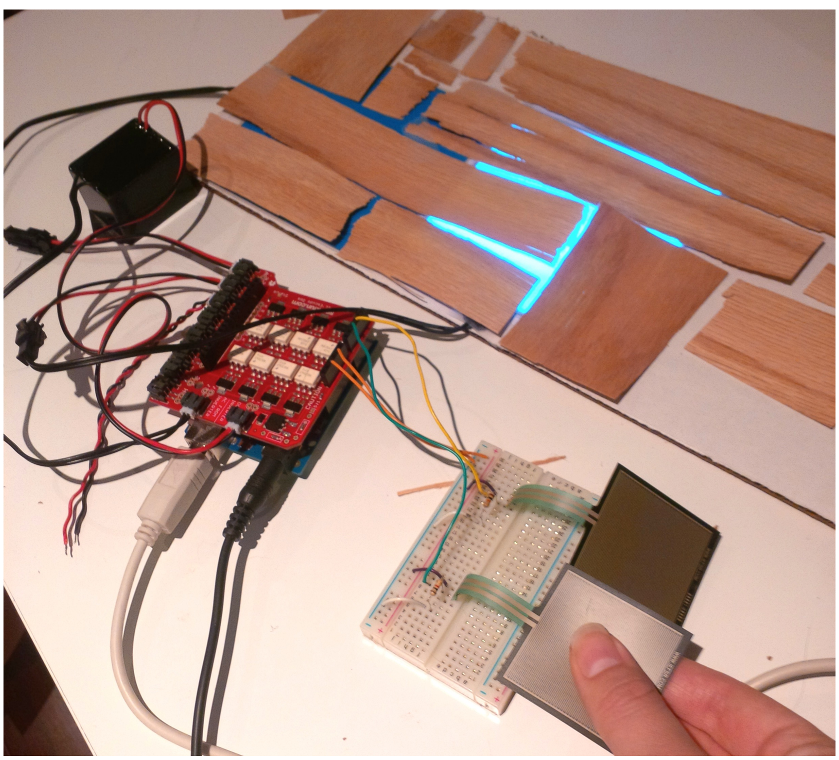


Figure 34 Mwezi Miniature Test

CREATION RESULTS & CHALLENGES

STAGE ONE – PRELIMINARY MINIATURE PROTOTYPE & LIGHTING

Electroluminescent lighting was chosen due to its resilience and overall evenly distributed illumination. During the creation of Mwezi, numerous decisions and obstacles were encountered. Once the concept of the floor installation and type of lighting (electroluminescent) was decided upon, basic hardware and software trials were initiated, using force sensors and EL panels. Next, the aesthetics and textiles were determined, and a miniature floor representation of the large-scale prototype was created, as seen in figure 35. This miniature model helped to solve a few key considerations including the choice of EL lights, textile usage and aesthetics, before moving to a large-scale model.

EL panels turned out not to be the best option of electroluminescence since their purpose in this model is to only shine through small specific sections of the floor rather than large square areas. The decision to switch from panels, then to strips, and finally wire, was made at this point. EL strips are flat EL that usually come 1cm wide by 100cm in length. At first it was decided that this would be a better option for the floor since the area that is lit is small and narrow. However, after extensive research it was evident that once these strips were cut they are very problematic when re-connecting, and it is not possible to connect in the middle of strips to make various shapes such as a “T” shape. Since the visual design of this floor involves vertical and horizontal light strips, using EL strips was no longer the best option. Most of the 100cm strip would be wasted because once cut, the leftover bits are basically inoperative. Either all the strips would have to be horizontal or vertical and not both because the arduino cannot fit that many EL connections. In addition, there is a negative visual implication having wires coming out of every end. With these concerns in mind, the last EL choice became the most viable option. EL wire is able to bend into various shapes, consequently a minimal number of wires will come out of every end, and it also means the wires will not have to be cut since many thin areas can be filled with one strand.

STAGE TWO – FLOOR MATERIAL

The second obstacle, which arose during user testing, was the fact that the lights are unpleasantly visible while turned off. This issue was solved through personal testing and creation, and then finalized with a confirmation from the user testers. Although the wood used in Figure 35 is veneer, the material is still not thin enough for adequate amounts of light to shine through. However, Sommers Flexwood is much thinner than regular veneer and so the same four types of Flexwood were tested with small sample strips and a decision was personally made with no user testing. The personal decision between the four types of wood was easy because again, only one option allowed the dim red EL light to shine through; birch with plastic backing. Following the same floor design as Figure 35, flexwood was placed overtop of the lit areas and the thicker veneer was replaced with sturdy, more reliable wood. Figure 35 shows two photos using two different wood planks along with birch flexwood and EL wire. Although the light works well under this textile and is virtually invisible when off, incorporating flexwood into the pre-existing design idea does not work because it is still obvious that the section does not blend and there are distinct thickness variances. In order to make the EL veneer sections an appropriate thickness and width I decided to create my own wooden planks for the EL sections.

Following this visual design obstacle I developed two ways to merge EL wire seamlessly with the wooden planks. The first way was to saw the planks in half and place EL wire in the middle and then flexwood on top. The second idea was to drape wider flexwood from the face of one plank to the next and then have EL wire underneath. Both of these ideas would cause the same design issue of inconsistency of wood. Although flexwood resembles and is actual wood, the contrast between flexwood and actual wood is still distinguishable. In addition, when a person steps on the flexwood, it would cave in if it has no support underneath. The next plank design solution, as seen in figure 38, sandwiches the EL wire between cardboard strips layered with one Plexiglas plank cut to appropriate size and then one layer of flexwood is placed on top. Small cardboard strips were used on either side of the EL wire to provide support so the materials on top would not rock back and forth and also would not damage the wire. The plank designs used in figure 38 did not sandwich the wires together but instead inserted the wires directly into the cardboard. This made it so that the velostat underneath did not show through and also helped make the EL not as obvious when turned off.

The final aesthetic design ended up reverting back to the idea of having light shine through between planks. During large-scale creation, the use of flexwood was not the right material because it was very obvious and gathered dirt very easily. The final implementation method within an actual hardwood floor is discussed in the final prototype section below. The above design implementation and the final prototype both solve the issue raised from user testing of the lights being visible when turned off. This also works in favour to induce a biophilic response by eliminated any artificial elements.

STAGE THREE – SENSORS MADE WITH VELOSTAT

The third part to Mwezi is the use of Velostat to detect resistance and therefore know when to turn the EL on or off. This stage involved only personal creation research with no user testing needed since all requirements are technical. Conductive material needs to be placed on either side of the Velostat so it can measure when the electric current flow is reduced when applying pressure. The same process was used as the first floor iteration. Using a miniature prototype with EL panels, tiny wooden veneer bits and force sensors, experimenting began with the Velostat in the smallest simplest way possible to avoid any large-scale mistakes that could happen. A small rectangular section was initially used and a conductive thread was fastened on either side using aluminum tape. The thread was then fastened to wires that plugged into the arduino. Since conductive thread was being used, any type of regular scotch tape could have been used instead of aluminum tape. The choice to use aluminum tape was simply because there was some handy and increasing conductivity only adds benefit and sensitivity. Once this small section worked as an analog input and the lights turned on in the same way as the force sensor previously had, the large-scale version was created. Many precautions were taken while making this large-scale version so that if anything did not work the hardware would be easy to check. Copper tape strips were stuck against the plywood base about five or so inches apart to ensure at least one strip is stepped on and to maximize the chance of the resistance being recognized as a person walks across the floor. This ensured that no lights would flicker as the person walks because there is a very slim chance resistance would go below the threshold value, assuming the user's foot is not smaller than five inches long. Copper tape was used instead of aluminum tape at this time because copper tape is far simpler to solder in case any power or additional wires needed to be added later. Furthermore, copper tape is apparently more conductive and was used in every tutorial on Velostat I found, so to further reduce any chances for failure, copper tape was also used. The copper tape was made long enough so that bits were left off the edge of the plywood to chain conductive thread between each and allow for only one connection to the arduino. The purpose for having these dangle off the side of the wood and not underneath is again to eliminate any possibilities of this test to fail. For the top of the Velostat same method was used as the miniature model, and used aluminum tape to attach conductive thread across the length of the strip. Alligator clips were then attached to the end of each piece of conductive thread and plugged into the arduino as an analog input. Once the first side worked, the exact same circuit was created on the other side, and set up to control two separate EL strips. Figure 36 shows the large-scale Velostat circuits.


Figure 35 Flexwood Tests

Figure 36 Velostat Large-Scale Test One

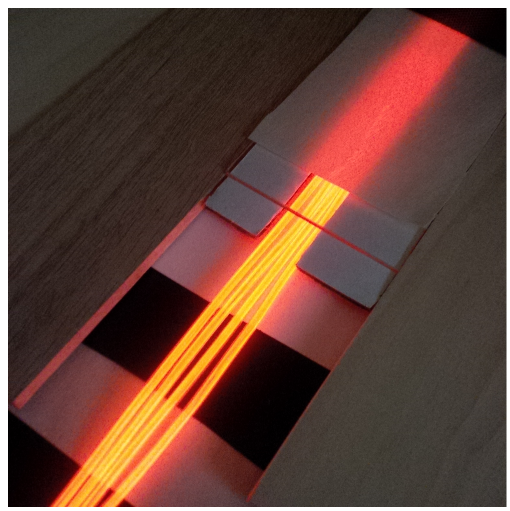


Figure 37 EL Plank Test

Figure 38 Mwezi El inside cardboard with flexwood

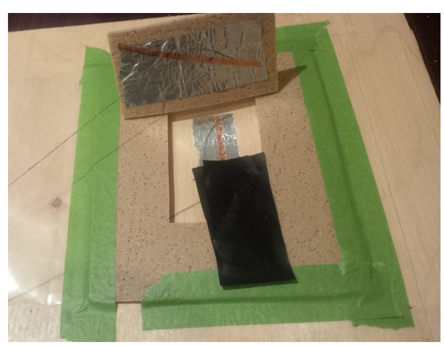


Figure 39 Final Velostat Layout for Mwezi

Figure 40 Mwezi Final, Lights On

MWEZI FINAL PROTOTYPE

The overall visual design of Mwezi was significantly fashioned by the type of materials that ended up being used. Each material was specifically chosen primarily for its appropriate function and then secondly for its look and feel. A plywood base was used to avert any conductivity between the wrong materials and because it's sturdy enough to prevent the various materials from shifting with the potential to cause the circuits to fail. The final circuitry used for the Velostat was only slightly tweaked from the large-scale test to reduce sensitivity and any chances of damage or improper connections to short out the circuit. A second layer of velostat was added to decrease the sensitivity because the final wood floor is very heavy, and without anyone stepping on the floor the amount of detected resistance was already nearly at maximum when two layers were not present. The second addition is the foam on top of the plywood. The conductive thread and tape are no longer attached to the velostat, because the tape was increasing resistance. Instead, the thread and tape were fastened on the plywood base and foam top.

The original idea of keeping the lights between the planks of wood was again taken into consideration and implemented for the final prototype. Seen in figure 40, the final prototype is a wood floor with the EL wires placed between each plank in such a way that they are only visible when turned on.

CHAPTER 5. CONCLUSION

This thesis document records the creation of two at-home lighting wellness prototypes and presents a grounded theory of bringing the outside in. This theory is based partly on a Grounded Theory research study involving four user testers and theoretical literature research. The theory of bringing the outside in explains how artificial technologies (in this case, lighting) can be altered and hidden to improve people's biological wellbeing through biomimicry (in this case, the sun and moon's colour temperature) while also promoting psychological benefits by evoking biophilic responses through aesthetics. Although properly syncing circadian rhythms through light was the main focus, every single quality of both prototypes framed the overall experience of using the objects. During creation of both the prototypes, every feature was taken into consideration. Various scientific research and theories were investigated and consistently reflected upon to ensure all aspects of the design would add value to the positive effects produced by the light and nothing would offset any benefits. My final prototypes, Mwezi and Musana, are two ambient lighting devices that mimic either the sun or the moon to improve people's sleep, energy and mood through biological means while merging aesthetic benefits of biophilia into the visual design. The concept behind them was not only to improve on the interaction and visual design problems of current light therapy, but also to create a device for the everyday person that does not have clinically diagnosed medical reasons to use light therapy. My main focus was placed on creating devices that would benefit people who constantly need to change their sleep schedule or for those whose work time is inside artificial environments. The main purpose for these items was not only to help the circadian rhythm through mimicking the main zeitgeber, light; it was also to alleviate present issues that transpire with current light therapy lamps and many other wellness technologies, including having to turn the light on, or simply remembering to use it everyday. Integrating ambient lighting into spaces where people already frequent, and having them turn on automatically or by natural interaction helps to decrease the possibility of users forgetting to use the device, therefore ensuring optimal benefit from the wellness technology.

Part of the value of these prototypes is that they demonstrate clear ease of usability and a pleasing aesthetic as evidenced in the user testing. Once research on circadian rhythms and light therapy clinical trials was complete, the focus during user testing was to make them extremely user-friendly and not only resemble organic forms for a biophilic response, but also to guarantee that the users would personally want to incorporate them into their house. While testing these pieces, a focus was placed on how well the tester was able to understand its use without guidance, and also constant feedback was obtained during creation for aesthetic opinion when choosing materials.

PERSONAL REFLECTION & CHALLENGES

These prototypes were materialized after countless failed creation attempts and continuous literature, product, and material research to create the final combination. The main obstacles that arose during this thesis investigation are summarized below.

1. Having to limit ideas to suit my technical capabilities, or to limit the ideas simply because the technology is not accessible was an ongoing challenge. This occured primarily at the beginning stages of my concept ideations. I was consistently switching prototype ideas and solving ways to simplify them so that a physical prototype could be made with the current technology and not just conceptualized.
2. Not only did my personal capabilities and availability of materials change the prototype idea but also the drive for wanting it to be innovative affected the ideas. This challenge was somewhat present during the beginning conceptual stages, however once it was conceptualization, it meant that more advanced ideas were developed and the issue of ensuring innovation didn't present itself as much of an obstacle until prototyping began. The issue mainly arose at this point in my exploration because through the creation process I was forced to simplify ideas leaving a larger chance that there was already a similar product invented or one that was more advanced.

3. Due to the fact that this is a Master's thesis, there are deadlines that needed to be met, and because a large corporation did not fund this, monetary constraint was also a very realistic obstacle.
4. As I was creating both of my devices, I was intent on using light to help circadian rhythms as the clear focus of this development. However, I also wanted to make sure that no part would cause negative benefits and that every quality used would only add benefits. Constantly focusing on this meant I had to do more research and strategize ways each element would induce a benefit.

Having to overcome these obstacles meant the entire process was elongated; ideas got changed completely and new research (either literature, material and/or product) constantly had to be found and strategized into ways it would be introduced. However, without these challenges it wouldn't have allowed for the appropriate changes and considerations to take place allowing Musana and Mwezi to be created how they are.

FUTURE RESEARCH & SUGGESTIONS

There are many potential opportunities for future investigations into wellness ambient technologies that can be integrated at home. Future steps for this thesis would include broadening the topics and explore other ways technology can be integrated into the home to provide biological and psychological benefits while also maintaining the idea of it working through natural interaction. Within this topic there is a surplus of ideas waiting to be created. Future personal and user suggestions for Musana include adding UV lights, creating similar lighting for office use, mobile synced lighting devices that can be brought around with the person, more aesthetic customization including being able to create their own form on the wall, varying textile options and other designs the wall installation can be made into. Future steps for Mwezi would be to create many options for the floor to ensure they will match pre-existing wood in other rooms or create identical pieces that do not include light so they can be used for other rooms and testing other materials beyond wood such as carpet. *Philips* and *Desso* have collaborated together to create a carpet with built in LED lights. The purpose of this floor is not interactive, but instead to provide directions or information. A future step would be further research on the transmissive carpet designed by *Desso* that has a unique backing to allow the LED light to pass through. Other future technical steps to implement and/or research would be OLED usage instead of EL, minimizing power consumption and incorporating other elements such as music or aromatherapy.

The conclusions and future suggestions that have been drawn from the work up until this point are very much dependent on the context that the participants and myself have used/viewed them, and the scientific gap has solely been filled with literature and clinical trial research. Exploring them in other contexts over a greater amount of time would produce greater and more specific variety of responses. A personal suggestion for future research is to complete a longer and more thorough user-testing process when time is not an issue. This would involve many more participants, including those who stay home throughout the day and those who constantly change their sleep schedule. The prototypes would be installed into their house for an extended period of time and, with the help of medical professionals, vital signs will be taken periodically to test the affects on their circadian rhythm. In addition, surveys about their mood, sleep and energy will also be taken and placebo testing and some minor observation via camera installations to ensure natural interaction should be done as a control. Time plays an important role when attempting to adjust a person's circadian rhythm and so does an individual's experiences. It would be very interesting to learn about long-term positive changes these objects can instill, both biologically and emotionally. A prolonged study of this type would help give a more thorough understanding of ways to improve the devices, and provide ideas to develop other devices that could add similar benefits.

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