WAVE: Brain-computer interface connection and biofeedback monitor

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WAVE
Brain-computer interface connection and biofeedback monitor

Kurtis Unruh-Kracke

Thesis submitted to the faculty of
the College of Imaging Arts and Sciences for
the degree of Master of Fine Arts in Industrial Design

Master of Fine Arts Degree
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School of Design
College of Imaging Arts and Science
Rochester Institute of Technology

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1. Abstract

Over the last couple of years I have had the unfortunate experience of helping a loved one through multiple hospital stays. Anyone who has ever been in a hospital knows it’s not the most pleasant experience one can have. These experiences have lead me to the question of, how do I create a space to optimize and inspire the body, mind, and emotional centers to heal and engage support and community? By using empathy I can create solutions for the most extreme patients and use those solutions for other patients and other situations.

Through interviews with ICU patients, nurses and doctors, a reoccurring theme clearly developed; fear, isolation and lack of communication. When a person is experiencing these emotions an optimal healing environment is not possible. What if we could create a healing space that could monitor a person’s mood and general well being? By monitoring mood and having alternative way’s to communicate we would create an environment that could potentially have faster healing times, lower amounts of medication usage and a happier work environment. It’s time to bring humanity back to healthcare. Healthcare needs to concentrate on more then just the physical; it should include the mental and the emotional as well. We need all three to line up in order to heal.

I have invented a Healing Space to help accomplish an optimum healing environment. The first device to come out of it is Wave, a brain computer interface designed to use EEG technology along with biofeedback. This device will change the relationship between, doctors, patients and nurses by giving them a way to communicate and to talk about mental states.
# Table of Contents

1. Abstract 3

2. Thesis Statement 6

3. Project Overview 7
   3.1 Design Types 10
      3.1.1 Empathetic Design 13
      3.1.2 Intuitive Design 15
      3.1.3 Evidence Based Design 15
      3.1.4 Design Thinking 16
   3.2 Stakeholders 23

3.3 History of Architecture in Hospitals 24
   3.3.1 View Through A Window 26

3.4 Senses 28
   3.4.1 Sight 28
   3.4.2 Sound 31
   3.4.3 Touch 33
   3.4.4 Smell 34
   3.4.5 Taste 36
   3.4.6 Breath and the Nervous and the Circulatory Systems 38

3.5 Meditation and Mindfullness 41

3.6 Biofeedback 42

3.7 Skin Conductance 45

3.8 Products Currently on the Market 46
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9 Electroencephalogram (EEG)</td>
<td>48</td>
</tr>
<tr>
<td>3.10 Neurodiversity</td>
<td>49</td>
</tr>
<tr>
<td>3.11 ICU Psychosis</td>
<td>50</td>
</tr>
<tr>
<td>3.12 Personal Interviews of Nurses</td>
<td>52</td>
</tr>
<tr>
<td>3.12.1 Bridget Hanson</td>
<td>53</td>
</tr>
<tr>
<td>4. Design Objectives</td>
<td>55</td>
</tr>
<tr>
<td>5. Design Brief</td>
<td>56</td>
</tr>
<tr>
<td>6. Ideation</td>
<td>57</td>
</tr>
<tr>
<td>7. Prototypes</td>
<td>62</td>
</tr>
<tr>
<td>8. Final sketches of Wave</td>
<td>65</td>
</tr>
<tr>
<td>9. The Wave</td>
<td>66</td>
</tr>
<tr>
<td>9.1 Form</td>
<td>67</td>
</tr>
<tr>
<td>9.2 Tech and Materials</td>
<td>70</td>
</tr>
<tr>
<td>9.3 Ergonomics</td>
<td>72</td>
</tr>
<tr>
<td>9.4 User Interface</td>
<td>73</td>
</tr>
<tr>
<td>10. Research Influenced Design</td>
<td>74</td>
</tr>
<tr>
<td>11. Conclusion</td>
<td>75</td>
</tr>
<tr>
<td>12. New Research Inquires as a Result of Project</td>
<td>76</td>
</tr>
<tr>
<td>13. Bibliography</td>
<td>77</td>
</tr>
</tbody>
</table>
2. Thesis Statement

Empathy and creativity are foundations of humanity, this thesis centers on these two foundations of the human experience and in the relationships that occur. I want to explore how art and design enhances healing in the hospital environment. Research suggests; more pleasurable environments result in faster healing times and a reduction in pain levels.¹ My goal is for the user (patient) to have the ability to create an environment to help them heal.

Through the exploration of empathy I want to create a better environment for patients. With the goal of healing, design can create a more positive experience, better quantitative results and therefore a healthier hospital environment.

¹ Gouin et al., “The Impact of Psychological Stress.”
3. Project Overview

Capsulating the importance of my research resulted in a series of questions. Can Art and design enhance healing? How does it feel to be in the hospital? How does that effect healing? What else does it affect? Is there an optimal feeling for a person to heal? If so how does it effect treatment and how does treatment effect the user? Does this state come from the environment? Does a device prompt it? What about emotional and spiritual needs?

The beginning research took a direct look at the problem from an empathetic and user-centered design approach starting with users and stake holders. I then approached the problem differently by investigating the five senses and their relationship to healing. That research was then confirmed and denied by doing personal interviews with nurses, doctors and patients. To expand the knowledge associated with the problem, time was spent studying the history of architecture in hospitals and how society got to this point.

The next aspect of the research was to narrow down the technical aspects of the medical world. I interviewed Anna Hope, a mental-health clinician at the Center for Applied Psychophysiology and Self-Regulation at Rochester Institute of Technology’s Institute for Health Sciences and Technology who studies biofeedback and the nervous system. As result of theses sessions and the research I gained I asked Anna to be on my thesis committee.

The biofeedback monitoring made me look at products currently on the market and see if they could be adapted to promote healing the elements of the mind, body and spirit. This exploration culminated by leading back to the big picture of ways to
boost two of the three elements that are not addressed in the hospital, the mind and spirit. For complete and faster healing, the mind and spirit need to be included into the equation, not just the body. This leads to the research of how to quantify these two elements of health.

I returned to the personal interviews to ask more about these aspects of the hospital. The nurses, doctors, and patients interviewed all said that the more progressive hospitals have a white dry-erase board on the wall with important information and a variety of smiley faces. The smiley faces indicated the mood and the numbers above indicated the level of pain the patient was experiencing. The nurse circled the one that fit the patient's mood and pain level after each assessment.

The take-aways from talking to the user was simple, they felt anxiety, confusion and isolation. I found this could be a very profound tool in the hospital as an open communication platform between the nurse, doctor and patient.

As the research progressed it became obvious that no one wants to think about being sick and what happens, much less how a person actually experiences healthcare and healing. The medical community is practicing amazing technological concepts but the patients
concepts of healing and the experience of it hasn’t been defined medically, personally or in society.

While communicating some ideas with my primary care physician I learned of a problem called ICU Psychosis. It is a disorder in which patients in an intensive care unit (ICU) or a similar setting experience a cluster of serious psychiatric symptoms. 1 in 3 patients who are in the ICU for more than 5 days experience some form of psychotic reaction.

We don’t ever think we are going to be in a hospital bed, aware of our surroundings but immobile and unable to speak. ICU psychosis occurs when a person is bedridden for long periods of time and experiences high pain levels, sensory deprivation, sleep disturbances, continuous light levels, stress, lack of orientation and constant medical monitoring, these effects can result in death. ICU psychosis is an extreme example of what is at the root of the dysfunction of the hospital environment as a place of healing.

Li Wei is an avant guard artist who represented the concept of ICU Psychosis perfectly through his solo show “ICU”.
“In the ICU series, the figures were comatose hospital patients. Each figure is unique, with posture, hair, and features rendered in painstaking detail. Most appear to be locked inside themselves, suffering in their own mute and invisible way.”

How much would healing improve if the patient could communicate and get support to the body through the mind and spirit? As medical techniques improve patient communication through body, mind and spirit will become more common.

### 3.1 Design Types

There are many aspects of design that combine together to reach the final outcome. Color and form are the basics but they are just the start of the journey. It is through the lenses of the deep-dive, reframing and design thinking that struck me as the powerful tools needed to address the increasing complexity’s of the world. The tools overlay the triad of empathy, creativity, and the underlying problem. This triad creates the user centered design model that has become the standard. However, from my own experience, I have found that the world is full of problems and a lack of creativity to solve them. I believe that as our society has evolved to understand the complexities it will take a more collaborative effort to creatively and collaboratively address the new shape our world will become in the future.

My narrative that lead me to my thesis ironically began the first week of class, I got a call from my mother informing me that my uncle was in a coma. He was in the hospital for a routine procedure and aspirated, causing him to be put into a medically

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2 White Rabbit Collection “Li Wei”
induced coma for 3 weeks. This was just one of several family experiences with the medical industry that really caused me to stop and think about how people experience healthcare and how we perceive what the doctors can do and what they actually do, what healing feels like and what we think it is to heal and also how it affects the caretaker.

The process of finding and framing the problems at first was overwhelming. The problems seem like the needle in the haystack. The strange thing was, it seemed as if the problems were the hay and healing was the needle.

In the design process many theories compete. The question was how to reconcile the difference between different theories in the complexity of the haystack sizes problems. As the medical industry is learning how to deal with the complexity of care that is available, it has to jump the chasm between specialist and specialties all the while losing the patient and their family’s in the chasm. The question of how to explore these problems with appropriate design thinking and structure was a major part of the project.

As a society, we dive into more complexities in the search of understanding, it takes more team players, or in the world of healthcare, more specialists. When there are more players on a team there are more chances for gaps. In these gaps lies the chasm, in the chasm lie a lack of communication, mistakes, and the lack of acknowledgement of feeling. The chasm works both ways, doctors, nurses and staff don’t get their emotional and informational needs met and neither does the patient. One of the hallmarks of user-centered design is gathering the data to inform the
process. This leads to a way to address two problems that are very common, emotional fatigue and communication.

   Emotional fatigue happens when one is overextended and exhausted by one’s work or life situations. Communication has a dramatic impact, there is the communication between the caregivers and the patients and the communication between the user and the object. If the objects were designed to need less communication then that energy could be spent in the chasm reconnecting the communication between people.

   Design thinking is a big part of the empathetic/user centered design process that applies to the way we experience healthcare in the United States. There are so many things a person experiences in the hospital that it’s almost impossible to look at as a whole, especially with the ever-increasing complexity of the medical care system. It raises the questions of, how does it feel to be in the hospital? How does that affect healing? What else does it affect? Is there an optimal feeling for a person to heal? If so how does it affect treatment? Does this feeling come from the environment? Does a device prompt it? Is it best to have a person in charge of a patient’s emotional needs?

   While we are still in the observation phase of the process it is good to revisit my personal experiences. Five years ago my mother-in-law, Ione, and sister-in-law, Emily, were both diagnosed with breast cancer. Emily was diagnosed with Stage 2c Triple Negative Infiltrating Ductal Carcinoma, a very aggressive form of cancer and was given chemotherapy to stop the spread and would later undergo a double mastectomy. Ione was diagnosed with Ductal Carcinoma In Situ with a small area of Invasive Ductal
Carcinoma and was prescribed radiation therapy. Thankfully the treatment for both of them was successful.

Because of the two cancer diagnoses our primary care doctor highly suggested my wife, Julia, get the genetic test for BRACA1 and BRACA2 mutations to test for inherited gene mutations. The test came back as positive for BRACA2 and the road to preventative cancer started here. Four major surgeries in three years and my wife now has a below average chance of getting cancer.

It doesn’t take much to sit beside people going through these treatments to ask yourself many questions. We will all agree that treatments that result in a longer normal life are worth the comparable short-term uncomfortableness caused by them, but are their other possible non-medical things that can be done to enhance comfort? With such complex problems lots of design thinking tools had to be deployed. In order to distill down to the core problem’s I began to mind map all the different angles, from the user to stakeholders to individual stakeholders even to secondary users.

3.1.1 Empathetic Design

In his book “Change By Design: How Design Thinking Transforms Organizations and Inspires Innovation” Tim Brown describes empathy as;

“the mental habit that moves us beyond thinking of people as laboratory rats or standard deviations.”

Empathetic design is more of a process than a thing. It has been used successfully all over the world for years. It has been very useful in large unwieldy problems because it

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3 Brown, Change By Design, 76.
is always asking questions like, what do we want to achieve? How would we know if we achieve the goal? What benefits would there be and what would the effects be?

Empathy is the perfect gift for healthcare. We as humans never experience empathy more than when a loved one is ill or hurt. As we sit with a person trying to relieve their symptoms emotions always run strong. It even works in the reverse when we feel someone is not being empathetic enough. Empathy is such a broad term, it can apply to relationships between objects and people or to people to people or even a person to a system. For me true empathetic design leverages all of these relationships to accomplish a positive outcome.

In this user-center design model, caution must be used to not take the design too far. The wonderful thing is, it encourages questions. I truly believe the world will only get better if we ask better questions. This theory is explored in great detail by, Warren Berger in his book “A More Beautiful Question: The Power of Inquiry to Spark Breakthrough Ideas”.

“Questions challenge authority and disrupt established structures, processes, and systems, forcing people to have to at least think about doing something differently.”

It was this book that brought me back to grad school and the industrial design department. I believe empathy is the intersection between art, design and science and the source that changes the world.

The roll empathy plays in healthcare is immense. There are countless examples thought out the world of using empathy to break down problems to basic and simple elements, where a simple change magnifies to extreme results. As an element of design, this is accomplished through

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4 Berger, A More Beautiful Question, 89.
communication and observation, then using these two elements to make meaningful changes.

3.1.2 Intuitive Design

Intuitive design is the ability of a design to communicate with the user so completely that learning how to use it is unnecessary. It directs people’s attention to tasks that are important. I use intuitive design in terms of a thread that will tie the design together and communicate simply and clearly. As I explore physical, emotional and spiritual health, intuitive design of the physical space plays its role. I see this as a way for the healing space to make healing better for the patients, doctors, nurses and caregivers.

Think of intuitive design as a way to teach health ideas in an indirect way like color, sound, smell and visualization. It is commonly known in advertising that a person needs to be exposed multiple times to things before they feel familiar to a new product, so why would new ideas not be the same. If we take into consideration different learning styles it would seem that communication is a large barrier to healing and being healthy. This ability of intuitive design to circle around and use all forms of communication to reinforce the design goals of healing, discovered in the design thinking process, could be used in the same manner as the advertising metaphor.

3.1.3 Evidence Based Design

I think of evidence based design as the price of admission for design to get a seat at the healthcare table. This table is constructed (especially in the US) by the law of “the road to hell is paved with good intentions”. The world of modern healthcare
grows more complex each day as the medical community gains more insight into the scope of the nature of the complexities of how the human body works. This table is crowded by the scientific method, therefore, design must be hypothesized, tested, evaluated and measured. The notion of measurement, qualitative or quantitative data and the ability of one to measure design brings up more questions. How do you measure design? How do you measure mood? How do you measure spirituality? How do you measure pain whether it be qualitative or quantitative?

This is why evidence based design has made more strides in healthcare than design thinking alone. One might argue that evidence based design is just an aspect of design thinking. I believe that the “softness” of the data in design thinking is not good enough for many when it comes to dealing with the possibility of mortality that is ever-present in the healthcare space.

Evidence based design is dominated by psychologists, architects and neurologist, what is missing in this team is creativity. Creativity in the design disciplines (graphic, user experience, interior, and industrial) is needed to make new strides in the way the experience of healthcare communicates to the stakeholders. It has been shown in the medical field that it take multiple disciplines to resolve the complexity of care. I would like to think that the notions of empathy and evidence based design are used to create the hypothesizes.

3.1.4 Design Thinking

I think the word empathy gets tossed around in design and it seems like another way to define user-centered design (even-thought I know this term was first used in
context of peoples ability to interact with computers). It took me awhile to find the subtle differences between the two. User centered design is about making things easier for the user while empathetic design is about design solutions that make things better, not necessarily easier, for the user by gaining perspective and employing empathy. Empathy is the heart of design thinking. This is the lenses in which we use to see the user and or problem. The other aspect is the process of how to use the gained perspective and knowledge. The beauty lies in the conversation of feelings + knowledge = solution. Unlike this equation, the design process can be repeated until the solution is clear. This can allow for the circular nature of problem solving.

It is the nature of humans to create organized systems to help with nonlinear problems. For myself, I find the notion and narrative of empathy itself to be the meat of design thinking. Defining, ideation, prototyping and testing are important, but it takes successful completion of all steps to make a change or object. But can an object have empathy? No, it can’t feel empathy for people, the exception being new artificial intelligence, but industrial design can be imbued with empathy from the maker. The empathy is in how it fits your hand without causing blisters. The magic potion of problems solving is empathy + creativity.

Can art and design enhance healing? Have you ever been in a hospital? What is the first word that comes to mind when you think of the word hospital? Was it a positive or negative word? This was one of my first starting points. By mind-mapping the word hospital itself, it became the jumping off point for the thesis.
Why don’t we associate the word pretty, sleep, relaxing, vacation or even resort with hospital? This sound almost laughable and trivial because nobody wants to be in the hospital. Now days it seems as if the hospital and insurance company’s don’t want you to be in the hospital. Don’t most people look forward to going to a place where they can rest, heal and have someone there to help as much as they can?

As I stated earlier, thought the years I have had the experience of siting bedside for several family members while they were in the hospital. It doesn’t take but a few minutes in a hospital room to think of ways to improve the place. The hospital seems to be a place where utility rules and humanity comes last. It is in this vein that I started with the physical space and the objects in room.
3.2 Stakeholders

In the complex system of healthcare there are direct and indirect stakeholders. Direct stakeholders are the patients followed by the doctors, then nurses and support staff. Many people can be considered support staff, housekeeping, food services, transportation and families. The indirect stakeholders are the administration, including accountants, secretaries, insurance companies, taxpayers and the federal government. With all these stakeholders involved, the healthcare system quickly becomes a wicked problem. For the purpose of this thesis I will consider the patient as the user and will not be including some of the indirect stakeholders such as administrative staff. I am not dismissing their roll in the problem of healthcare, but want to isolate the problem to the patient and their direct surroundings in relationship to the hospital.

One of the most powerful tools in a designers toolbox is Empathy. The empathetic design process take attention to the users feelings through an experience to help understand problems and solutions. To me, this is a great way to use the mind to acknowledge the differences in perspective. In terms of the stakeholders this makes the landscape much more complex and allows the acknowledgement of feelings. It is my opinion that since the Renaissance and Age of Enlightenment the western world has been wrestling with the acknowledgement of feelings and how they equate to facts. This clash of ideas is very apparent though the history of medicine, there are countless examples of doctors ignoring patients feelings, only years later to find it was a “true” ailment. This clash of how to deal with the “problem of feeling” has fallen to the discipline of psychology. This works back to the notion of perspective and how
empathy is powered by observation. The techniques used to obtain the observational data are growing and becoming easier to navigate.

### 3.3 History of Architecture in Hospitals

I looked into the history of architecture and hospitals. It was very interesting to see how the rise of the scientific method and the Industrial Revolution changed how we in the west perceive medicine and hospitals. Before modern medicine, if you did something and you felt better, it worked. If a person was sick they went to the country to get sunlight and fresh air. Hospitals during the 1700’s to early 1800’s were large rooms with 50 to 100 patients. The rooms had very high ceilings to allow large windows for light and movement of air. Health and wellness retreats were all the rage with large estates and hotels in the middle of nowhere. Dr. John Harvey Kellogg, MD, the inventor of Kelloggs cereal, ran one of the most famous ones, the Battle Creek Sanitarium.\(^5\) Diet and exercise were often prescribed, and the facilities focused on homemade remedies, what we would now call lifestyle cures or preventative medicine.

As modern medicine came to the forefront, the practice of medicine began to change quickly. The acceptance of the germ theory of disease changed the world and changed how we perceive healthcare. The 1854 cholera outbreak in London was the start of a new era. This outbreak, which killed 616 people, is best known for the physician John Snow’s study\(^6\) of its causes and his hypothesis that contaminated water, not air, was the source of cholera. This discovery came to influence public

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5 Markel, “Dr. Kellog”

health and the construction of improved sanitation facilities. This study came out as people were coming to terms with this new way of living ushered in by the Industrial Revolution.

Once the necessity to be clean was accepted the large open rooms of the hospital slowly come to an end. It also lead to more democratization of healthcare but by no means was healthcare seen as a right or even a necessity. It was the wealthy that could afford to leave town for months in order to reap the benefits from the fresh air in the country. Unfortunately, the largest medical advancement came through war, it was the US civil war that spearheaded hospital development and growth.

With the invention of electric light and indoor sewage systems the infection rates dramatically dropped. However this was also a time of discovery for medicine in terms of advancements in diagnosis and surgery. This all came from a new vision in design terms of urban planning after the 1893 Chicago World's Fair. The fair was an influential social and cultural event and had a profound effect on architecture, sanitation, the arts, Chicago’s self-image, and American industrial optimism. The visions and advances shown at the fair quickly filtered to the hospital. The rooms used electric lights therefore windows got smaller and work efficiency for staff came to the forefront. It is from this point that we have retained the majority of the current elements of hospitals today.

As the world wars came to an end the Technology Age began. The technology of the day began to improve and fit into the scientific method. Hospitals were designed for the machines and technological requirements and less for the patients and

7 Novak, “1893 Chicago World's Fair”
caregivers. For example, air-conditioning units were installed for the needs of the equipment, not the needs of the patients. As most of the post World War II infrastructure has reached the end of its life span this is going to allow for an opportunity for design.

3.3.1 View Through a Window

After the exploration of the modern history of the hospital, this led me to the physicality of the space itself. Once again the design process leads to more questions. Why does one space feel good and another doesn’t? Imagine sitting in the sun on a park bench looking across a meadow with trees swaying in the wind. Now imagine sitting in your car stuck in traffic as the sun beats down and a breeze of car exhaust fills the compartment. Which of these sound healthier? Ok we all know that the two scenarios may be laughable, but the intent is there. How does the entire variable affect us? It is accepted that a reduction in stress can help promote healing, so how would having a hospital room in a park enhance healing? Can the spaces around us help us to heal? Can hospitals be designed to enhance their healing properties? Can a physical space contribute to healing?

These questions were asked in Roger Ulrich’s study “View through a Window May Influence Recovery from Surgery,” published in the journal Science in 1984. Ulrich conducted his study from 1972 to 1981 in a hospital in Pennsylvania. He chose to look at the records of patients all undergoing the same gall bladder surgery. The study involved a total of 46 patients, 30 women and 16 men. All the patients where

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8 Sternberg, Healing Spaces, 2.
kept in the same ward with the same staff and doctors. The patients had all been completely documented with heart rate, EKG, blood pressure, temperature and medications. The thing that made this hospital the most ideal place for the study was the location. This hospital had been recently remodeled. The rooms on this particular ward were on opposite sides of the same hall. However the rooms on one side of the hall had windows that looked out to a brick wall. The other rooms look over a forest of trees. The resolution of the study was conclusive. Ulrich’s main question was to find out if the windows had any effect on healing. He found that patients with beds next to a widow of trees left the hospital a day sooner than the patients next to a brick wall. The patients with the view of trees required less pain medication and reported less complications. Most of us would consider this a success and proof that if these ideals could be incorporated into the design of the space it would help the body’s ability to heal.

Thought the process of designing a space to heal, once again finding an answer just led to more questions. Was the result from a reduction in stress? Was it the light's ability to move across the room helping to regulate our circadian rhythms? Could it be the scene out the window? Would a person who is unconscious have the same benefit? In order to explore these questions I tried to break the scene down further. I began to think how does each sense play a roll in the healing process

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3.4 Senses

The 5 senses, sight, sound, touch, smell and taste are the building block of our ability to exist in space. They are the communication tools of life. What would life be like without one of our senses? What would it be like without two of our senses? What if we didn’t have any?

3.4.1 Sight

Sight is the sense most people say they would hate to loose.¹⁰ Do you remember what you saw the last time you were really sick? Because of this project I was keenly aware of my senses, actually my lack of senses when I was sick. I got food poisoning that put me in the hospital for 5 days. I fist noticed that I preferred to keep my eyes closed at times of great pain and I observed that my focal range had changed to being fairly close up. Meaning that I could not focus on anything more that 5 to 10 feet away.

While in the hospital the two features of my room I liked the most related to sight. I had a great view of the skyline and a TV channel that was nothing but waves on a beach. The TV was soothing without having to concentrate on it and the window was by far the most important as it gave me a sense of time and place. The

¹⁰ Sternberg, Healing Spaces, 100.
window was facing west and I looked forward each day to watching the sunset. In the book *Healing Spaces: The Science of Place and Wellbeing*, Esther M. Sternberger MD says;

“perhaps the most important thing a window does is provide a portal–an escape from the frightening, painful reality of disease, or a way of accessing memories of a better time and place. Maybe windows exert their effect by allowing a patient to step into a space of meditation–a reverie that brings not just distraction but relief.”

Rogers Ulrich’s now famous study brought architect’s and neurologist together and in 2003 the Academy of Neuroscience for Architecture was created.

“There goal was to bring together psychologists, architects and neuroscientists to study 3 things, stress research, visual perception, and environmental psychology”

The end game was pretty straight forward. They wanted to find “proof” that could be shown to the clients building the hospitals that would help justify the extra cost. How physical space effects emotion in a positive way may pay back in healthier people and lower medical costs.

Later on Ulrich’s famous study was replicated in other hospitals. It was soon discovered that hospitals with urban landscapes did not provide as much healing benefits. Was it the trees themselves or maybe the color? Is it the lower stress of nature that puts people into a meditative state that allows the body to enter its own

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12 Academy of Neuroscience for Architecture, “History”
innate state of healing? Once again we come back to better questions though the design process.

With my past history in photography, color has always been of great importance to me. Like many modern artists a color alone can be a captivating subject. During my undergrad work, I proposed a series of works based on the notion of color and mood. Are you feeling blue, I am red with anger, green with envy and so on. I believe these sayings may be a little like a stereotype but also may contain an element of truth. How can color promote healing? Which color? What if the patient could choose the color of their environment? How does color relate to stress? Once again one answer led me to more questions. We have learned that the color green may have some positive healing properties. Green is the first color our ancestors evolved to see: therefore, a large part of the cones in the eye are dominated to see all the subtle shades of green.\(^{13}\) The middle wave length of light is found to have a calming effect and the ability to boost the immune system.

In the early twentieth century light was used to treat tuberculosis. The latest research has shown a link to vitamin D and cancer. The most common way to get large amounts of vitamin D is through sunlight. Should we combine going green with light therapy to create lower utilities and improving health? The relationship between color and light is inseparable. It seems easy to create light in hospitals that promotes well-being and incorporating color to correspond with mood. Light itself could be used as a valuable tool in hospitals settings. The movement and qualities of light imply’s time and a sense of rhythm contributing to the wellbeing of the patient. It could be used to

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\(^{13}\) Sternberg, *Healing Spaces*, 39.
change the look and feel of a space to make it feel larger or smaller. Just as the lights off in a room may signal a person is trying to sleep, could there be a way other than noise beeps and chirps of equipment to get the attention of the nurse?

One of the design possibilities for older hospitals was to create a closed circuit TV for every room of the building. Each room would have a large LED screen on the ceiling connected to a camera on the roof, this would create a virtual sky light. The patients could then have some idea of the outside, thus accomplishing the ability to ground the patient in a place and time in an attempt to use the senses for what they are intended, as a communication device to improve our connections to reality and other people. However, because of the increased experience and need for added infrastructure I ultimately gave up on the idea. One of the largest barriers for this, as a student, was high cost of experimentation.

3.4.2 Sound

If you were to ask 100 people to close their eyes and tell you what they hear when you say the word hospital I bet you would get mostly the same description. The noise level in a hospital is actually so high it can be considered dangerous. The average range for a rock concert is 115 decibels, typical speech is 55 and the average ICU can be in a rage of 45 to 98 decibels.\textsuperscript{14} Now ask the same people to do the same

\textsuperscript{14} Darbyshire et al., “Sound Levels,” 2.
exercise but now think of the sound of healing. What popped in to your mind? Was it sounds of the ocean, other sounds of nature or was it silence? Is there such a thing as silence? This sounds like a question for philosophy class, not design. But lets re-frame the question. Can you ever escape the sounds that our own bodies produce to function? Like your heart beat? People in sensory depravation chambers report a period of getting used to the sound their own body makes. Did you know that the cells in your nervous system actually make a sound when they fire to relay information? Our bodies may not be the silent sanctuary we think they are. However interesting the practical application of noise is in the clinical setting, it’s overwhelming and may be a huge problem. I should use this as the opportunity to point out somethings that are obvious. People recover and heal faster in single occupancy rooms, it is the noise pollution of the other patient that is most often the complaint. Beside the reduction of noise levels, how would sound be the most conducive to healing?

The relative new field of music therapy has proven itself in the ability to reduce pain and stress levels, it has also been found very helpful with dementia and autism. I have a close friend who works for Lifetime Care as a music therapist in Rochester NY, and specializes in hospice and end-of-life care. I had the opportunity to interview him and observe him about his work. As he sat and played his guitar for his patient I asked him how he decided what music to play? “Generally if the patient is able they will pick the music.” He says that he tries to play music with a metronome rhythm and tempo. I asked if his goal was to be stress reduction, distraction from symptoms or communication? He answered “YES”.

16 Marshall, interview.
Recently there have been several studies of people who listened to relaxing music from the time of anesthesia to 1 hour after awaking from hernia surgery. The ones who listen to music used half to a third less amounts of morphine. Once again, we have a sensory stimulation done in the right way to promote relaxation, the result is the same, less need for pain medication, faster healing and a small boost to the immune response. In short the next time you have to go to the hospital don’t forget your headphones.

3.4.3 Touch

Touch is one of the most essential elements of human development, a profound method of communication, a critical component of the health and growth of infants, and a powerful healing force.\textsuperscript{17}

In Tiffany Field’s study “Preterm infant massage therapy studies: an American approach”\textsuperscript{18} Premature babies in the NICU were massaged 3 times a day for 15 minutes. The resulting evidence proved that on average, the preemies receiving massage therapy were gaining 49% more weight than preemies not receiving touch therapy, and were discharged an average of 6 days earlier from the hospital, with an average hospital cost savings of $10,000 per infant.

Once again we have a soft science that stimulates communication and relaxation to the alignment of emotions resulting in boosting the immune system and better physical outcomes. Massage therapy is becoming more mainstream, however some of the uses for it are new, therapy for depression and wasting disease in the

\textsuperscript{17} Zur et al., “To Touch”

\textsuperscript{18} Field, “Preterm Infant Massage”
elderly.\textsuperscript{19} I think it is clear that touch changes the way that we feel therefore it changes the way we heal.

3.4.4 Smell

The "father of medicine" Hippocrates is said to have practiced aromatherapy for healing purposes, the practice of using infused aromatic oils as a mood enhancer.\textsuperscript{20} Most recently aromatherapy has been the therapy of choice for the new age movement. In an effort to neither prove nor deny the new age claims on what aromatherapy can cure, the fact is that aroma is not possible without the breath. The breath itself is known in the eastern cultures as the center of the body, without the breath there is no health.

Because of the speed of breath and the nervous system the brain can detect a smell in 200th of a second making it one of the fastest senses we have. New medical tools have allowed researchers to peer into cells further then ever before. They have discovered olfactory receptors turning up in internal organs. Why would our internal organs need to smell? I am taking a leap that has not been proved yet, but it seems that the body in all its wisdom has ways of communicating. The places these receptors for smell have been found are spine, sperm and kidneys.

In 2010 Darek Fidyka was paralyzed from the chest down in a knife attack. In 2014 A team of doctors from Poland and London transplanted olfactory ensheathing cells (OECs), specialist cells that form part of the sense of smell, into his spinal cord.

\textsuperscript{19} Sternberg, Healing Spaces, 91.

\textsuperscript{20} Aromatherapy, “History.”
OECs act as pathway cells that enable nerve fibers in the olfactory system to be continually renewed. In the first of two operations, surgeons removed one of the patient's olfactory bulbs and grew the cells in culture. Two weeks later they transplanted the OECs into the spinal cord. About 100 micro-injections of OECs were made above and below the injury. The scientists believe the OECs provided a pathway to enable fibers above and below the injury to reconnect, using the nerve grafts to bridge the gap in the cord.21

[Diagram of Olfactory System and Spinal Cord]

There are also new findings that the epidermis has the olfactory ability to promote healing with some smells like sandalwood and some essential oil’s causing the skin to heal faster.22 This demonstrates the need for divergent thinking. This is an example of a non-obvious connection to health but like the other examples the new era

21 Walsh, “Paralyzed Man”

22 Roehr, “Smell”
of science research is providing evidence for home remedies. If I asked you to close your eyes and tell me what a hospital smells like, what would you say? Does it smell like healing? What does healthy smell like? We know that traditional smells like sandalwood, peppermint, sage, cinnamon, orange, rosemary, and lavender have measurable medicinal properties, they help lower blood pressure and ease pain.\textsuperscript{23}

There is a scientific link between mood and scent. Certain scents have been used in stores to make customers feel relaxed which increases buying, relators have been known for making cookies in the house they are showing before open houses. Like the other examples of our senses, smell can promote a better environment of relaxation and lower stress levels with the end result of more healing.

This is all good, however there is a down side, like with sound this varies widely from one person to another and by culture. Smell is difficult because smell has the strongest connection to memory, therefore the smell of a new box of crayons may evoke good memories of the beginning of the school year or it can evoke bad memories of poor early school experiences. Smell could be the second most disregarded sense in the healing process because it may be one of the most complicated.

3.4.5 Taste

I know the old joke about the only thing worse than being in the hospital is the food. I am happy to report from my most resent stay that the food is much better. The five hospitals I have experienced recently have moved to a more restaurant style where the patient can choose what they get from a list of options. What does this have to do

\textsuperscript{23} Aromatherapy, “History.”
with taste? Our senses change while we are sick, we have all experienced a cold or flu when we can’t taste anything or things taste off and eating is not a pleasure but more of a chore and necessity. Eating embodies many physical, emotional, and mental states that have short and long term implication on our health. We learn every week about a new study that tells us that what we are eating is killing us. This builds a battle for control between the three elements of mind, body, spirit. That physical craving for french fries makes us argue with the mind about eating the saturated fat that could shorten the length of our life with each bite, but think how happy we will be as we eat the french fries. This back and forth is a good metaphor for the complexities of our health and healing. There are the dynamics of emotion and control and when you wrap in the variable of how each of our bodies processes the chemicals of the french fries differently, your thought about french fries are now different that when I first mentioned them.

Now take those complexities and we will apply them to being sick. Lets go back to being sick when our sense of taste isn’t right. How does this affect the healing process? It takes the notions of our place and the whole environment that we are accustomed to and turns it upside down. Where are we if we can’t trust our senses? When food doesn’t taste normal it’s very unsettling, just like being in a new place. I think with the help of new studies, and perhaps a little training on our own, we will be able to use taste as an indicator of health.
3.4.6 Breath and the Nervous and the Circulatory Systems

Breath in not considered a sense, but it should be. Breath communicates to us, like all our other senses do, about the interaction of our environment. It can tell the temperature of the air, how hard we are breathing and how hard we are pushing our bodies. It is known that breathing exercises can reduce pain, stress and lower blood pressure\textsuperscript{24}, but it does so much more than that.

The breath is connected to two systems in the body. The nervous and the circulatory systems. The breath feeds the oxygen that burns fuel for our body. When a part of the body is damaged it naturally increases the circulation and oxygen to that area. The better the circulation the faster the healing. Deep breathing has been associated with health and spirituality. A deep breath can pump immune cell rich fluid from the lymphatic system that kills bacteria and viruses. The breath is part of the autonomic nervous system meaning it’s one thing that we have the ability to do consciously and unconsciously. This is included in the peripheral system, which is things our body does without us thinking about them, like heart rate and digestion. For example you can’t think “make my heart beat faster” and it does. But you can think stressful thoughts and the result is that the heart speeds up in anticipation. This is because you have activated the sympathetic nerves system where the he fight or flight syndrome is rooted. If the sympathetic nervous system was the yen than the yang would be parasympathetic nervous system.\textsuperscript{25}

\textsuperscript{24} Marksberry, “Breath.”

\textsuperscript{25} Sternberg, \textit{Healing Spaces}, 70-71.
The nervous system is important because it is like the internet of the body. It is the highway that connects the senses to each other. All the senses use the nervous system to do their job and are interpreted by the brain. The overwhelming theme from looking at health and healing through the five senses is that they all play an important role in healing the body. Most of the time we don’t realize we are experiencing stress and that can have a big impact on the healing process. The more relaxed a person is, the better and faster they heal. The same system of senses can be used for good, however if ignored might actually be causing harm. The key is too not involve the nervous systems fight or flight response. This can be difficult due to the changes we experience in our body while we are sick.

How do we use empathy and creativity to construct an environment that communicates healing to the body while making it flexible enough to work with different people. This is where the roll of art and design can help. What if we were able to combine all the healing power of every sense at the same time to create an environment where the patient can smell the fresh air, hear rhythmic sounds of nature and see beautiful colors of the landscape while being bathed in warm light. It sounds almost absurd, ridiculous and futuristic. But, there are some architects and new organization with the goal of improving healthcare though designing a situation just like this.

Star Trek the Next Generation had the Holodeck. A room that could create any environment you wanted. What if you could lay in your hospital bed on the
beaches of Hawaii or maybe a high alpine meadow, or maybe your childhood room for some comfort. Another thought was instead of looking outward what if we looked inward. They say the key to space travel will be suspended animation. What if we could put someone in that state with the confidence that they were having a pleasant experience? As it turns out we are doing this right now in a somewhat crude form called a medically induced coma. Which is used in a lot of cases because the medical equipment used, like ventilators, pumps and tubes, are so unpleasant and painful it would be considered cruel to be awake and conscious during treatment. But, when I try to think of ways to accomplish this in a practical manner some roadblocks occur. Mainly, how to modify preexisting buildings and stimulate these senses while they are under the duress of illness.

I have notice by own experiences and living with family members who are ill that the person who is ill experiences the world differently. I have come to my own conclusion about what happens to us when we are ill. Because I am a visual person I will described this in a visual manner but it is not intended to be only associated with vision. Imagine your are looking down on a person from above and they have a circle drawn around them. When that person is ill that circle would have a six inch radius. Any thing with
in that circle is what that person has the ability to perceive and deal with. If we look at a healthy person they might have a twelve foot radius of what they perceive and can deal with. It is this inward progression of illness that interests me.

Doctors can detect when our senses are communicating by keeping track of this boundary and look for it as a sign of recovery. As we heal from a fever we seem to emerge from a trance or as if we have traveled from another place, our senses shut down as part of the natural response to being ill. It’s a coping mechanism meant to deal with pain and it’s the body’s way of conserving energy to concentrate on fighting the illness. However, what I find interesting is that the same process seems to happen with most physical ailments as it does with mental and emotional ailments. We are seeing signs of recovery from divorce or the death of a loved one as signs of recovery from a physical ailment. The same applies to many mental disorders like depression. In an effort to show my thought process behind my work, this is where the breath is the sense that connects health, mind, body and spirit. To be clear there are other senses that accomplish this, but it was the deep eastern culture relationship in Buddhism and meditation that focuses on the breath that were most interesting.

3.5 Mediation and Mindfulness

Recently in western medicine, meditation and mindfulness have been documented to be helpful with physical pain, mental pain (stress) and emotional pain. Both improve mood, promote happiness, lower blood pressure, and can be as effective as some drug therapies for depression. Once again to clarify my thought process it

\[27\] Sternberg, Healing Spaces, 102.
seems to me that we have all these tools to measure the body but we are only using them in the physical aspect of health.\textsuperscript{28}

What about the other two aspects of health, mind and spirit? What are next questions? It seems that the standard measurements of healthcare also applies to mental and emotional health. Are their other measurements that could help? What if wearable technology could give us all a better view of where that circle lies on each given day? What if doctors had access to this data to be able to diagnose events? Therefore, a data driven reason for problems could be taken, making people aware of emotional and spiritual states, thus improving their physical health and improving overall health over the course of a lifetime.

\section*{3.6 Biofeedback}

At this point I began steering away from architecture and looked more into the different measuring devices in the mental health community. One of the first things I found was an instrument that has been used since the 1970's called biofeedback. I learned how biofeedback was being used to help many different situations in relationship to stress reduction, concentration, control of emotions and mindfulness. The Mayo Clinic was a great resource to understand the different kind’s of biofeedback\textsuperscript{29}.

**Brainwave.** This type of method uses scalp sensors to monitor your brain waves using an electroencephalograph (EEG).

\begin{footnotes}
\item[28] Corliss, “Mindfulness.”
\item[29] Mayo Clinic, “Biofeedback.”
\end{footnotes}
Breathing. During respiratory biofeedback, bands are placed around your abdomen and chest to monitor your breathing pattern and respiration rate.

Heart rate. This type of biofeedback uses finger or earlobe sensors with a device called a photoplethysmograph with sensors placed on your chest, lower torso or wrists using an electrocardiograph (ECG) to measure your heart rate and heart rate variability.

Muscle. This method of biofeedback involves placing sensors over your skeletal muscles with an electromyography (EMG) to monitor the electrical activity that causes muscle contraction.

Sweat glands. Sensors attached around your fingers or on your palm or wrist with an electrodermograph (EDG) measure the activity of your sweat glands and the amount of perspiration on your skin, alerting you to anxiety.

Temperature. Sensors attached to your fingers or feet measure your blood flow to your skin. Because your temperature often drops when you’re under stress, a low reading can prompt you to begin relaxation techniques.

Some common ailments that it is found to be successful treating include:

Asthma, attention deficit hyperactivity disorder (ADHD), chemotherapy side effects, chronic pain, constipation, fecal incontinence, fibromyalgia, headache, high blood pressure, irritable bowel syndrome (IBS), motion sickness, Raynaud’s disease, ringing
in the ears (tinnitus), stroke, temporomandibular joint disorder (TMJ) and urinary incontinence.\textsuperscript{30}

I was thrilled to find that right here on the RIT campus there was a biofeedback trial going on to help students with stress reduction. As a person who loves to experience things firsthand I quickly signed up and began working with a new video game-biofeedback device that had been created by students. These sessions introduced me to a woman who was conducting the studies and is now on my thesis committee, Anna Hope. Anna is a mental-health clinician at the Center for Applied Psychophysiology and Self-Regulation at Rochester Institute of Technology’s Institute for Health Sciences and Technology who studies biofeedback and the nervous system. I did 2, 45 minute sessions every other week during the spring semester of 2015. The point of biofeedback is to help the person realize subtle changes in their physical body in order to reduce stress anxiety and pain. This is accomplished by monitoring different aspects of the body and giving the feedback to the user to train them to be aware when things start to go awry.

Anna would have me play a video game that was integrated with the biofeedback machine. As a monster begin to hurl a ball toward me I had to maintain my composure. When the balls began to come faster I noticed the stress increase. I had to control my body’s response to stress, pay

\textsuperscript{30} Mayo Clinic, “Biofeedback.”
attention to how my body was responding to the stress and learn to control the stress reaction. Anna’s help and experience in healthcare, especially hospice, gave the perspective of how the medical community might be able to use biofeedback measurements to help quantify the mind and the spirit.

Biofeedback appeals to people for a variety of reasons: It's noninvasive, It might reduce or eliminate the need for medications, be a treatment alternative for those who can't tolerate medications or when medications haven't worked well. It might be an alternative to medications for some conditions during pregnancy and It helps people take charge of their health. One of the things that fascinated me about biofeedback was that it worked with all of the elements of the learning process. It works with the nervous system, it can be done non-invasively and through wearable technologies.

### 3.7 Skin Conductance

Skin conductance is a measurement element in biofeedback that I found fascinating because it works as part of our sympathetic nervous system that we cannot consciously control. Similar to our heart rate we can't think “I want to sweat” and make ourselves sweat. Sweat is easily measurable through skin conductance and fits the criteria of being part of the sympathetic nervous system, and is an indication of psychological or physiological arousal. If the sympathetic branch of the autonomic nervous system is highly aroused, then sweat gland activity also increases, which in turn increases skin conductance. This is one of the main tools used in lie detector tests because of these unique qualities. This can also be called the GSR (Galvanic Skin Response). Researchers have found that sweat is also a very good indicator of mental and emotional stress and the relationship of how it affects the
physical body. Because it is apart of the sympathetic nervous system our emotions are
effected but are not controlled, therefore learning to control our emotions allows us
the power to our GSR.

3.8 Products Currently on the Market

If there were wearable devices that could measure GSR throughout the day this
data could be reviewed by a doctor or therapist and could help the patient learn
exactly when these events happened and what was going on to help them learn from
them, ultimately helping the doctor to improve the patients overall well-being. Through
my research I found that there are many devices currently on the market that are
beginning to incorporate GSR technology. The one I found most interesting was the E4
Wrist Band by Empatica.31

31 Empatica, “E4 Wristband.”
The E4 Wrist Band has features in which I believe could be very helpful for patients and doctors.

**PPG Sensor** - Photoplethysmography Sensor - Measures Blood Volume Pulse (BVP), from which heart rate, heart rate variability (HRV), and other cardiovascular features may be derived.

**3-axis Accelerometer** - Captures motion-based activity.

**Event Mark Button** - Tags events and correlate them with physiological signals.

**EDA Sensor (GSR Sensor)** - Electrodermal Activity Sensor - Used to measure sympathetic nervous system arousal and to derive features related to stress, engagement, and excitement.

**Infrared Thermopile** - Reads peripheral skin temperature.

**Internal Real-Time Clock** - Temporal resolution up to 0.2 seconds in streaming mode.
An electroencephalogram (EEG) is a test that detects electrical activity in your brain using small, flat metal discs (electrodes) attached to your scalp. Your brain cells communicate via electrical impulses and are active all the time, even when you’re asleep. This activity shows up as wavy lines on an EEG recording in real-time, thus providing a direct link to ones mental and emotional state. It was surprising to me that technology has moved so far in which the censors are small and easily work by wearing hats or just placing the sensors directly against the skin of the scalp. What I found interesting was, there were no large machines or beds in which the patient had to lie very still during the process. This excited me to the possibilities of harnessing of our own thoughts. This also made me very nervous that soon technology will be able to read our minds. Soon we will be walking around with EEG devices on our heads and communicating with other people and machines by thoughts only.

So now we have all of these tools at our disposal for mental and emotional health that give us constant feedback in real-time of how we are doing. What if we were to treat our mental and emotional health like our physical body, meaning we have to exercise it and eat healthy? There’s a lots of research that supports the idea that if you keep a person mentally active it helps keep dementia at bay. What if these tools are applied to the hospital so measuring your mental health would be as common as taking your temperature? It’s not that these tools know how to fix it but just like your temperature it can let people know when there’s something wrong. What if we had nurses that where in the hospital for the sole purpose to check on our mental and

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32 Mayo Clinic, “EEG.”
emotional well-being and not just our physical? Could the faster healing times and better outcomes save enough money to cover the costs of the increase in personnel? Would adding two more parts to the hospital and healthcare system cause the whole system to just collapse? Wouldn’t it be great if we as a society excepted mental and emotional health to be as important as physical health.

3.10 Neurodiversity

Right now there is a movement going on called the Neurodiversity Movement. This movement involves people who have neurological functions different from what is considered “normal” to be accepted as a society. Neurodiversity advocates promote support systems including inclusion-focused services, accommodations, communication and assistive technologies, occupational training, and independent living support that allow those who are “non-neurotypical” to live their lives as they are, rather than being coerced or forced to adopt uncritically accepted ideas of normality, or to conform to a clinical ideal. 33

When we apply empathy to this problem we see why society has had such a hard time with mental illness. Because our brains are the center of our world it’s very scary to empathize and/or put ourselves in the shoes of someone who’s brain is no longer functioning the way we believe is “normal”. The best example of this is Alzheimer’s, dementia and schizophrenia. These are a little easier to wrap our heads around and we think how awful it must be to not be able to remember anything or hear voices in our head at random times telling us to do things or see things. It takes a large amount of empathy and compassion to work with these people.

I have found it to be an extraordinary challenge in applying the principals of

33 Somashekar, “Autistic Adults.”
design to the mental health landscape therefore, I am focusing more on preventative measures and overall health to create a place of healing. So let’s now circle back to the original statement of how art and design can help people heal. I have found that within the environment you can improve the situation dramatically, I’ve also found that wearable technologies can be a large help in the future of predicting, maintaining and taking responsibility for one’s own health.

### 3.11 ICU Psychosis

I began to ideate on what a wearable might be and how it might look. I felt like I did not have a full grasp of the answers to the questions that kept arising. Sometimes the answer defined the question, so what if we reverse the question. If we ask how could we create the worst possible environment for healing what would that be like, what would we learn. As I asked people close to me about their experiences in the hospital I began to look for answers from a more professional point of view. My primary care physician Dr. Christine Borghi-Cavallaro M.D. was always interested in my progress in industrial design as her son
graduated from the Rhode Island Institute of Art with a degree in industrial design. As we began to talk about my experiences in the hospital with my loved ones she introduced me to the notion of ICU Psychosis. ICU Psychosis is when the patient has a mental break due to a number of factors that all tend to correlate in the most extreme. The patient can literally lose their mind in as little as a few hours to a few days and usually becomes more pervasive the longer the patient is in the ICU. If the psychosis is not quickly addressed at the beginning the end results are usually fatal. The causes of ICU psychosis are long term immobility, large amount of pain for long-term, constant medical monitoring and disturbances to the circadian rhythm, in short all the machines the noise and stress of the hospital settings of the ICU can literally cause a person to go psychotic. This phenomena is not limited to one type of person or case, this happens to 75% of ICU cases.  

34 Welker et al., “ICU Psychosis.”
So, we found the worst-case scenario where the medical environment that has been created can actually harm the patient. Here we have two sides of a coin, one side the person would not exist, the other side the cure could kill you. I feel the place to start adding design thinking into the hospital is the worst case scenario, the ICU. If we can fix the worst case scenario and then scale it out to the rest of the hospital, over all healing and well being should become easier. This is where quality information from all of the senses combined together can create a way to communicate with patients and with their bodies at the brink.

### 3.12 Personal Interviews of Nurses

To learn more about the situation I began to reach out to the community to talk to people that directly have experience in the subject. I first talked to doctors, however I found doctors were not very aware of the subject of ICU Psychosis and none of them took it quite seriously, but they are not the users in the sense that they were not the caretakers of the patients in the ICU. The majority of care fell to the ICU nurses, therefore I went about trying to find ICU nurses to interview and discuss the situation. In the end I spoke with three ICU nurses, these conversations took place over the phone and lasted an average of 45 minutes. I had 10 standard questions that I asked each nurse;

- What is the hardest part of your job?
- Why is it the best part of your job?
- How do you address pain in your patients?
- How do you communicate with patient who are unable to talk?
• How do you find the physical environment, light, window, sound?
• What do you feel is needed to make patients heal as fast as possible?
• Would it be helpful to have a record of changes in a patient's blood pressure and galvanistic response?
• If you had a way of measuring a person's mood or temperament, would that be helpful?
• How does mental health affect healing, in your experience?
• What piece of the puzzle do you feel is missing in the tools that you have?

However after hearing their stories and their responses, the 10 questions spurred additional questions. Overall, I found three of the nurses to be the most helpful, the most interesting was Bridget Hanson.

3.12.1 Bridget Hanson

Bridget Hanson
R.N.
Rochester General Hospital
Rochester, NY

Bridget Hanson R.N worked in the ICU at Rochester General Hospital, in Rochester, NY in the mid 2000’s for 5 years. What was unique about Bridget’s situation was not only was she a nurse in the ICU but she was also a patient. Bridget suffers
from celiac disease which put her in the hospital for 12 weeks, with 6 of those weeks in the ICU. She had great insights in what it was like to be a patient and nurse in the ICU.

She believes that if it were not for the large amount of medication that disoriented her she would not have been able to survive. I asked her if it would of been better to be more aware. She said it was a blessing to be unaware as possible. At no time did she feel that she was in danger of ICU psychosis and was very well aware of the dangers and the problems the occur.

The most frustrating situation for her as a nurse was not being able to communicate with the patient and as a patient not being able to communicate because of the many medications she was on. The medications dulled her mental and emotional abilities to communicate. As a nurse in that situation many times she used a white dry erase board to communicate with her patients. She found this to be very difficult for the patient due to sedation medications and that they didn’t have the coordination to write and if the patients didn’t speak english it was even more difficult. Ironically enough Bridget expressed that the hardest part of nursing for her was not the patient, but co-workers, the regulations of the hospital and dealing with family members. In her words, “the politics of healing”. I asked her what do you feel is needed to make the patients heal as fast as possible, her answer was very short, “quiet, nursing care, and communication”.

I ask her if there were problems dealing with pain in the ICU. She said “yes, It would be helpful to have a record of changes.” She found the idea of GSR (Galvanic Skin Response) very exciting because many of the patients in the ICU are first placed in a medically induced coma making it very difficult to communicate. Nurses monitor
machines that monitor the patient. One sign that the patient is in pain is a rise in blood pressure. The nurses closely monitor the patient’s blood pressure and administer pain medications accordingly.

However is there a better way to glean this information? The study “Skin Conductance as a Measure of Pain and Stress in Hospitalized Infants” 35 found GSR monitors could administer pain relieving medications 20% to 40% faster by keeping track of the Calvinistic responses then just heart rate alone. I suggested that this might be able to be applied in the ICU with these newer technologies. One of the ideas that came through the ideation process was, what if we took the wearable technologies away from the patients but gave him to the nurse; therefore, the nurse would be alerted with subtle vibrations. This will help lower the disable levels in the hospital.

4. Design Objectives

My design objectives are very simple, use design to promote health and healing in the hospital ICU. The product must improve healing by increasing the comfort of the patient and to reflect promotion of the body, mind and spirit.

Research shows that one out of four people in the ICU experience some from of psychosis caused by the environment, medical monitoring and pain levels.36 Therefore, the product must improve the humanity of patient interaction in the environment, reduce the stress of medical monitoring, and help communicate the pain levels a patient experiences.

35 Harrison et al., “Skin Conductance,”

36 Welker et al., “ICU Psychosis.”
I started with the hospital room itself. What elements of the room could be optimized? Light, shape, size, smell, air quality, color and windows were all considered. Because of the high construction costs needed to transform existing rooms these options are seen as part of the design to be added together to create a comprehensive healing space. In order to keep the perimeters of the design under control, some of these elements were eliminated or taken in context individually to maximize the impact they might bring to the project.

5. Design Brief

To create an object or device that improves a person's well-being in a normal hospital situation to the highly critical aspects of the ICU. The object or device can improve a person's well-being by the simplest means necessary, reductions of stress or improvement of the environment. The restrictions on the object or device are complicated due to the fragile nature of the patients themselves.

The object or device must fit a variety of sizes and different stages of healing. It must not interfere with, but take into account, standard medical protocol and procedures. It also must be comfortable and easy to use. Depending on the severity of the patient, the actual use of the object or device by a patient has different restrictions and uses. The patient may be severely limited in their cognitive abilities. They may have breathing tubes that keep them from talking. They may be restrained or paralyzed and unable to move. The object or device must be intuitive enough to be placed in current medical situations without the need for large amounts of re-education for ease of use.
6. Ideation

The Ideation processes for the Wave began as typical consumer electronic goods with the minimal amount of materials needed. At this junction I begin to look into fashion and was very interested how 3D printing influences the styles and works of fashion designers. This seemed to be the way to make the two worlds collide. Use the 3D printer to construct the Wave and influence the form. The complexity of this soon became apparent that it was going to be necessary for me to learn Grasshopper to accomplish the form which was well beyond my capabilities at this point.
After drawing some basic sketches I moved into a 3D sketch mode of using paper and wire to make basic forms to see the aspects that carried to more complete thoughts about materials and form. The 3D sketches began to show me that the rounded curve was the underlining theme of the form. That inspired me to look at the ups and downs that come with the theoretical "wave curve". This is why I began to make it a dominate line and form in the device.
7. Prototypes
8. Final Sketch of the Wave
9. The Wave
9.1 Form

I felt it was important for the form to be expressive and communicative, to reflect the Waves function. Research from movies and websites were important in terms of functionality and form and it was very important to see the extreme places the Wave could be used, like the ICU. Personal visits, pictures and other accounts of user experiences in the ICU helped to created the limitations in the design brief.

The form needs to celebrate the body while communicating information to medical staff, enabling a good emotional feeling for the user and viewer. I started with traditional jewelry design and expanded into science fiction, popular culture and steam punk to think of how to cover the head in a beautiful and unique way. Inspiration came from Jordi’s glasses from Star Trek, and steam punk culture.
With the form and research it was important to balance the consumer electronic trap, making everything look black and shiny and taking minimalist modernism to the extreme. Donald A. Norman’s book *Emotional Design: Why We Love (Or Hate) Everyday Things* was very helpful to put this all in context of the history and relationship people have with design and objects and why attractive things work better.

“Beauty comes from the reflective level. Beauty looks below the surface. Beauty comes from conscious reflection and experience. It is influenced by knowledge, learning, and culture. Objects that are unattractive on the surface can give pleasure. Discordant music, for example, can be beautiful. Ugly art can be beautiful.”

The final form that evolved into the Wave was a combination of the influences above. It’s shaped by the technical aspect of the placement of the sensors by naturally creating a rhythmic pattern across the frontal lobe of the head. This was incorporated into the body that houses the electronic needs of the batteries and bluetooth technology. By keeping the housing on the top, this allows the user to have the

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other sides of their head clear, allowing for different positions in the hospital bed and also applicable to scenarios in which the user may be using the Wave in an “average day” situation.

It was my intention for the Wave’s structural elements to be folded into the form. For example, the circular arched wires that connect the sensors to the body of the unit created more rigid stability but also become an element of form and a way to cut back on materials.

The current trends in wearable tech objects are made with an emphasis on minimalist design to the point of almost negating the user and their personality, for example the design of Apple products. I find it funny that we cover up these brilliant designs and form with protective cases and stickers. Consumer electronics are the new bumper sticker. This is why the element of jewelry was implemented into the design of the Wave. I would like to offer it to users in many other forms with the ability to pop the mechanics out of one Wave body and place them into another Wave body that suits the user better.
9.2 Tech and Materials

The material requirements for the Wave are quite low. For the Wave to communicate, the sensors must be in contact with the skin on the frontal lobe of the scalp. The connection needs to be boosted by the sensors being wet or damp. This can be accomplished by using small amounts of water, oils, wax, and petroleum jelly. A wire then carries the signal to the transmitter to be sent to the software. The software then translates the signals through a series of algorithms that need to be calibrated to each person. Once the algorithms have been translated, nurses, doctors, and patients can gather information and communicate.
Two major things could be accomplished by this. First, collect data about the mental and physiological state of the patient which will help quantify the reactions of the patient to the treatment and their environment. Second would be for the patient as a way to offer a “sixth sense” to interact and “keep-in-touch” socially with the world and loved ones. This is were ICU Psychosis and the pain management scale on the dry erase board meet. The algorithms and predictive software would create a virtual mouse to allow text and talk by thinking.

Given all that the Wave has to accomplish, the material needs should remain flexible for the need of application. In terms of the consumer electronic industry standards for durability, the materials need to be hard, like plastic injected molds, metal and glass. Researchers who have been testing wearable EEG devices for research purposes have been sewing them into hats, headbands and other soft goods. Flexible and hard, the empathy for the users is missing in both examples. Softness and soft goods need to be brought into the design dialogue, things like fleece, foam maybe even knit. The soft good approach has many aspects that can be helpful in terms of heat or cold and can be constructed out of a blend of cotton and synthetic fibers with patterns similar to the consumer model.

The Wave consumer model would be made of more traditional materials, metal and plastics. The metal will allow the user to bend the Wave to fit the each users head. The white portion is the body of the Wave and where future development can be made in the form of jewelry. Currently the body area is injected molded plastic to keep costs and weight low and have high durability.
9.3 Ergonomics

Neurodiversity, the idea that we all have the same basic machine in our heads but everyone’s is tuned and optimized differently. Therefore, everyone utilizes different parts of their brains differently giving us the diversity in skills and personality that make humanity the beautiful mixture that keeps thing so interesting. The ergonomic’s of the Wave take into consideration the neurodiversity distinctions that are possible with the user. To collect data from the different brain waves four general areas on the frontal lobe will be the same starting points on each user in order to get a base line of the user and the Wave. The four general areas are behind each ear and on each side of the forehead. These areas gives the algorithms a base line of the Beta, Alpha, Theta and Delta brain waves to run the program.

9.4 User Interface
The user interface should be finished with the help of professional UX designers and psychologists, but my basic design is to emulate the medical dry erase board.

I found through my interviews that the user needs the same information communicated to them many times daily. Confusion and loss of cognitive skills are very common and are due to the loss of time, noise levels and heavily medicated states. When a patient comes to the ICU unable to talk the only means of communication is the white board or family members. Therefore the Wave interface would provide a way of communication for the patient, doctors, nurses and staff and will increase the quality of care.

The user experience must be taken very seriously because the users will not be at their best cognitively, therefore it must maintain almost childlike ease of use.
Graphics and colors should maintain very primary states, such as circles and squares, red for stop or no, green for go or yes. As the user concentrates ‘Left’, the curser seen on the tablet would move left, as the user concentrates ‘Right’, the curser seen on the tablet would move right, the same would be for up or down. This would enable the user to click on one of the buttons on the tablet. They would be able to alert the nurse, doctor or family, and find basic info like time, date and weather. With an interview from RIT professor Jeremy Brown, I discovered because of its simplicity this application is very plausible and would need about 6 months to develop with another 6 months of testing to work out problems. It already partially exists with consumer models on the market using standard programming codes.

10. Research Influenced Design

The Wave was influenced through interviews of patients, nurses, doctors and staff. Their comments and suggestions can be seen in the aspect of the design. It was invaluable to be able to ask questions to help inform me of the technical aspects that may pose a hazard for all the stakeholders. Doctors were good at giving insight into the aspects of the big picture problems, while the nurses were very good with practical information to develop the parameters of the how the Wave could interact with them and most importantly with the other devices being used. The nurses also were instrumental with the priority of problems they and their patients experience in the ICU.

11. Conclusion
The significance of the Wave is to improve how we treat ourselves and each other in order to increase the amount of empathy in the world. The ICU is the perfect metaphor of how our knowledge has bought us to a state of creating a belief that health is repairing weak or broken parts but not the spirit of the patient. This thinking approach is systematic thought out western culture, it is time to step back and see the big picture.

The big picture is quality of life; how the body, mind and spirit of a person function together to heal. The experience of being sick can be a lonely and isolating and can get worse in many cases due to medical treatment. The Wave will bridge the body, mind and spirit becoming a metaphorical medical smart phone between doctors and nurses and also a medical smart phone between the user and themselves.

It is not hard to make the intellectual leap from the ICU to the solitary confinement of prisoners in a super max prison. Studies\textsuperscript{38} have proved how detrimental solitary confinement can be to a persons mind, body and spirit. Prisoners in this condition suffer from psychologic breaks, physical ailments and long term problems. A person in the ICU is very similar. They are restrained, and unable to speak in many cases. The intent of solitary confinement in a prison and an ICU in a hospital are very different but the results are similar. The Wave is a way to break out of the chemical prison that the patient feels from medical sedation and pain meds.

The Wave does have some difficulties, right now the technology is not advanced enough to work without intensive training for the user. I find that the Wave currently maybe too difficult to use given the state in which the medications puts the user in. The

\textsuperscript{38} Breslow, “Solitary Confinement.”
sensitivity of the device needs to increase and the algorithms need to be advanced in order for it to work in a more seamless way. I also believe that this will only be the first step in future cyber mind manipulation.

12. New Research Inquires as a Result of Project

After studying this problem, more information always creates more questions. I have recently spent time in the hospital both as a patient and as a family member. I have realized that there are other concerns with the relationship between the nurses and the patient. Communication is what binds us together to create the human experience. Do more avenues to engage with the patient come at a cost to the caregivers in the form of more emotional stress and burn out? What is missing in the equation is a holistic view of the cause and effect relationship between patients and caregivers by a sociologist.

More research needs to be done on the 5 senses and their relationship to the body, mind and spirit. This would give insight to defining the roles environment and relationships play on each of us. This would also give valuable information to other designers and architects that would effect all aspects of our life moving forward. Taken to the extreme this could create not only hospitals optimized for health but homes and cities too.
13. Bibliography


Marshall, Phil. interview by Kurtis Kracke, June 20, 2016.


