Sensory Reduction
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Executive Summary

The purpose of the design project was to examine the methodologies involved in the development of a design solution to a given problem. Students worked in teams of five and worked with a client to consultatively identify a problem, develop a strategy to meet the client's needs and compose a proposal for a solution. The team created a project management plan in the form of a Gantt chart, which was kept up to date as the project evolved, up until the final day. The team was encouraged to think creatively, using their individual backgrounds to enhance the group's creative capacity. This required each member to respect the diverse disciplines at play and to understand the ever-evolving roles of each member of the group. The goal was to present a final deliverable to the client in a timely and professional manner.

The client in this project was Kidspace, a multidisciplinary pediatric therapy clinic located in San Francisco, Californa. Kidspace provides occupational therapy, speech therapy, physical therapy and psychotherapy. Their clients seek treatment for a broad range of child development challenges including sensory processing disorders, Austism Spectrum Disorders, ADD/ADHD and a few neurological disorders. The teams worked closely with the therapists to understand their perspectives and concerns and to identify the problem that the design team would attempt to solve.

Many of the children at Kidspace are sensitive to sensory feedback and are easily overstimulated by a variety of sensory inputs. During the busier times and transitions at Kidspace, the high levels of sensory input can create a difficult environment to have a productive therapy session. The goal of the project is to design an environment to reduce auditory and visual stimulation throughout the facility.

A very thorough, human-centered design approach was followed, guided by the policies with which the design consultative firm, IDEO, has become so successful. This process included facility and interaction observations, large group brainstorming sessions, rapid prototyping, proposal analysis and selection, refinement and implementation.

To address the issue of sensory reduction in Kidspace, the team inevitable designed three final products, which were formally presented to the client four weeks after the first meeting. The first deliverable was a working prototype of a partition that would be used to close off the gap in the wall between the waiting room and the main hallway to reduces the sound travel between the two areas. The second design was a working model of a door made of several overlapping 6" PVC strips. which provided a safe alternative to a solid door and also reduces sound travel between the gyms The final deliverable was a sound sensor implemented into a structure that hangs on the wall and provides feedback in the form of LED lights to indicate the noise level of the room.

After the presentation, the client was very pleased with the products delivered, and it is likely many of these designs will come to fruition within the facility in the near future.

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Introduction

The purpose of this project was to examine the tools and methodologies involved in the development of a design solution to a given problem. Individually and as a team, students studied different design methods in a real-world setting and worked with the client, Kidspace, in order to solve a specific set of problems. The course focused on various aspects of a design process, including: project management, prototyping, design documentation, iterative process, and implementation. As a team, we were expected to: work with Kidspace to consultatively identify a problem, develop a strategy for meeting those needs using the teams' assets and strengths, write a full proposal for the project, develop a project management plan to maintain and update, work in a creative capacity, understand all team member roles, understand and respect other disciplines in the design approach, and finally present project to the client in a professional manner. Overall, this course utilized our knowledge, as a senior student to perform a major open-ended design project that meets the ABET Accreditation requirements. The project was conducted in a professional manner that resembled a real business environment.

This capstone course was intended to integrate liberal learning with specialized knowledge attained during undergraduate studies at Miami University. It emphasized sharing of ideas, critical thinking, informed reflection, and student initiative in defining and investigating problems or projects. Collectively, students understood context, thought critically, engaged with other learners, reflected, and acted on those actions. This all contributed to the Miami Plan liberal education learning experience required by Miami University.

Kidspace is an occupational therapy, speech therapy, physical therapy, and psychotherapy clinic located in San Francisco, CA. Practitioners work with a variety of clients, newborn to adolescent, to help children develop and overcome occupational and physical adversities. The facility uses advanced assessment tools, equipment, and professional experience to provide a treatment to a range of child development challenges. These challenges include sensory processing disorders, mild to severe Autism, ADD/ADHD, speech and language pathology, fine-motor skill development, developmental delays and a few neurological disorders. There currently exists high levels of sensory input at Kidspace, which can cause a great deal of overstimulation. This impacts those who are sensitive to sensory feedback and can create a difficult environment to have a productive therapy session. The goal of the project is to design an environment to reduce auditory and visual stimulation throughout the facility.

The design team was comprised individuals from various engineering disciplines and business backgrounds. The team members included: Chris Richani (Mechanical Engineering Major), Christian Trapp (Engineering Management Major), Devin Calori (Marketing Major with IMS Minor), Molly Bayer (Biomedical Engineering Major with Spanish Minor), and Patrick Gallagher (Manufacturing and

Engineering Management Major). All of the members have knowledge and expertise ranging in topics, but compliment each others' skills in a variety of ways. The design process enabled each member to use their specific skills and background, while simultaneously allowing them to cast aside their educational labels and work in an open, multidisciplinary and creative environment.

The team developed a Gantt Chart in order to illustrate the design process and timeline that would be followed during this course. The chart outlines specific milestones and goals that must be achieved in order for the team to complete the project in a timely manner. Throughout the project, the team was able to follow the outlined process schedule and completed the deliverables on time to the client. The following is the project Gantt Chart developed at the beginning of the design process.

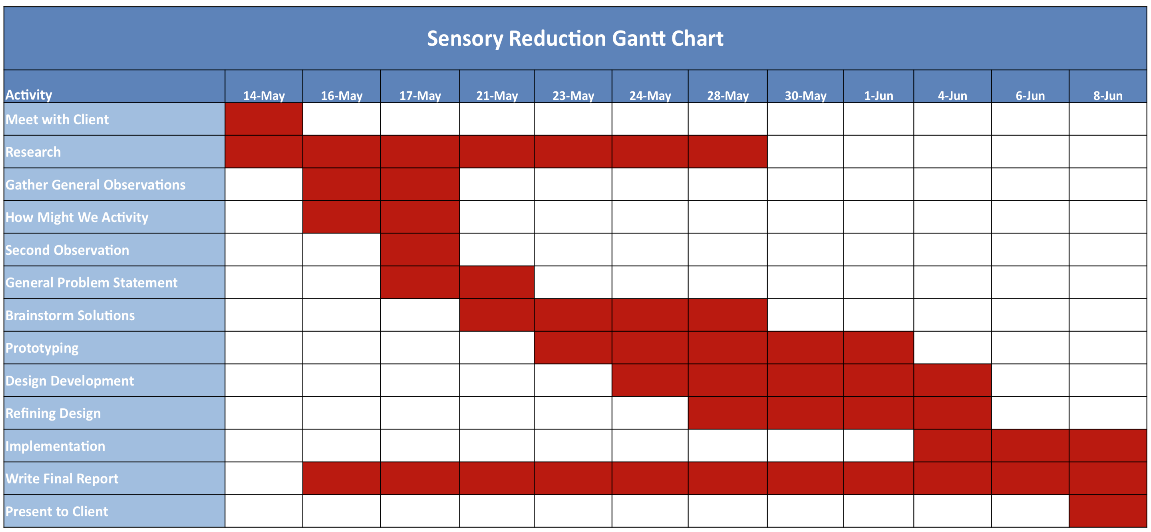

Figure 1: Project Gantt Chart

When the problem was initially proposed, the exact locations for change were not specified. The issue of overstimulation could happen anywhere in the facility, especially during their busiest hours in the middle of the afternoon. In order to determine what changes and designs would be the most beneficial to the entire facility, the team of students sat and observed between 3 and 6 pm on two different weekdays. Decibel readings were taken in each room and general observations were made so that the students could determine the most important issues.

In order to focus in on what deliverables would be provided, the group chose to address three main issues in both the waiting room as well as the back gyms: a sound barrier to be placed in the gap between the wall and ceiling in the waiting room, doorways between and into the gyms, and a feedback system to inform those in the room how loud it is. The group found that these changes would be the most profound in the reduction of noise and visual stimulation. From there, a great deal of research and prototyping of the materials went into the final designs that were used.

The following report will inform the reader on the preliminary and prototype research conducted by the team, including SWOT analysis associated with problem at hand. Next, the report reveals preliminary and finalized prototypes that the team generated. From proposals, the report presents the testing results, design deliverables, selection matrix, suggested models, and photos of final deliverables. Finally, the report discusses project conclusions, references, acknowledgements, and appendices. By the end of the report the reader will have a thorough knowledge of the problem at hand, the design process, and the inevitable solutions and data to support them found by the design team from Miami University.

Research

The client for whom the team is designing is Kidspace, a clinic that offers occupational therapy, speech therapy, and psychotherapy to children with neural disorders. Kidspace focuses its efforts on children with sensory disorders, autism spectrum disorders including Asperger's syndrome, children with attention deficit disorder (ADD) and attention deficit hyperactivity disorder (ADHD), as well as children who have experienced neural damage from trauma. The first step when working with a client such as Kidspace requires the engineers to familiarize themselves with the field. Thorough research was performed on the various disorders experienced by the young patients of Kidspace. There was also a great deal of research performed on various therapies, materials tested and used throughout the design process, and the municipal codes of San Francisco.

PROPRIOCEPTIVE SYSTEM

To fully understand the background from which the children at KidSpace are coming from, it was necessary to develop a general understanding of the proprioceptive system. Proprioception is an individual's sense of the parts of the body and their relative positions, as well as the strength employed to each part. Alternatively, exteroception is the sense of the world outside the body and interoception is the detection of senses within the body, such as hunger and pain.[22] The body receives this proprioceptive information from the sensory neurons, the liquids in the inner ear, and the stretch receptors in the muscles and joint-supported ligaments. The sensory information is sent from the contraction and stretching of muscles via the bending, stretching, pulling and compressing of the muscles and joints between bones.

In a healthy individual, the proprioceptive system can be sharpened and trained with balance exercises and blindfolded tasks.[12] However, in the case of many of the children at KidSpace, the proprioceptive system is not sending the brain the necessary information on the positioning of their body, or how much force to use when completing a task. Children experiencing this lack in sensory response will find themselves tapping their feet in order to know where they are without seeing them, or using far too much or too little force when writing with a pencil.[10] The holistic occupational therapy approach that KidSpace employs aims to target the proprioceptive system and force it to "relearn" this method of communication.

SENSORY PROCESSING DISORDERS

Sensory processing disorder (SPD) is a neurological disorder that causes difficulties in reception, process, and response to sensory information from their own body and the surrounding environment. Sensory processing disorder can affect all of the body's sensory systems including the visual, auditory, olfactory, gustatory, vestibular, and proprioceptive systems. Some difficulties that people suffering from SPD may face are trouble planning or organizing events and problems with self-care, work, or leisurely activities. SPD, as its name suggests, also causes extreme over or under sensitivity to various sensory inputs, which can result in the afflicted patient avoiding certain activities and developing distress, fear and confusion in the face of a wide variety of tasks.[3] There are three classifications of SPD. Sensory Modulation Disorder (SMD) is characterized by the over or under responding to sensory stimuli and sometimes actively seeking stimuli for satisfaction. Sensory Based Motor Disorder (SBMD) causes disorganized motor output, postural control challenges, and dyspraxia. Sensory Discrimination Disorder (SDD) leads to the incorrect processing of sensory stimuli, which causes inattentiveness, disorganization, and poor performance in school. A patient with SPD can be either hyposensitive or hypersensitive. Hyposensitivity gives the patient unusually high tolerance for sensory stimuli, which can cause the sufferer to become restless and seek sensory stimulation for satisfaction. Hypersensitivity is also referred to as sensory defensiveness and can cause the patient to experience discomfort or pain when exposed to even small amounts of environmental stimuli. This can manifest itself as pain from textured clothing rubbing against a patient's skin or discomfort with normal lighting levels and eye contact.[29]

AUTISM AND ASPERGERS SYNDROME

Autism and Asperger's Syndrome are developmental disorders that usually appear within the first 3 years of a child's life. Autism negatively affects the normal development of the brain and the patient's social and communication skills. Autism can reveal itself in a variety of symptoms including communication problems, problems with social interaction, stress accompanying a change in routine, repeated unnecessary body movements, unusual attachment to a certain object, and over sensitivity to light, sound, touch, smell, or taste.[6] Some communication problems that autistic patients usually experience involve difficulty in verbal conversation, use of gestures in place of words when conversing, slow or no development of language. These problems permeate into the social behavior of the patient which often leads to not playing with peers, avoiding eye contact or smiles, dehumanizing others by treating them as objects, and lack of the ability to empathize. Behavior in response to sensory stimulation can vary with autistic patients. Some patients may not startle at loud noises, while others can find normal noises painful and react by covering their ears. Patients can experience a heightened or lower response to pain, and in the cases of oversensitivity patients may withdraw from physical contact altogether. Some accompanying behavior with these symptoms can include tantrums, short attention spans, over activity or overly passive behavior, and aggression towards others or the patient himself.[7] Patients suffering from Asperger's Syndrome experience the same symptoms as autistic patients, but the conditions are different in that Asperger's Syndrome does not inhibit the development of linguistics and cognitive ability.[4]

ATTENTION DEFICIT DISORDER AND ATTENTION DEFICIT HYPERACTIVE DISORDER

Attention deficit disorder (ADD) and attention deficit hyperactive disorder (ADHD) have become extremely prevalent words used in today's world. It has been said that one child in every U.S. classroom suffers from one of the diseases. ADD/HD is a biological, brain based condition that is characterized by poor attention and distractibility and/or hyperactive and impulsive behavior.[47] The terms are usually used interchangeably for they involve very similar symptoms. Difficulties with concentration, mental focus, and sporadic behavior are the most common symptoms involved. ADD's roots were developed in the early 1930s but were first brought to the mainstream in the late 1960s. Even with its long history, scientists have yet to pinpoint exactly what the cause is. It is thought to be a condition based on genetic or biological functions.[48]

Children make up the majority of those who are diagnosed with ADD. They are diagnosed after showing six or more specific symptoms of inactivity and/hyperactivity on a regular basis for more than six months in two or more settings. There is no single test for ADD.[49] The use of amphetamines to control symptoms has been used since the 1930s however today studies are just coming out with some negative long term use of such drugs. 40% of children do tend to outgrow the disease once they reach their teenage years however scientist have yet to determine the reason. There is still over 4% of the adult population who are still affected by ADD. Adults are likely to change employers frequently and perform poorly, have marriage problems and have fewer occupational achievements. Stress management and therapy have been successful in treating ADD in adults.

TRAUMATIC BRAIN INJURIES

A brain injury can be classified as a mild loss of consciousness and/or confusion and disorientation is shorter than 30 minutes.[43] Many people receive brain injuries and believe that the side effects are common to any accident. Traumatic brain injury (TBI) usually involves a sudden impact to the head which forces the brain into a collision with the skull. Over 35% of TBI incidences are caused from falls, followed by motor vehicle accidents and random strikes to the head. Falls are especially prevalent in children and adults over 65 years old who have a reduced control over their balance.[44] The symptoms of TBI are often overlooked and are one of the most misdiagnosed incidences. With over 1.5 million reports of people who suffer from TBI each year, it is estimated that the number of unreported incidences is 2-3 times higher.[43]

TBI is divided into two categories; mild and moderate to severe. Mild TBI is the most common and most misdiagnosed of the two. Since a mild TBI is only actually felt for less than 30 minutes and is usually coupled with other symptoms involved in the incident, it is often initially overlooked. However 15% of people with mild TBI have symptoms which last one year or longer.[43] Symptoms can include headaches, difficulty sleeping, and sensory problems are a few of a long list. These symptoms can appear immediately after the event while others may appear days later.[45] Moderate to severe TBI is defined as a loss of consciousness from 20 minutes to greater than six hours. The impact to the brain can cause cognitive deficits, speech and language problems, as well as sensory difficulties.[43] In order to determine the severity of an incident, the Glasgow Coma scale, a 15 point scale, is used. There are three categories; motor response, verbal response, eye opening, which have points assigned to specific functions pertaining to each group. The more severe the incident, the lower the Glasgow Coma Scale score.[43,45] Unfortunately for young children this scale is not applicable for they are not capable of describing their symptoms or understand instructions. Although the TBI may be extremely undiagnosed, there is a major push from the athletic community, especially contact sports such as football and soccer, to further research the subject.

COLOR

Colors have been proven to have an effect on moods. Certain colors can make instill relaxation, while other colors can stimulate the brain. Muted colors have a calming effect upon children with autism[18]. Pale pink has been demonstrated through tests to be their favorite color overall. Cool colors such as blue and green are also soothing. Monochromatic color schemes are preferable and designs in fabric and wall hangings should be non-linear and non-obtrusive. Solid and uniform colors should be used throughout a room to reduce distraction. The primary colors of red, yellow and blue are prevalent in everything from classrooms to therapists' offices to bedrooms[19.] However, these colors can be overwhelming and distracting. When picking out colors it is better to use blues, greens, or violets as a color palette due to their calming nature, as opposed to the louder primary colors. The brain, on a subconscious level, takes in these colors and this creates a soothing effect[14]. An effective calming theme to use is aquatic colors in the blue/green family.

Lighting can also affect moods. It is important to use either diffused lighting or up lighting to reduce glare. Florescent lights should also be avoided as they can flicker or make a distracting buzzing sound. It is important to incorporate soft lighting without glare into any living environments especially for children with autism. Another strategy is to create an all-white multi-sensory room; this kid of room allows the play of color as a calming and focusing treatment[19] There are lighting techniques available to create changing and moving color in a white sensory room that can be programmed to change colors depending on what type of mood desired.

SOUND

Sound is the sensation produced by the stimulation of the organs in the ear evaluating vibrations transmitted through an elastic medium[30]. It is a mechanical oscillating sinusoidal wave of pressure that has the ability to propagate through solids, liquids, and gases. Depending on the medium and ambient condition, sound can travel at a variety of speeds thus causing a variety of impacts to those in which sound is being transferred. Kidspace is conducive to high levels of auditory inputs due to the set up of the facility and number of people in various spaces. The fluctuating sound levels impact therapy session effectiveness for patients and therapists. Based on observations within the facility, the team researched sound in order to better understand it and the sciences behind how sound effects humans.

A 1993 Cornell University study found that children exposed to noise in learning environments experience trouble with word discrimination and various cognitive development delays[16]. Further, the presence of sound was shown to cause children to have a difficult time with speech development while learning in noisy classrooms rather than quieter ones. Children are unable to fully focus on a given actvity and thus do not develop at a rate expected. Barreirs to learning and development set a child on a delayed learning path, which can be detrimental in the long run. While Kidspace is not a formal classroom setting, there is a great deal teaching and learning the occurs. Therapy sessions focus on motor skill development and spatial awareness, which require a child to be focused on their activities.

In addition to just the presence of noise, noise intensity has been found to decrease helping behaviors. A study conducted on a busy street corner attempted to discover if there was a relationship between human helping behaviors. The study concluded that with higher intensity, people were less likely to answer questions and be helpful to others[13]. Further, high intensity noise affected a wide range of interpersonal behaviors in participants. Additional studies have shown that unpredictable noise results in greater variability in behavior and increases distractions in an environment. Aggressive environmental conditions decreased attractions to others and exacerbated sound behavior relationships.

Internationally known otolaryngologist and inventor, Dr. Alfred Tomatis was well known for his treatment methods targetted to those suffering from attention defecit disorders, developmental delays, autism, head trauma, learning disabilities, and multiple sensory system disorder. He believed that the ear functioned as an "integrator" and thought that it facilitaed organization at all levels of the nervous system[16]. Tomatis performed a variety of studies utilizing electronically altered music for therapy. While this yielded mixed results, it was the foundation for future sound based treatment. Guy Berard developed the Auditory Integration Training treatment method that also used electronically enhanced popular or classical music at Distorted or modulated sound frequencies at random intervals for random periods. His results were inconclusive as well, with some patients showing improvement while others did not show any improvements.

Today, occupational therapists now use therapeutic listening adjacent to intervention. Sound stimulation appears to calm and organize child and found to influence children's arousal, potentially enhance spatial-temporal organization, and improve children's behavior[2]. Additional benefits included: improved attention, greater interaction, better listening, greater self-awareness, better communication, and more consistency in following directions. Overall, the treatment prepared children to attend and focus on perpetual motor activities, which could be very beneficial to patients and therapists at Kidspace.

SCENT

Scents can also be used to create a certain atmosphere or mood. There are a variety of scents that can make people more alert, or scents that are meant to help people relax. Scents can come in different mediums such as candles, sprays, oils, and aroma diffusers. Some of the scents that have been proven to be stimulating are: instant coffee, peppermint extract, lemon extract, pumpkin pie spice, cinnamon, ginger, ground cloves, and basil. Some calming scents are: vanilla extract, lavender, roman chamomile, neroli, honey, anise extract, and licorice.[35] It is best to stay away from artificial scents because they can cause nausea or irritation. Using certain types of olfactory stimulation, it is possible to create a soothing or stimulating atmosphere.

SNOEZELEN THERAPY

In an attempt to understand the effects of soothing and stimulating environments on children at KidSpace, Snoezelen therapy and the products used in its practice were studied. Developed in the 1970s in the Netherlands, a Snoezelen room is a controlled multisensory environment for those with autism, traumatic brain injury, dementia or developmental disabilities. The word "snoezelen" is a combination of the Dutch word "snuffelen" (to seek out or explore) and "doezelen" (to doze or snooze). The room uses innovative devices designed to deliver multisensory stimuli using lighting effects, colors, sounds, scents and textures.[20] This therapy is meant to improve communication and functioning by engaging the patient via motivational stimulus and maximizing his or her potential to focus on his or her own free will.

Beit Issie Shapiro, a program and center in Israel that uses Snoezelen rooms in its treatment methods for disabled children is the main pioneer and developer. The program director, Michele Shapiro, and her staff help to train therapists around this world to spread the use and benefits of Snoezelen rooms.[8] A study led by Gillian A. Hotz and funded by the Florida Brain and Spinal Cord Injury program was performed to find the effects of Snoezelen rooms and products on children with traumatic brain injuries. The room was 20 square feet with white padded walls, ceilings and floors and several Snoezelen products to appeal to each of the senses:

Olfactory	Aromatherapy diffuser with a lavender scent
Vibratory and tactile	Tactile panels, vibrating pillows, cushioned bubble tube platform, interactive bubble tube, fibre optic bundles
Auditory	Soft new-age music playing, interactive light and sound wall
Visual	Stationary mirror ball, interactive light and sound wall, liquid effect wheel, shimmering light curtain, fibre optic bundles, acrylic mirror panels, interactive bubble tubes
Vestibular/Proprioceptive	Bean bad bed, leaf chair, glowing ball pool with clear balls

Table 1: Snoozelen Products

The fifteen children who participated (11 boys and 4 girls) all suffered from severe traumatic brain injuries. Each child took part in between three to ten Snoezelen sessions and several quantitative measurements were taken including heart rate, systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, blood oxygen saturation and muscle tone. While a need remains for more evidence-based research on this treatment method, the study revealed an overall positive reaction from the children who participated in the Snoezelen sessions. They noted a significant decrease in heart rates ($p=0.032$), a decrease in muscle tone in the affected extremities, decreased agitation levels as well as overall cognitive and qualitative improvements when compared to the beginning of the treatment.[17]

BUSY HOUR OBSERVATIONS

Throughout the research and design process, it was necessary for each member of the team to observe Kidspace during its busiest hours of the day. While Lani and Kelly had given a description of the environment between 3 and 6 pm during the week, it was very important for the team to have a visual of the problem in order to determine the most valuable solutions. The first day of observation occurred on Thursday May 17th from 3 pm until 5:30 pm. Molly (the group contact with the client), Christian and Devin each took general observation notes and recorded decibel readings on their phones, which were later collected and graphically analyzed. One person sat in the waiting room, another in the hallway and the third in between the two back gyms. Unfortunately, there were several cancellations this particular Thursday and both the parents and therapists claimed it was an "uncharacteristically calm Thursday." Nevertheless, the team observed several times when the decibel readings reached nearly 90 dB in the waiting room and hallway. It also allowed the team to see the kind of interactions that occurred in the waiting room during transitions.

The team visited a second time the following Wednesday, the group this time consisting of Molly, Chris and Patrick. Lani was once again disappointed with the level of activity witnessed that day, though we did find the waiting room and hallway to be very busy and loud (>90 dB), especially before the 5 pm feeding group session.

After the two days of observations the team was able to draw several conclusions about the sensory overstimulation problem. In the back gyms it was found that the waiting room interactions are very audible. Additionally, the ability for the children to see into the other gyms and move freely between them was a distraction during some of the sessions that were observed.

In the waiting room, the team was surprised to see that most of the noise was generated by the parents and siblings of the children receiving therapy. The waiting time before the session was generally no more than 5 minutes, and the only times it lasted that long was when the parents and therapists would talk before starting the session. The siblings of the children were often the ones making the most noise while they were playing with the toys available in the waiting room. Additionally, there was a great deal of parent-therapist interaction in the waiting room, the conversations ranged from how the week or the session went, explanations of homework assignments and even finances. The lack of privacy for these types of conversations was surprising and an issue that the team decided to attempt to address as well.

At the conclusion of the second day of observations at KidSpace, Lani outlined what she viewed as the main issue. Aside from the busy afternoons, there are also several situational issues they face from day to day. She admitted that there are days that are quieter than others, but quite often there arises a spontaneous situation in which the visual and auditory overstimulation is at its maximum. This could happen at the busy times, or in the morning when there are only a few sessions at a time. All it takes is one child to have a hard day or throw a tantrum and the entire facility is overcome with noise and distractions. She asked the team to consider a solution that provided a place or way to calm a child when an outbreak like this occurs. This observation time was crucial, as it gave the team an unbiased view of the problem at hand, and enabled the team to focus in on the main issues.

VISUAL BARRIERS

In addition to blocking out sound, the initial intention for the doors between and into the gyms was also to act as a visual barrier. During observations it was noted that many of the children were distracted by what they could see in the adjacent rooms. They would deviate from what they were working on with the therapist to go do their favorite activity or retrieve a toy, and the therapist would need to follow them around until they could focus their attention back on the appropriate activity. Many teachers and tutors of autistic or sensory challenged students have found visual barriers to be a very effective way to create an environment where the child can focus on the task at hand. They often take the form of corner barriers or shields that block the child's view of the rest of the room while they are seated. This still allows for the teacher to see the children at work, but the students cannot see over the top unless they stand up.[33] However, shields can also make the child stand out compared to their classmates, and often if the barrier is too close to their eyes it can also backfire and be a distraction.[9]

SOUNDPROOFING MATERIALS

In order to address the lack of enclosure over the doorway between the waiting and hallway, a variety of materials were researched. High amounts of auditory inputs to the gym space have been attributed to the lack of sound barrier in this space. Thus, the team made it a top priority to develop a solution to fix this problem.

Interoffice and home noise reduction is a very common renovation, so there is a great deal of information available on how to make a space quieter, reduce echoes and prevent noise transmittal throughout a building. The team initially researched a material called Acousti-Lead. Comprised of lead, this material is an ideal for ceiling plenum barriers and machinery enclosures.[31] A major consideration that the team had to make was for the presence of pipes running across the ceiling in this space. Acousti-Lead has the ability to be easily installed, handled, and cut into shapes in order to fit it around objects. Below, Figure 2 is a diagram display the method for implementation and installation in a similar space.

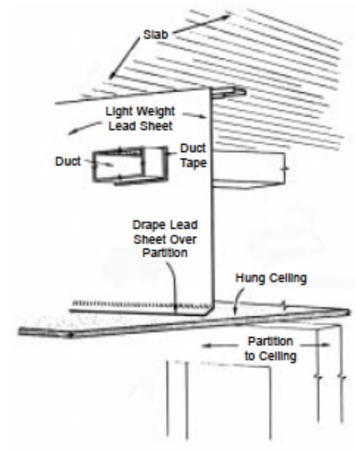

Figure 2: Acousti-Lead Installation Process

In addition to ease of implementation, Acousti-Lead is proven to significantly reduce decibel levels. In Figure 3 below, it can be seen that it has the ability to reduce between 30-50 db depending on the input frequency. This is significantly higher than a ceiling board without Acousti-Lead, which only reduces decibels an average of 19 db.

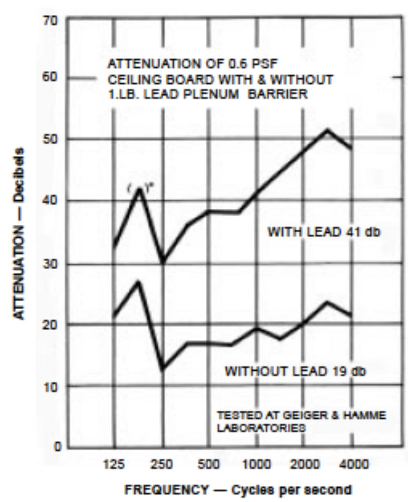

Figure 3 : Acousti-Lead Decibel Reduction

The team also researched sound absorption sheets. These sheets could be customizable to fit the space restrictions as well as adaptable to pipes. Through a variety of websites, these sheets can be ordered at varying thickness and Noise Reduction Coefficient Levels (NRC), with NRC ratings between 0 to 1.0. In particular, the Audimute Sound Absorption Sheets have been tested and shown to have an NRC rating 0f 0.70, suggesting that 70% of the sound reverberation is absorbed.[5] This is very impressive rating for sound absorbing materials and has been proven to absorb up to 40db of sound. Figure 4 is a diagram of how this sound absorption material could be implemented within the wall created for this space.

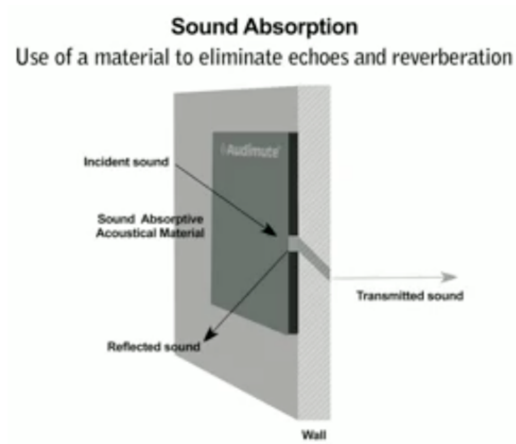

Figure 4: Sound Absorption Material Implementation

While this is a plausible option, there is one misconception that many have for sound absorption sheets. These sheets are often referred to as 'soundproofing blankets,' which are, in fact, very different. Sound absorption improves sound quality, but does not block sound transmission from room to room. Sound blocking, on the other hand, prevents sound from entering or leaving a room. This distinction greatly affects the type of material selected for the final design.

One of the most common and affordable methods of noise reduction is the addition of a sheet mass loaded vinyl to an existing door or wall. Mass loaded vinyl is a thin, limp material that can be purchased in 1-2 lb/ft^2 densities and is usually placed across the studs or joists in a wall the reduce the flow of sound through a barrier (Figure **5**).

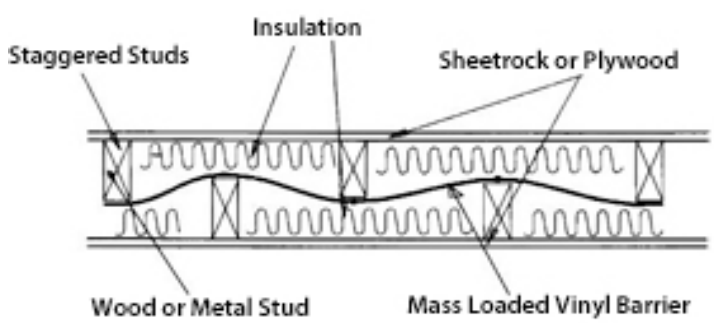

Figure 5: A visual of the most common use of mass-loaded vinyl within drywall. [31]

The Sound Transmission Class (STC) is a number assigned to a given material that represents its ability to reduce sound transmission between a source and a target. The table below shows the results obtained when measured over a range of frequencies from 100 Hz to 4000 Hz (which covers the speech range).

Frequency (Hz)	100	250	500	1000	2000	4000	STC
Non-reinforced MLV 1#	16	17	21	26	31	36	26
Non-reinforced MLV 2#	19	19	27	34	38	43	32
Reinforced MLV 1#	17	18	22	27	33	37	27
MLV 1# with Closed Cell Foam	13	15	23	25	33	38	27

Table 2: Acoustic Transmission Loss (dB)

As can be seen above, using a sheet of mass loaded vinyl in addition to a layer of closed cell foam increases the decibel reduction. It also acts as a support layer for the vinyl to be attached to, as it can tear easily without additional weight support.[32] Closed-cell foam is high-density foam that both absorbs and blocks sound. This is unique in that while all foam absorbs sound, most types let noise pass right through. In this type of foam 90% or more of the individual cells are closed and are filled with gases that increase both its insulation and stability. This structure prevents the passage of both air and moisture through the foam. The air stoppage allows for noise reduction, while the lack of moisture prevents the growth of mold.[25] The foam sheet is a 220 Polyethylene and has a density of 2.2 lbs/ft^3.[15]

PVC MATERIAL

Poly(vinyl chloride) is a common synthetic plastic that is known by the name of PVC. Invented in 1912 and then reinvented in 1926, PVC has a variety of uses from house plumbing to soccer goal posts.[27] When first discovered, it was found to be very useful because it resists fire and water. The material not only resists water, but also is flam resistant due to it containing chlorine. Transparent PVC Vinyl is a HB - 5VA material, based on the UL 94 flame classification. This classification relates to materials commonly used in manufacturing enclosures and structural parts.[36] New uses for this material were discovered over the years, including its effect on sound transfer. Transparent PVC has been shown to function as effective noise barriers in a variety of applications. Through clocking the transmission of sound energy and dampening vibrations, this vinyl has been implemented in spaces to isolate noisy equipment.

Some of the features that PVC vinyl has to offer are: Exceptional acoustical performance, moderate sound barrier characteristics, and durability. Studies have shown PVC vinyl to have an Sound Transmission Class rating of 19. Sound Transmission Class is a rating of the effectiveness of a material to impede the transmission of airborne sound. (Acoustical Surfaces Website) While 19 is not the highest attainable rating, it reduces sound transmission (db) while also allowing normal speech to be understood quite clearly. Combined with the use of a sound partition enclosure in the hallway/waiting room space, this type of material would perform quite will to reduce any additional sounds transferred into the gym spaces. Current applications of this material include room dividers, strip curtains, soundproof partitions, and stamping press enclosures.[23]

The durability of PVC vinyl is a key element of this material that initially attracted the team to the material. In general, the material has an ultimate tensile strength ranging between 912 – 6,200 psi, with an average value of 2400 psi.[26] Ultimate tensile strength is the maximum strength that a material can withstand without tearing.[37] The Elongation at Break is between 16.0-520%, with an average of 339%. Elongation at Break is the percentage that the material will deform at the point when it breaks. The Modulus of Elasticity is between 0.260-477 ksi, with an average value of 1.52 GPa. The Modulus of Elasticity is the mathematical description of a material's tendency to be deformed elastically when a force is applied.[21] Finally, tear strength is the force required to rip a sample of PVC vinyl.[39] The tear strength for PVC Vinyl is between 94.7-673 pli, with a average of 70.7 kN/m. Below in Table 3 is a full table of PVC Vinyl mechanical properties.

Transparent PVC Mechanical Properties Tables			
Mechanical Properties	**Metric**	**English**	**Average**
Hardness, Rockwell R	100 - 124	100 - 124	Average value: 106
Hardness, Shore A	33.0 - 96.0	33.0 - 96.0	Average value: 73.0
Hardness, Shore D	37.0 - 85.0	37.0 - 85.0	Average value: 71.2
Tensile Strength, Ultimate	6.29 - 42.7 MPa	912 - 6200 psi	Average value: 16.9 Mpa
Tensile Strength, Yield	2.38 - 62.7 MPa	345 - 9090 psi	Average value: 22.0 Mpa
Elongation at Break	16.0 - 520 %	16.0 - 520 %	Average value: 339 %
Modulus of Elasticity	0.00179 - 3.29 GPa	0.260 - 477 ksi	Average value: 1.52 Gpa
Flexural Modulus	1.41 - 3.24 GPa	205 - 470 ksi	Average value: 2.73 Gpa
Flexural Yield Strength	68.1 - 96.9 MPa	9880 - 14100 psi	Average value: 83.8 Mpa
Tear Strength	16.6 - 118 kN/m	94.7 - 673 pli	Average value: 70.7 kN/m
Dart Drop Total Energy	23.1 - 199 J/cm	0.0433 - 0.373 ft-lb/mil	Average value: 100 J/cm
Abrasion	117 - 201	117 - 201	Average value: 138
Compression Set	18.0 - 62.0 %	18.0 - 62.0 %	Average value: 34.2 %
Clash Berg Modulus	0.00689 - 0.996 GPa	0.999 - 144 ksi	Average value: 0.462 Gpa

Table 3: PVC Vinyl Mechanical Properties Table

CITY AND COUNTY OF SAN FRANCISCO MUNICIPAL CODE

When designing prototypes for Kidspace, the team considered building and fire codes outlined in the City and County of San Francisco Municipal Code. As engineers, it is essential to perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct. This includes not only the City and County of San Francisco Municipal Code, but also the NSPE Code of Ethics for Engineers. All cannons are paramount to the ethical practices, however the first cannon can be applied directly to work we are doing with Kidspace. The cannon states: Hold paramount the safety, health, and welfare of the public.[24] In our current practice, the therapists, patients, and families are those that we must keep safe with any design that we develop. Therefore, all design consideration must hold this as a priority in order to do our job in an ethical manner.

The design for the Hallway/Waiting Room enclosure needs to be validated by both sets of code to ensure that no permits or inspections would be required. The requirement of a permit or inspection would incur greater costs within the project and likely alter the project timetable that the team established. When first looking at the building code, the team read through all various classifications for our enclosure partition. Section 106A.2 of the City and County of San Francisco Municipal Code stated: Work exempt from permit. Exemptions from the permit requirements of this code shall not be deemed to grant authorization for any work to be done in any manner in violation of the provisions of this code or any other laws or ordinances of this jurisdiction. A building permit shall not be required for the following: 4. Movable cases, counters and partitions not over 5 feet 9 inches (1753 mm) high.[11] As stated in the code, our design is exempt from the permit requirements of this code. It is exempt, because the design of our partition is only 2 feet 3 inches in height. However, this does not mean that we do not have to take into account many of the codes specified in this document. We still need to consider an earthquake friendly design and mounting system due to San Francisco being in an earthquake prone area. Ventilation and smoke considerations also need to be taken into account in the event of a fire.

The next major consideration for the enclosure partition is the fire sprinkler water pipe that runs through the area where it will be installed. Through research, no regulations have been found in the City and County of San Francisco Municipal Code pertaining to construction around a fire sprinkler water pipe. However, the US Fire Administration has very distinct policies on the clearance required around sprinkler pipes. The policy states: "In those areas where earthquakes may cause buildings to move, sprinkler pipe and tube must be protected from physical damage. The potential for shifting walls, floors, slabs or other rigid elements may result in shearing the sprinkler pipe with catastrophic consequences."[38] Further, the policy suggests creating a hole with a diameter of 2 inches larger than the pipe in the enclosure partition. The policy will force the team to revise current designs and accommodate the space required to prevent physical damage to the pipe in the event of an earthquake. While this will create more space for sound to be transferred between the hallway and gym space, the team can fill the gap with a flexible material such as insulation materials or mastic. This will provide an adequate sound barrier to the small gap and reduce any negative impacts on our design.

Door covering designs are also subject to the specified restrictions from the City and County of San Francisco Municipal Code. Research revealed no building restrictions for installing a door covering. The main considerations that the team needs to take from this research are the safety factor associated with the covering design, mounting system, and longevity of the design. The design and mounting system must be earthquake friendly and maintain structural integrity in the event of such an occurrence. This will require proper installation techniques and a reinforced mounting system. Next, fire code regulations outlined in the City and County of San Francisco Municipal Code were very limited for door coverings. The coverings will not function as "fire doors", therefore not requiring a fire retardant material. However, the doors do need to be easy to use in the event of a fire. They should also not inhibit ones ability to vacate a space or prevent them from safely navigate an area. Properties of potential door covering materials are discussed in other sections of this report and it is from these thermal properties that specific selections decisions will be made.

CRITERIA FOR SUCCESS

Based on the research performed on all areas of study, the team was able to determine six criteria for a successful final product. These were variables that were found to be the most important after several observations at Kidspace, interviews with therapists, and research performed by the team. The first criterion was to reduce the auditory sensory inputs throughout the facility, as the high noise levels were one of the main issues described by Lani and Kelly when presenting the problem. Similarly, the therapists also asked for a reduction in visual sensory inputs as well in order to reduce distractions and prevent overstimulation before and during therapy sessions. The third criterion, one that had an overriding importance in all of the proposals, was to increase the productivity and effectiveness of the interactions between the patients and their therapists. In addition, through several observation sessions at Kidspace, the team determined that it was very important to attempt to increase the privacy for the families and their interactions with the therapists. It was observed that many parent-therapist conversations occurred in the waiting room, ranging in topic from how the session went to the description of homework assignments, and even finances. Although this was not an issue explicitly stated by Lani and Kelly, the team felt that by increasing the privacy of those conversations they would simultaneously reduce the amount of activity and noise in the waiting room. It was also determined that attempting to reduce costs while maximizing safety were very important criteria for the success of the project.

Proposals

The methodology of this project followed the human-centered and design-based approach employed by the global design consultancy, IDEO. The students were encouraged to think creatively and without judgment, so as to not be limited by occupational labels (engineer, business person, etc.). The brainstorming and proposal processes were long and in depth, followed by simple, rapid prototyping and proposal selection. The refinement and implementation stages were performed the last few days of the four-week process, as the design and proposal processes spanned much of the time allotted.

After the first three visits to KidSpace, the group performed a sticky note observation session, in which each member wrote down their observations of the facility, the problems they noticed and the initial research conducted. This resulted in around 100 sticky notes, which were then categorized into seven or eight groups based on their content (including waiting room, back gyms, families and conditions).

The next step was to come up with a question for each group to address the main issues. These questions began with "how might we..." and went on to ask about how to solve the problem presented in each group. Two of these questions were, "how might we reduce visual and auditory stimulation throughout the facility?" and "how might we accommodate the needs of the therapists?". These questions were presented to the entire group of fifteen students and there was a rapid brainstorming session in which each student had a sticky pad and marker and wrote down every solution that came to mind, read them aloud and put them on the board for everyone to see. These sessions lasted about 15-30 minutes and resulted in approximately 190 sticky note ideas. The group then broke back down into their small groups of five to organize and categorize the ideas.

Following the "how might we..." brainstorm, a selection matrix was created for each related proposal, categorized by the room that the proposal targeted. The first selection matrix was broad and was made to serve as a guideline to choose the best alternative for each space in the facility. The proposals were categorized as pertaining to only the waiting room and hallway area, the back gyms, or the entire facility. The criteria for success was weighted by priority thus reduction of auditory and visual inputs were weighted as the most important criteria. The scores for each cell of the selection matrix were voted on, and the totals were calculated. The resulting selection matrix is below:

Project Selection Matrix								
	Waiting Room & Hallway				Back Gyms		Throughout	
Criteria	Sitting Area/Snoezelen	Two cubicle	Space Partition	1 Intermediate Room	Door Coverings	Increased storage	Carpeting	Mr. Fish
Reduce Auditory Inputs (25%)	3	3	5	5	5	1	5	4
Reduce Visual Inputs (25%)	5	4	2	3	5	5	1	1
Increase patient/therapist interaction effectiveness (15%)	4	2	5	3	4	3	2	3
Low Cost (15%)	2	4	4	1	4	3	3	3
Safety (5%)	5	4	4	4	2	2	3	3
Feasibility (15%)	3	5	4	2	4	4	4	3
Total	**3.6**	**3.6**	**3.9**	**3.1**	**4.4**	**3.1**	**3**	**2.75**

Figure 6: Selection Matrix

The results of the selection matrix were used as a starting point for deciding with which proposals to move forward. For the waiting room and hallway area, the two cubicle design and the space partition totaled the highest. In the case of the back gyms, door coverings came out much higher than the increased storage proposal. Throughout the facility, the carpeting total and the Mr. Fish design total were very comparable. Discussion and further voting eventually narrowed the remaining proposals to various door covering alternatives and hole covering alternatives, as well as led to the selection of Mr. Fish as a project to design.

PARTITION PROPOSAL

After some initial research and a great deal of brainstorming, there were a number of ideas that had been developed for a method of closing off the gap in the wall between the hallway and waiting room. The gap was about 26.5” in height between the top of the wall and the ceiling and spanned the width of the wall, which was measured to be 13 ft (Figure 7).

Figure 7. The gap in the wall dividing the main hallway and the waiting room, taken from the main hallway. Note that the air duct and vent are completely on the waiting room side and the red sprinkeler is on the hallway side. http://www.acousticalsurfaces.com/noise_barrier/vinylbar.htm?d=14

The two most important criteria to consider when examining the materials were the auditory sensory reduction and low cost. Safety was also a concern as it was necessary to look into municipal and fire codes to ensure it was safe to close off a gap that large and how to deal with the sprinklers that run along the ceiling. All of these requirements were met, which can be referenced in the research section of the paper on the municipal codes of the city of San Francisco.

The first round of brainstorming and proposals included several different materials. The team considered a simple solution of using the same PVC flaps as were going to be used for the doors, which would be mounted in the same or a similar way. However, this material was not as effective of a sound barrier as some of the other materials found during research. A very informative resource for soundproofing materials was the website for Acoustical Surfaces, Inc. From this resource the team considered and analyzed the possibility of using a foam barrier, sound deadening curtains, mass-loaded barrier panels and a product called Acousti-Lead.

The proposal for the use of a foam barrier was supported by the idea that it was lightweight, easy to install and provided a friction seal around the edge of the barrier to minimize the open spaces that sound could travel through. It was at this point that the team, through research and a few conversations with a sound proofing consultant, Bill Hagemann, from a company named Sound Away, found the importance of the difference between a material that absorbs sound and one that blocks sound. Seeing as foam absorbs sound, it was not the best material to prevent noise from traveling from the waiting room to the rest of the facility.

The proposal for a sound-deadening curtain had a similar issue. Although the curtains were cost-effective and easy to install, they also only absorb sound in a room as opposed to blocking its travel.

Acousti-lead was another material proposed as a barrier between the hallway and the waiting room. The major advantage to this design was the simplicity of the installation of this material. Since it can easily be formed and cut, it would be very easy to cut and shape around the pipes that run along the ceiling. Acoustilead was also a sound barrier, so it would be the only material necessary to block the sound and any other material could be used to cover the Acousti-Lead for a more aesthetically pleasing visual. A major disadvantage to this material is that it is made of lead, which is a toxic material that could prove to be dangerous to the people in the facility.

One of the most popular materials used in cost-effective soundproofing was found to be mass-loaded vinyl (MLV). Although not quite as inexpensive as some of the other proposed materials, MLV was an actual sound barrier, in that it prevents noise from traveling through it. The material was 1/8th inch thick and 1 lb/ft^2 in density (Figure 8).

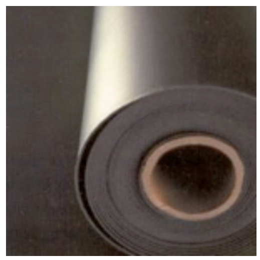

Figure 8. The mass-loaded vinyl which was ordered from Sound Away. [32]

In order to determine how each of the initially proposed materials met the criteria for success, a selection matrix was used. The criteria were weighted based on their relative importance, and each proposal was ranked on a scale of 1-5 based on its ability to meet each criterion (Table 4).

Gap Covering Mechanism Criteria	**Alternatives**				
	Flaps	**Foam**	**Curtains**	**Acousti-lead**	**Panels**
Auditory (50%)	3	5	3	4	5
Low Cost (25%)	3	2	3	3	3
Feasibility (25%)	4	5	4	5	3
Total	**3.25**	**4.25**	**3.25**	**4**	**4**

Table 4: Selection matrix for the material used to cover the gap between the waiting room and the hallway, used as a guide in the selection process.

After the creation and analysis of this selection matrix, the team determined that safety needed to be taken into account when selecting a material, which effectively ruled out the Acousti-Lead. Also, after conducting more research into the differences between sound barriers and sound absorbers, it was determined that a sound barrier would be much more effective in this space, as it was essential to reduce the sound travel from the waiting room through the rest of the facility. For this reason, the mass-loaded vinyl was ordered through Sound Away so that it could be prototyped and tested as a standalone barrier.

In the process of ordering the MLV from Sound Away, the soundproofing consultant, Bill Hagemann, was a very valuable resource for his experience in the field and with the materials being researched. MLV is a very thin and flexible material, but is still quite heavy when due to its relatively high density. Table 5 shows the calculations performed to determine the weight of the MLV needed to cover the entire gap.

Density (lbs/ft^2)	Width (in)	Length (ft)	W x L = Area (ft^2)	A x D = Load (lbs)
1	26.5	13	28.71	28.71

Table 5: Weight calculation for the MLV

With the material weighing nearly 30 lbs, it was then necessary to reanalyze the method of attachment. The MLV would most likely tear at the points of support, and would require several points of attachment to be able to stand upright. This then lead to the proposal of combining the MLV with a layer of closed-cell foam and a layer of plywood for extra support as well as additional sound absorption and blockage. Sound Away also sold closed cell foam, but after performing a cost analysis (Table 6) the team found that ordering the closed-cell foam from a local Grainger would be much cheaper.

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Material	Supplier	Qty Needed	Price Per Unit	Total Price
Mass-Loaded Vinyl	Sound Away	3	$33.00	$99.00
Closed-Cell Foam	Sound Away	9	$32.00	$288.00
Closed-Cell Foam	Grainger	3	$25.35	$76.05

Table 6: Cost analysis for partition materials

These materials were ordered and assembled in order to construct a working model of the partition and test it to ensure its effectiveness.

DOOR PROPOSAL

A major issue that the team felt needed to be addressed was the lack of doors and space enclosures throughout the Kidspace facility. Various observations of therapy sessions and engineering design process steps revealed that the lack of doorway enclosures as a major contributor to the visual and auditory overstimulation. Primarily focused in the gym and hallway spaces, the non-existence of doors allowed for high levels of sound to be transferred from room to room. Thus, various door-covering proposals were developed in accordance with the criteria for success.

Research conducted showed that there were a variety of door options that could be easily implemented into the space and provide effective sensory reduction. The three major considerations included PVC swing doors, curtain doors, and PVC door flaps. Each proposal had a their own benefits, but all focused on the end users who would interact with it on a frequent basis.

The PVC swing door design was inspired by designs utilized as restaurant swinging doors. They are designed to be easy to use, withstand high impacts and traffic, and reduce sound transfer between spaces. Further observations reveled increased use of double swing doors designs made of PVC. These types of doors are tough, durable, maintenance free, lightweight, thermal insulting, and posses sound reduction capabilities. Based on this, a preliminary design was developed to be implemented in the front gym door way. This door is a high traffic area and is the main avenue for sound to transfer from the waiting room to the gyms. The door prototype proposal, which can be seen in Figure 8 below, would comprised of transparent PVC vinyl, light in weight, durable, safe, and reduce sound transfer between the gym and hallway. The door would open in both directions, allowing the user to push through it whenever passing through. Depending on the design, the door could also reduce visual inputs. In addition, the transparent PVC vinyl would increase safety and reduce opportunities of "run ins" occurring. Overall, the design would be easy to install and could permanently replace the door that exists in the front gym. The door that is currently in the space is used sparingly.

Figure 9: Swing Door Design

The next design proposal that the team developed was a flap design. This design was based off transparent PVC door covering flaps that are commonly used in manufacturing facilities and warehouses. That type of design allows major equipment to move into various spaces with ease, while also reducing sound transfer. In addition, it works as a thermal barrier to keep temperatures regulated in spaces. The proposed design would have strips hanging down from the top of the doorframe and hang slightly off the floor in order to reduce the chance of injury or damage. The design would be very durable, flexible, easy to implement, have simple installation, inexpensive, reduce sound, and potentially reduce visual stimuli based on the design. In addition, it could be implemented in each door and opening between the gyms and the hallway. Figure 9 below is a basic prototype of the design that would be developed further if chosen.

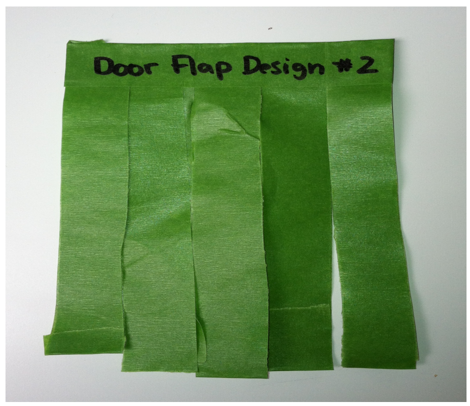

Figure 10: Door Flap Design

The final design proposal that the team developed was the curtain design. This design was developed from research conducted on sound canceling material and prior experience with curtain doors. The design would be made of sound dampening curtains that would absorb sound in a space. Attached at the top by a rod with hooks, the curtain could be easily open and would hang just slightly above the floor so as to not be a hazard. It would be relatively inexpensive to build, easy to implement in each of the door enclosures, absorb sound, reduce visual stimuli, and durable. The basic design would look very similar to any curtains hanging over a window, however it would be mounted directly to the frame and hang down to the floor.

Once all three of these proposals and the designs developed, the team utilized a selection matrix to determine which design would be best. The selection matrix took into account all of the criteria for success and weighted them according to which are the most important. Table 7 shows the Door Covering Selection matrix and results.

Door Covering Criteria	Alternatives		
	Curtains	**Swing Doors**	**Flaps**
Reduce Auditory Inputs (25%)	3	5	4
Reduce Visual Inputs (25%)	4	2	4
Low Cost (15%)	5	2	3
Feasibility (20%)	5	2	4
Safety (15%)	5	2	5
Total	**4.25**	**2.75**	**4**

Table 7: Door Covering Selection Matrix

As it can be seen, the curtain and flap designs received relatively the same ratings. The swing doors received the lowest ratings overall. The results from a selection function more as a guideline than a definite quantitative selection model. Using the guidance of this model and personal discretion, the team chose to move forward with the door flap design. It was believed that this design would reduce auditory and visual inputs, inexpensive to implement, extremely feasible, and safe. Safety is an important factor and based on personal discretion, the team saw the potential for safety hazards with the curtains versus the door flaps. Moving forward, the team will begin to develop this proposal further and generate a finalized design.

TECHNOLOGY-BASED PROPOSALS

One of the more technology-based prototypes that was proposed was a tablet check-in system for the waiting room. An iPad or Android tablet would be secured in an enclosure and mounted on the wall in the waiting room space. An accompanying application would be developed which would include the schedule for the appointments taking place at Kidspace on a specific day. Patients or parents of patients would be required to check in on the device, acknowledging that they have arrived for their appointment. The application running on this tablet would be designed to be compatible on mobile devices as well, which would allow therapists to use their smart phones to find out whether their patient was in the waiting room space yet. The criteria for success that this proposal effectively meets are reduction of visual stimuli and reduction of audio stimuli. The waiting room space often fills up with patients, families, and therapists. The tablet check-in system would allow therapists to remain in the office or back rooms until their patient arrives, eliminating the need to constantly go to the waiting space to check for patients.

Without therapists meandering through the waiting room there is more space, less visual distraction, and less audio stimuli generated. The cost of this proposal could be an issue, as suitable tablets can range from $200-800 with an average price of approximately $420.

Multiple proposals utilized sound sensors in a variety of applications to meet the criteria for success. One of these proposals was a read and react colored light system for the waiting room. The idea behind the proposal involved an optimally placed sound sensor in the waiting room which would record decibel levels reached in the space. At various decibel thresholds different colored lighting effects would be projected on the white walls of the waiting room. The colors would be determined from the research that was performed on various stimulating and calming effects that certain colors possess. The specific criterion for success that this system would target is the reduction of audio stimuli. Soothing colors would be used to calm and quiet the atmosphere of the waiting room if the sound sensor was to detect high decibel levels. The criterion for success that this proposal could negatively affect is the reduction of visual stimuli. The changing colors could be visually distracting or over-stimulating to some patients. The cost of this proposal would be reasonably low, only needing an Arduino, color changing lights, and a sound sensor. The project could cost as little as $100.

Another proposal using sound sensors was implementing an autonomously variable white noise machine in the waiting room. The white noise machine could produce a quiet level of white noise at all times, but in conjunction with the sound sensor could also increase the volume of the white noise if decibel readings from the waiting room exceed a specified threshold. Based on the research done on white noise, this system would be geared towards the reduction of audio stimuli and low cost criteria for success. White noise promotes a quieter atmosphere and could reduce audio sensory inputs at low cost. This proposal would only require an Arduino, sound sensor, and white noise machine, all of which could be purchased with a total less than $100.

The final proposal that incorporated sound sensing technology was a visual decibel meter. This proposal was not solely planned for one area, but could be utilized in the waiting room space, the back gyms, or both. A sound sensor would be placed in the room and would be connected to a themed, visual decibel meter mounted to the wall. The decibel meter would have various colored lights and would light up as the volume level of the room increased. The decibel meter would be decorated with a kid themed graphic faceplate. This proposal would meet the reduction of audio stimuli and increasing effective communication between therapist and patient criteria. The decibel meter would serve as a visual for a child to get a concrete reading of how loud they are being, and this awareness of volume would encourage all to operate more quietly. Likewise, communication between therapist and patient can become more effective if the therapist has a visual display to point to for informing the child when they are being too noisy, and they can set a target light level range in which the child should keep their volume. The addition of a themed faceplate to the decibel meter could also serve to intrinsically motivate the child to behave properly. Several themes were considered in the proposal, including 'Mr. Fish' and 'Mr. Monkey' themes. The cost of this project would be similar to the other sound sensing proposals, but slightly more expensive due to the building and decorating of the apparatus to house the decibel meter. The project would still be relatively inexpensive at around $150.

WAITING ROOM PROPOSAL

When designing the prototypes for the waiting room and hallway the team followed the criteria for success model. Many of the design ideas generated for the waiting room were based on observations made during the visits to KidSpace and addressed issues the students noticed, beyond simply what the client had requested.

The first waiting room design was made to reduce auditory and visual distractions. The team noticed that in the waiting room there was a lot of noise created by both the siblings playing and the parents talking. With both the parents and siblings in the waiting room, it also was a visual distraction. After reflecting on the observations the team redesigned the waiting room so that the original waiting room would be designated for the parents and the back room would be converted into a playroom. With this new design the noise will be isolated into to two separate rooms and take the most of the noise further away from the gyms, which would lessen the overall noise. Also with this design there would be less visual distractions with less people in each room.

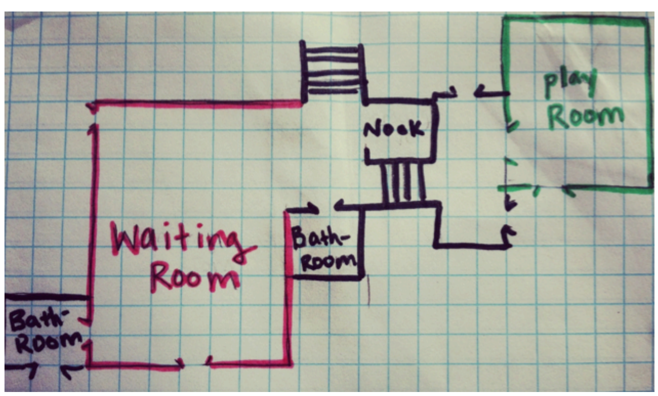

Figure 11: Waiting room design that uses the back room as a play room to take the noise the siblings make away from the waiting room and gyms

The second prototyped waiting room the team designed was meant to increase privacy between the therapists and parents. During visits to Kidspace the team noticed that there was no specified area for the therapists and parents to talk. Most of the talking took place in the waiting room in front of other families. The team thought that this was unusual because some of the information discussed was about finances or other personal information. Also these discussions created more noise in the waiting room. The Team redesigned the main hallway to include two privacy cubicles against one of the walls by moving the large storage cabinet. By adding these two cubicles the parents and therapists would have an area to talk privately and it would make the waiting room quieter.

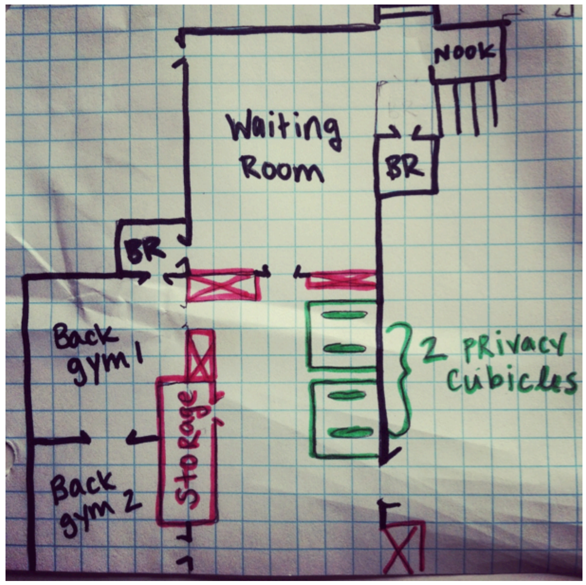

Figure 12: Waiting room and hallway design that increases parent-therapist privacy.

The third prototype waiting room and hallway the team designed was to be relaxation type room. After observing the Kidspace facility the team observed how hyperactive kids can get and at times this can turn into a situation where a kid needs to calm down. The team talked to Lani who suggested that Kidspace could use an area to take a kid to calm down. Using the hallway the team decided that you could use the storage closet and turn it into a relaxation room. Inside the storage room you could put snoezelen products that the kid could play with to relax and calm down.

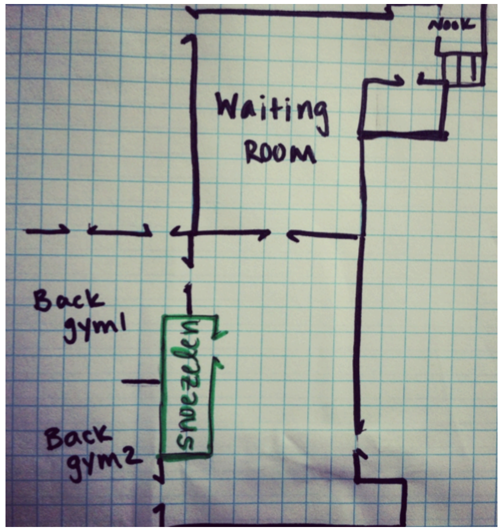

Figure 13: Final waiting room design that incorporated a relaxation room by clearing out a storage closet. This was a design inspired by a conversation the team had with Lani about spontaneous outbreaks during the day.

After a few discussions with the client, the team determined that these proposals would be better served as recommendations for future work at Kidspace. Due to limited space and time, the other proposals were more feasible and would provide immediate sensory reducing results for the therapists and patients at Kidspace.

Design Deliverables

After much deliberation, research, prototyping and analysis the team was finally able to determine three deliverables that would be presented to Kidspace to resolve their sensory overstimulation problem.

PARTITION DESIGN DELIVERABLE

The final design chosen for the partition to close the gap between the waiting room and hallway was three-layered structure of mass-loaded vinyl, closed-cell foam and plywood. Figure 14 is a diagram of the layers of the partition and their relative thicknesses.

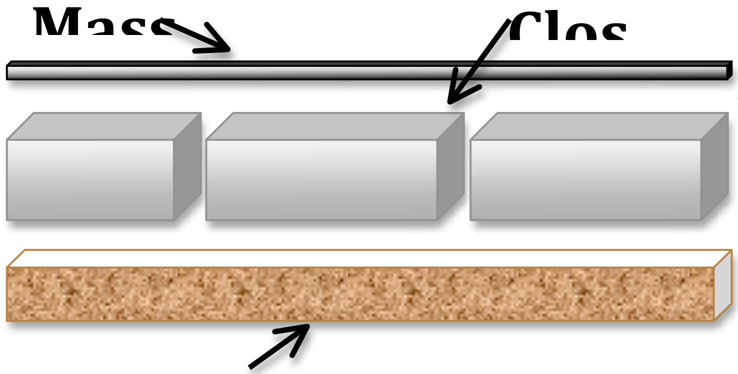

Figure 14: Diagram of the partition and the thicknesses of each layer. View from the top.

This design stands upright in the middle of the ledge on top of the wall and completely covers the entire gap. The foam was cut so that it was slightly bigger than the gap itself in order to friction seal the edges. All three materials needed to be cut in order to fit around the pipes that run through the partition, which required a 2-inch clearance, but could be sealed off with any additional foam. L-brackets and screws along the sides and ceiling were then used for additional support. Figure 15 is a 3-D sketch and visual of what the partition would look like installed on top of the wall.

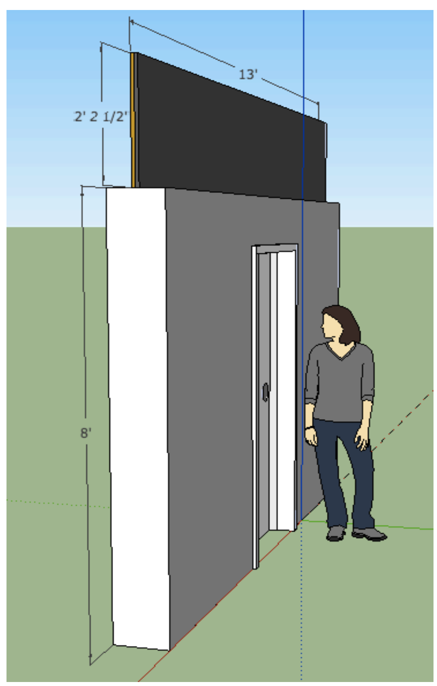

Figure 15: 3-D sketch of the partition installed on top of the wall between the waiting room and hallway with dimensions. View from the waiting room.

Several engineering analyses were performed in order to verify the selection of the final design as well as ensure the results predicted in the proposal process. First, a load analysis was conducted for each of the materials to give a total weight for the partition (Table 7).

Material	Density (lbs/ft^2)	Area (ft^2)	Load (lbs)
1/8 in MLV	1	28.71	28.71
1/2 in Plywood	1.42	28.71	40.77
3/4 in Foam	0.1375	28.71	3.95
		Total Load (lbs)	73.43

Table 7: Load analysis performed on the partition.

The partition was sturdy enough with the support of the plywood and the foam to stand on the top of the wall without collapsing. Therefore, the wall already in place can reasonably support this load, and L-bracket supports can be added along the walls and ceilings to balance the partition and keep it in place.

The next analyses performed on the partition were decibel readings and sound testing. First, tests were performed on the MLV as a standalone barrier. One student stood inside an empty room holding a decibel reader (the Decibel Ultra application on the iPhone), while another stood on the other side of the doorway and played a song at maximum volume on a computer. The first test was done with no barrier, and in the second test the MLV was unrolled and used to seal the doorway by two other students holding it against the doorframe. Figures 16 and 17 depict the results, respectively, from these tests.

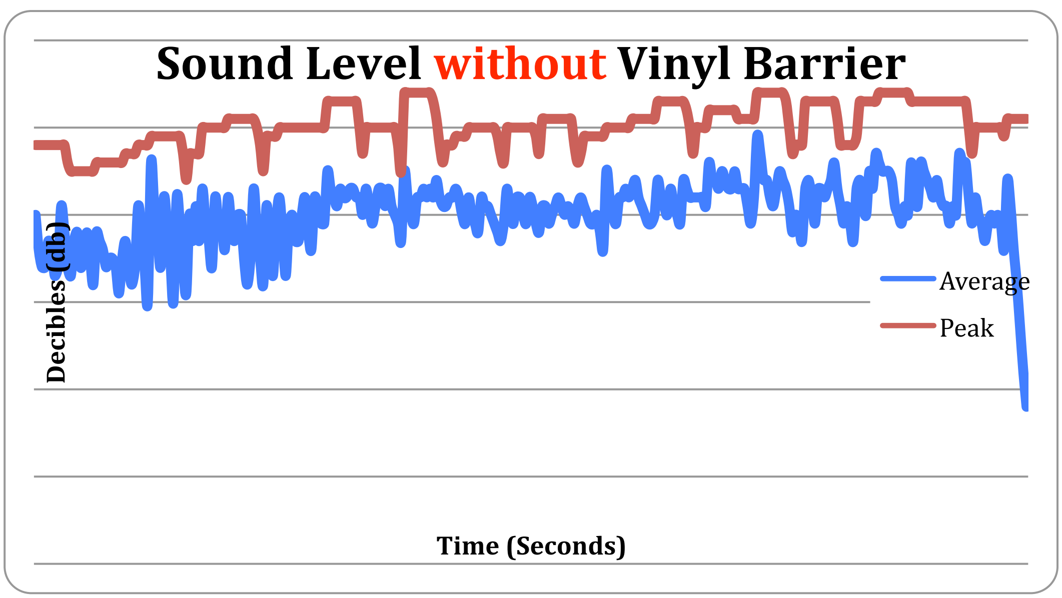

Figure 16: The first run of the MLV sound test with no barrier between the computer playing music and the decibel reader. The peak remained around 90 db while the average was between 80-85 db.

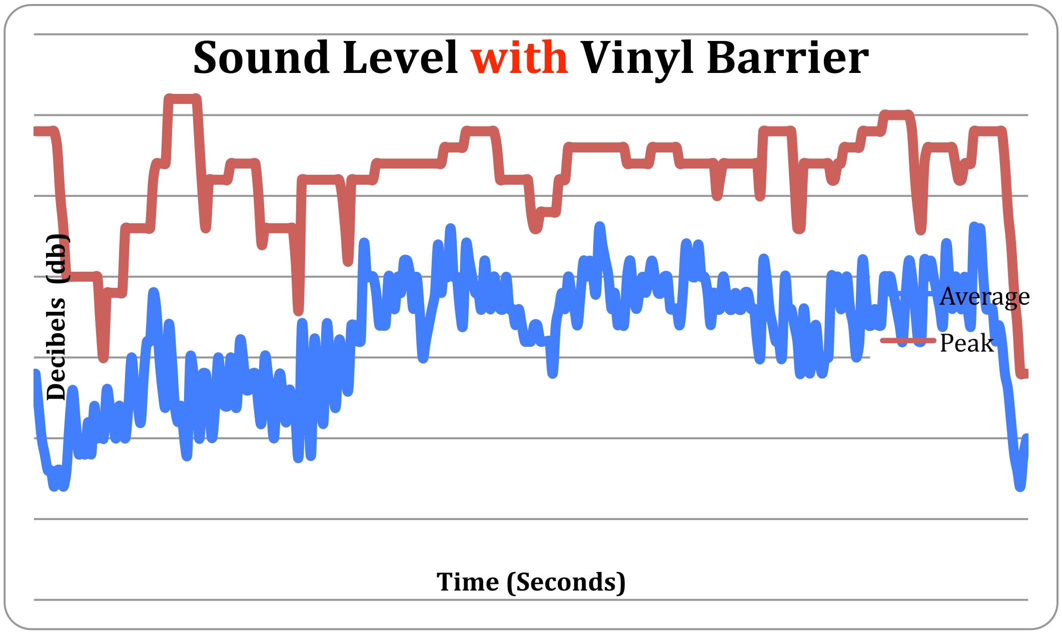

Figure 17: The second run of the MLV sound test with the MLV barrier in place between the music source and the decibel reader. The peak dropped to about 67 db while the average dropped to about 60 db.

The same song was used for both runs of this test and played for the same amount of time. The results showed around a 20 db drop in the peak readings and as well as a 20 db drop in the average decibel readings.

A similar test was performed on a working model of the complete partition. This model included all three layers, was 4 ft long and 2 ft wide and was secured together along the edges with 1 ¼ in screws. The team used an opening in a wall that was small enough to be completely enclosed by the model of the partition. The decibel reader was placed inside the opening and a song was played at maximum volume just outside the opening, first with no barrier, then again with the partition held up against the wall to seal the opening completely. The same song was played for both tests for the same amount of time, however the second reading occurred two seconds later to account for the time between pressing record, placing the partition over the hole and starting the song (Figure 18 and 19).

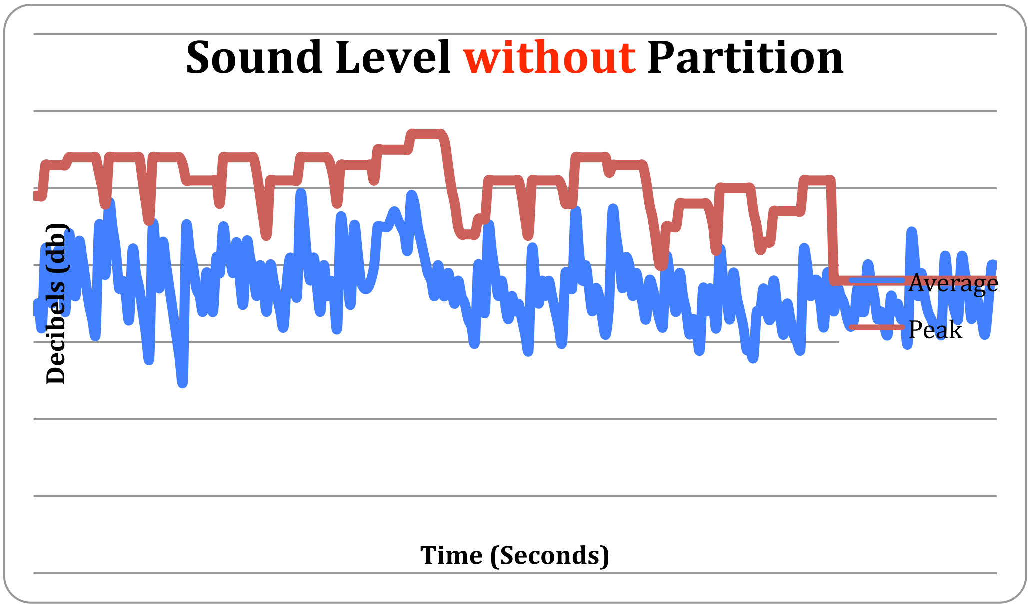

Figure 18: The first sound test with no partition between the decibel reader and the music source. The peak remained around 90 db while the average was around 80 db.

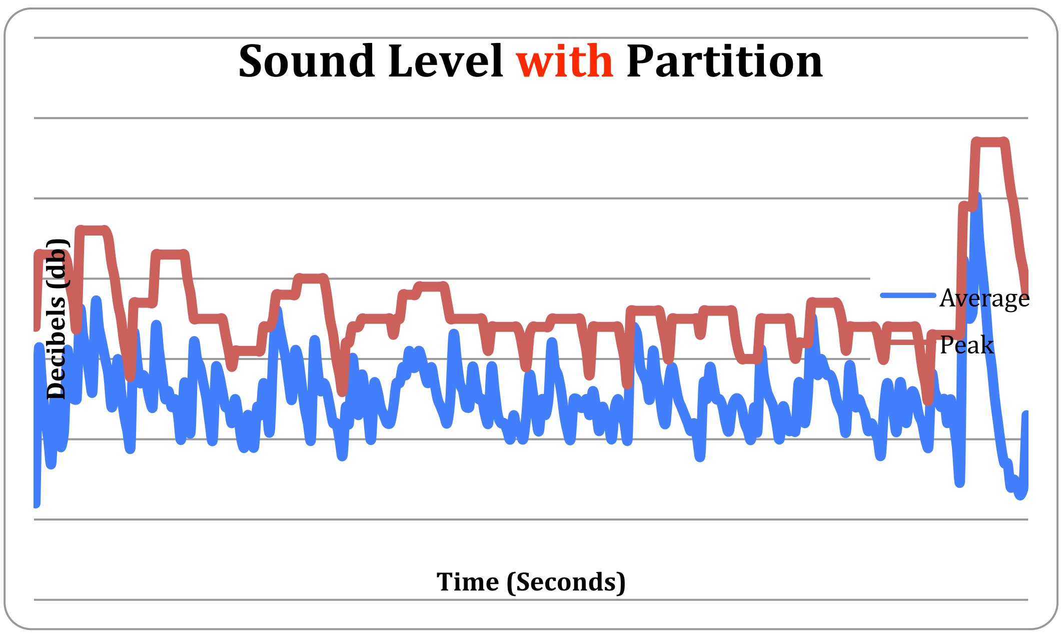

Figure 19: The second test performed with the partition in place. The time range is two seconds higher than the first test because it was necessary to take into account the time to press record, cover the hole and start the music. The peak range from 77-85 db while the average dropped to about 65 db.

These results showed a drop in the peak readings of about 15 db as well as a decrease in the average decibel readings of about 15 db. While these values do not show a significant increase in the sound blocking abilities of the partition over the MLV on its own, it was determined that the results could not be completely conclusive due to the environment in which the tests were performed. These tests required a completely quiet environment, which was not readily available. Also, due to the size of the model of the partition, the tests had to be completed in different areas of the building and in a different manner. It can be assumed that the need to press record, move the partition and then start the music would have had a definite impact on the average and peak readings that resulted in the testing of the partition.

A 15-25 db loss in sound transfer between the hallway and waiting room will be significant. There were many instances in which the readings maintained a level between 70-80 db, so the installation of this partition alone would bring the levels down to between 50-60 db, a level that the research performed found to be conducive to effective learning (see the effects of sound in the research section of this paper). The two extra layers of material in the partition were also necessary for the installation of mass-loaded vinyl, as it would tear under its own weight if left alone. Figures 20 and 21 show the final design and working prototype that was delivered to KidSpace, as well as the model that was used during testing.

Figure 20: Partition model and final design. All three layers of material and the screws used to secure them are visible.

Figure 21: Partition model and final design.

DOOR DESIGN DELIVERABLE

Door covering units have been viewed as a crucial element of this project to reduce sensory inputs around the facility and particularly in the gym space. Crucial to success, the team felt that the design must reduce visual sensory inputs, reduce auditory sensory inputs, increase patient and therapist interaction effectiveness, increase privacy, be low in cost, and safe. Through the engineering design process the team generated ideas, evaluation, and refining, the team was able to come to a final design to deliver to Kidspace.

The final proposal that the team developed will be implemented in the front gym doorway, gym divider door, and the back gum door. The door will be made of transparent PVC vinyl flaps. Transparent PVC vinyl has to offer exceptional acoustical performance, moderate sound barrier characteristics, lightweight, and durability. The material is ideal for the purpose that it will serve as an enclosure with high traffic and will be easy for the patients and therapists to pass through. The formability of the material allows the design to be durable and can realign easily after a parson has passed though.

Each door flap piece is 6" in width, 0.06" thick, and are cut in a variety lengths according to the door size. The flaps were laid out in an overlay design, with 1/3 of each flap laying on the other (2" overlay). Below in Figure 22 is an image of the overlay design for the door flaps. As it can be seen, each flap is overlapped to stay closed and provide the greatest amount of sound reduction possible. In addition, the design reduced the amount of material needed to cover the door, thus reducing costs. Keeping in mind the end user, the team prototyped and concluded that the 1/3 overlay design was easiest style to walk through. The overlay design could also function as a good visual barrier if the strips were to be printed on with a vinyl covering or other covering methods.

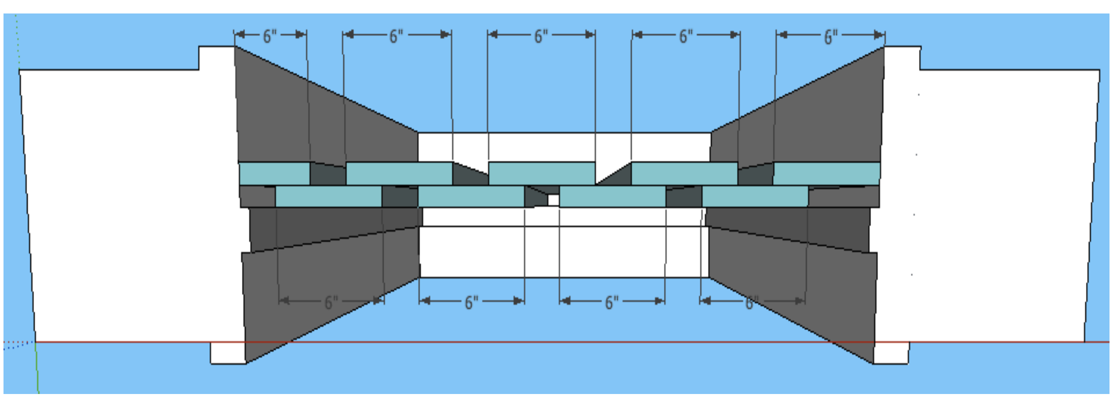

Figure 22: Overlay Design

Each door had different dimensions, thus each design required a custom lengths. The design of the front gym doorway utilizes nine strips, all 96" in length. The strips will be placed in the overlay design, then attached to the mounting bracket using five bolts. Holes were drilled at specified lengths in order to fasten all of the flaps in specified locations. This ensured that the strips would be secure and increase the longevity of the design. Once attached to the mounting bracket, the entire unit can be attached to the inside of the doorframe. Below in Figure 23, three-dimensional sketches of the front gym door can be seen. Additional views can be found in the appendix along with dimensioned sketches. Overall, the entire door flaps with mounting bracket will fit within the current doorframe and not require any additional construction.

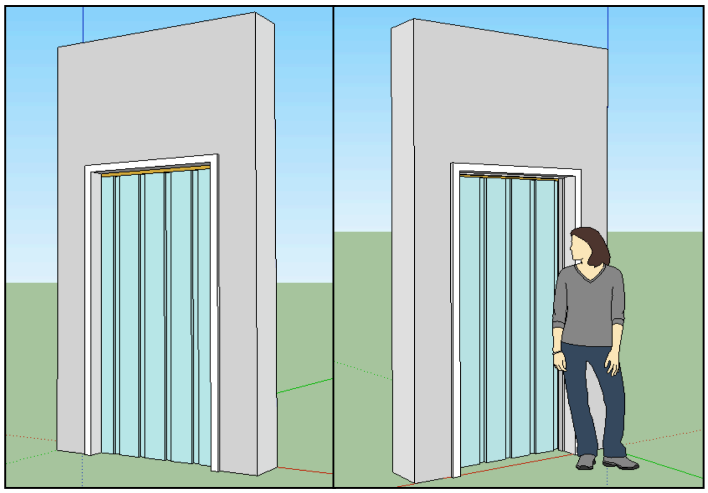

Figure 23: Front Gym Door Flap Design

The design of the doorway between the two gyms utilizes nine strips 96" in length and twelve strips 59" in length. The strips will be placed in the overlay design, and then attached to the mounting bracket. Holes were drilled at specified lengths in order to fasten all of the flaps in specified locations. Once attached to the mounting bracket, the entire unit can be fastened to the top of the doorway into the studs. Below in Figure 24, three-dimensional sketches of the doorway between the two gyms. Additional views can be found in the appendix along with dimensioned sketches.

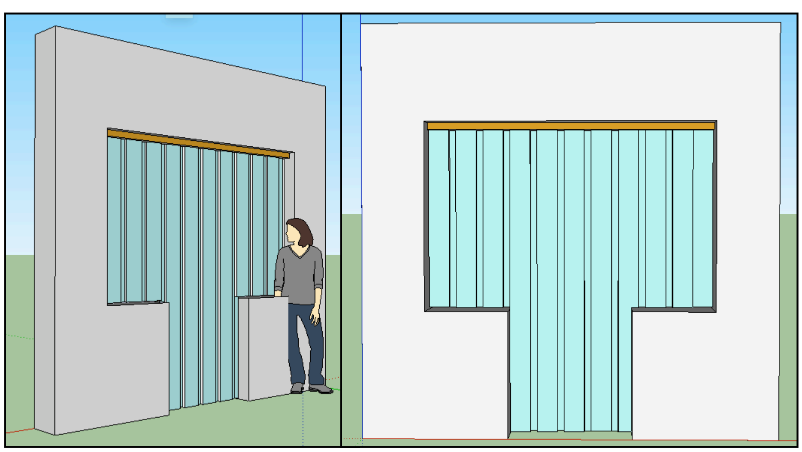

Figure 24: Doorway Between Two Gyms Design

The design of the back gym door utilizes ten strips 81” in length, nine strips 117” in length, and four strips 65” in length.. The strips will be placed in the overlay design, and then attached to the mounting bracket. Holes were drilled at specified lengths in order to fasten all of the flaps in specified locations. Once attached to the mounting bracket, the entire unit can be fastened to the ceiling and into the studs. The difficulty with this doorway is the presence of an air duct, thus additional constriction will be require to build. This construction would serve the purpose of building a frame around the duct that the door flap back can be attached to. Below in Figure 25, three-dimensional sketches of the doorway between the two gyms. Additional views can be found in the appendix along with dimensioned sketches.

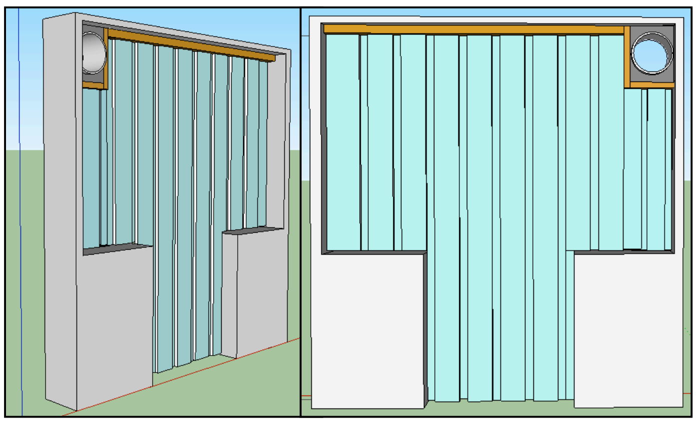

Figure 25: Back Gym Door Design

Following design development, the team began to perform engineering analysis. This analysis enabled revealed additional information about the effectiveness of the design and overall performance. First, load analysis was conducted to determine the long-term effects of stress and strain on the material. The goal was to determine the tendency of transparent PVC vinyl material to deform permanently under stress, which is known as creep. Stress for each strip was calculated in Table 8 below and then the values were compared to the Stress-Strain Graph in Figure 26.

Length (in)	Width (in)	Thickness (in)	Area	Load	Stress (psi)
96.00	6.0	0.06	34.56	11.135	3.103726987
59.00	6.0	0.06	21.24	5.0405	4.213867672
108.00	6.0	0.06	38.88	13.1796	2.950013657
117.00	6.0	0.06	42.12	15.5351	2.711279618
81.00	6.0	0.06	29.16	6.9617	4.188632087
65.00	6.0	0.06	23.40	10.201	2.293892756

Table 8: PVC Stress and Load Table

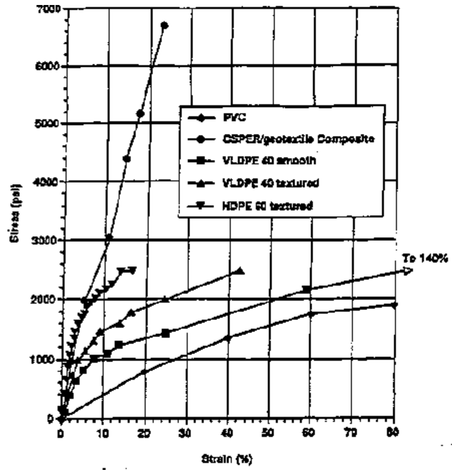

Figure 26: PVC Stress Strain Curve [40]

As can be seen in Table 8 and Figure 26, there is a maximum stress of 3.9 psi. When comparing this value to the Stress – Strain table above, the strain will be likely be extremely small and potentially negligible. Overall, this is very acceptable and ensures that the design will have minimal deformation over its lifetime.

Next, the team performed load analysis on the mounting brackets to determine the amount of load that each would have to support. Simple calculations were carried out to determine the overall load per support bracket. The analysis revealed that the load for the front gum door will be 11.135 lbs, the load for the doorway between the two gyms will be 23.76 lbs, and the load on the back gym door space will be 27.81 lbs. All bracket load calculations can be found in the appendix.

Finally, sound analysis was performed on the PVC door flap prototype to determine the amount of sound that the door would reduce. The goal of this analysis was to provide feed back on the effectives of our design and the impacts it will have in the Kidspace facility. A room in Start Up House was selected as the testing area. A sound reader application was downloaded to a mobile device in order to take decibel readings over a period of time. A song was selected to play, which would provide a variety of tones and frequencies. First, the doorway was left unblocked and the sensor was placed inside at a specified location. Outside of the doorway, a computer was placed on the ground a music was played for 30 seconds. After that time, the sound sensor was stopped and the data uploaded to Microsoft Excel. The sensor and song was reset to conduct the test with the PVC door prototype in place. The same steps were carried out and data uploaded. The following two figures are the graphs of the decibel data that was collected during both tests. The first graph is the sound readings without the PVC door and the second is with it.

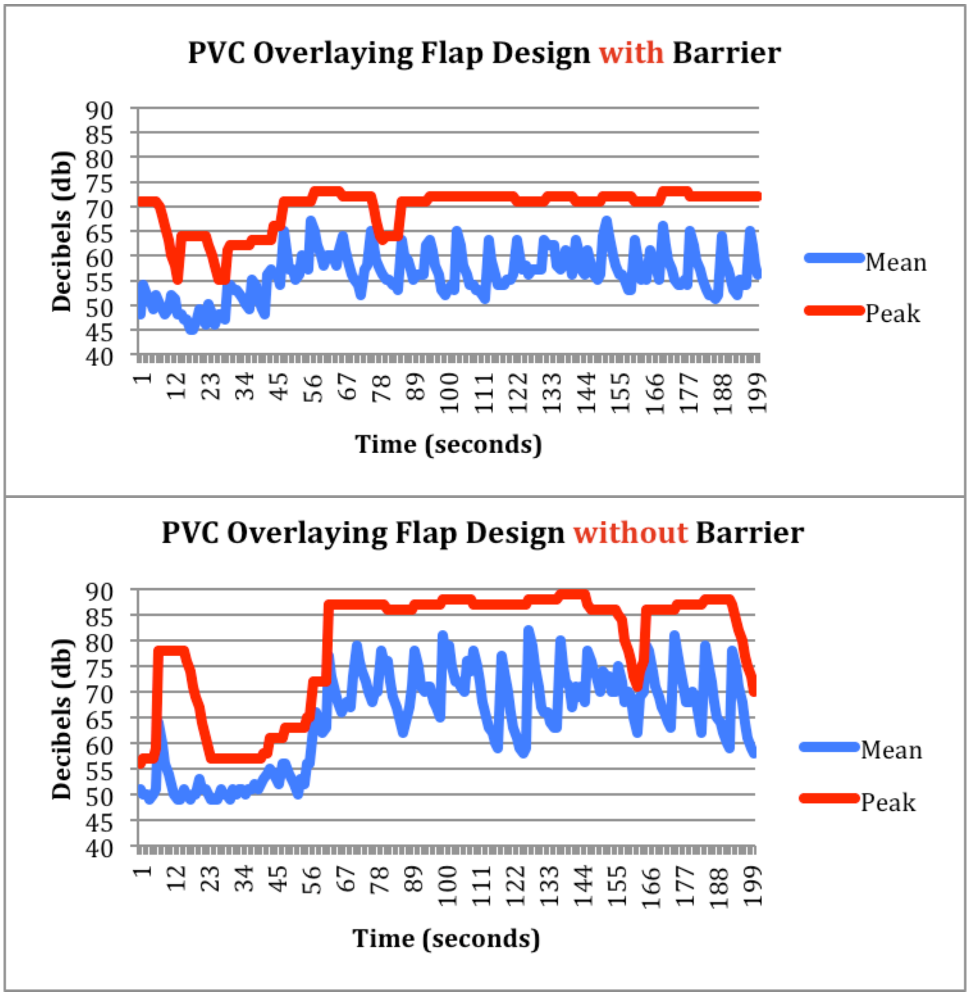

Figure 27: PVC Door Sound Analysis

The graphs show that the PVC doors reduced the mean sound level by 15 decibels and the peak readings by 15 decibels. This is a significant reduction and proof the doors will be effective if implemented in Kidspace. Theoretically, the doors could reduce sound levels further since there will generally be conversations occurring in the gyms and not a song constantly playing. However, design implementation will be the only source that will truly prove this. If they were shown to have this amount of success, it would be practical for Kidspace to implement these doors in other spaces in the facility. Moving forward, implementation would be the next step to verify analysis and proof of concept. Overall, the team feels very confident that this design will come to fruition within the facility (Figure 28).

Figure 28. (left) The working model of the PVC flap door temporarily installed in the doorway to the front gym. (right) The method of attachment still allows for the existing door to be shut.

In the future, the team felt that adding a design to the strips of PVC would be very helpful in reducing distraction and visual stimuli from adjacent rooms. The team looked into having a vine graphic printed on some of the strips using a clear vinyl adhesive. Below is a sketch of what this design would look like in the doorway between the two gyms.

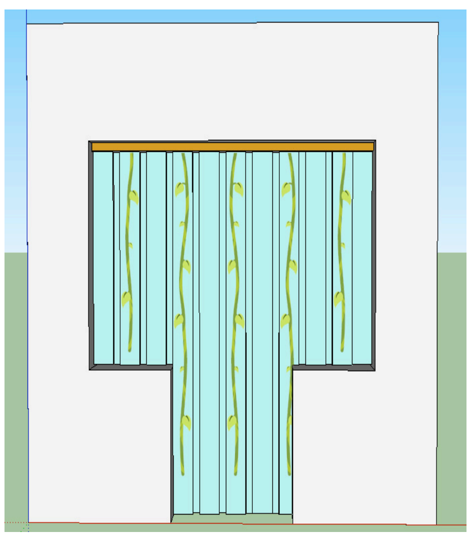

Figure 29. Doorway between the two gyms with the vine design incorporated.

While an opaque blockade between rooms would minimize the visual distractions, it is necessary to take into account the safety of the children and therapists moving from room to room. The table below shows the amount of blockage a design would provide on a 36" wide door using 9 strips to cover the area.

Number of strips with a design	**Percent of strip covered by design**	**Percent visual blockage**
4	50%	33%
4	50%	66%
5	100%	41.7%
5	100%	83.4%

The team took this design to a local printing company in San Francisco, Budget Sign. Their contact, Noël Birbeck, estimated the cost of printing on the minimal number of strips (24) to be $643.78. A few other cheaper alternatives would be to hand paint the strips or to sew and insert strips of fabric between or over alternating PVC strips.

SOUND SENSOR DESIGN DELIVERABLE

The initial plan for the construction of Mr. Fish was to use off the shelf hardware interfaced with an Arduino microcontroller to output a visual indication of the decibel reading in a room. The critical component of the circuit was the sound sensor. The optimal module would contain an input speaker, which would record the sound intensity in either a digital or analog signal. After talking with the therapists, they explained that at times the room would be full with kids while at other times their sessions would be with only one kid. It was decided it would be necessary for the module to be adjustable to fit the particular situation. It would also have to be easily accessible as well as simple to adjust. The module must also contain a potentiometer, which would be a simple means to adjust the sensitivity. Another component that must be included was an amp, which would amplify the lower signals due to the dimensions of the room. After searching for compatible modules, the Arduino sound sensor analog sensor module for sensor shield was chosen to be the best option for its ease of use and low price. This module contained every criterion, which were necessary for implementation. It also was able to make certain adjustments depending on the environment in which it was installed. The problem was, however, that this module was not available anywhere in the United States. The earliest that the module could have been received was around eight days. The price would also have been more than 5 times the actual cost of the module in shipping. It was clear that this device would not be chosen.

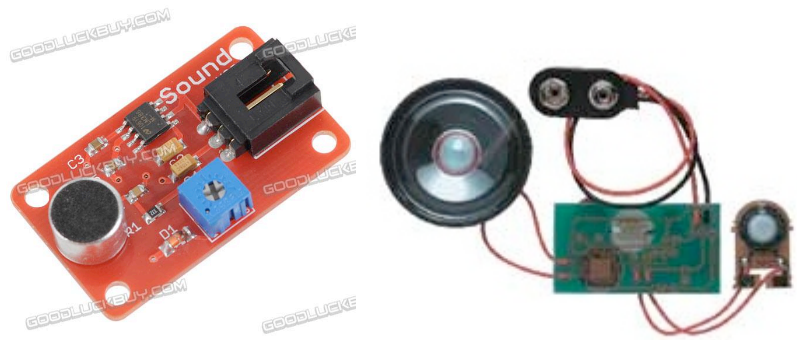

Figure 30: (left) First sound sensor chosen. (right) Final sound sensor module

The search then focused on only local shops from which the parts could quickly be picked up to begin prototyping. With only Radioshack and a few electronics stores to choose from, the options were limited. After consulting with Dr. Bailey-Van Kuren, it was decided to go with a 9V digital recording/playback module from Radioshack. The module was intended to be used to record up to 20 sec of sound by manually pressing a button and outputting the recorded signal via a 16 ohm speaker by pressing the playback button. The outputted sound was converted to an analog signal, which would be easily read through the Arduino. Although surprisingly there was no circuit diagram included, it was thought that the main components could be hacked to perform the tasks needed. The analog output signal from the module would be inputted into the Arduino and converted to a voltage through the serial monitor. By comparing the voltage change and corresponding decibels from a decibel reader on an Android device, the decibel readings could be sorted into defined ranges. Mr. Fish would have five bubbles, which would be lit by LEDs based on defined readings. The first bubble from the mouth of Mr. Fish would always be lit, signifying the ideal decibel reading. With increasing decibel readings, more bubbles would be lit as each predefined decibel ranges were read.

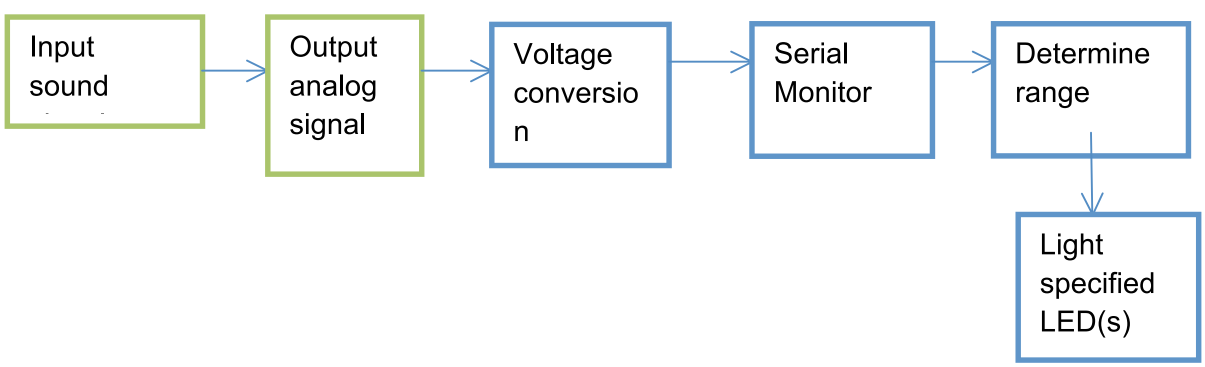

Figure 31: Box outline of logic

It was decided that the bubbles should be colored as to distinguish the differing sound levels as well as appeal to kids. There were many options, which could be used to light the bubbles. Options which were considered included:

- Cover bubble holes with colored material and light with standard white LEDs
- Differing colors of multiple standard LEDs

- Differing colors of a single high output LED
- ScotchBrite
- RGB (Red-Green-Blue) LEDs

After talking with the therapists at Kidspace, they noted that they would prefer Mr. Fish to be located in the gyms in order to give them immediate feedback from the kids. We determined that the lights must be extremely bright in order to be clearly seen from a distance, have an ability to turn on/off quickly as well as be adjustable. The ScothBrite and RGB LEDs were the best options, which met all of the criteria due to their adjustability. After examining power requirements and code, the RGB LEDs were chosen. The RGB LEDs came in digital strips, which were controlled by a flexible circuit board imprinted on the surface and came in meter lengths. Each length was divided into 16 segments, which included two LEDs for every segment. The most important aspect was that the 2.5" segments could be cut and controlled individually. We would thus be able to cut certain lengths according to the differing bubble sizes. Being digital, the strip can be controlled by thousands of color combinations and light intensities. Ideally the flexibility of the strips would allow the team to program combinations, which would give immediate visual feedback based on the behavior of the environment.

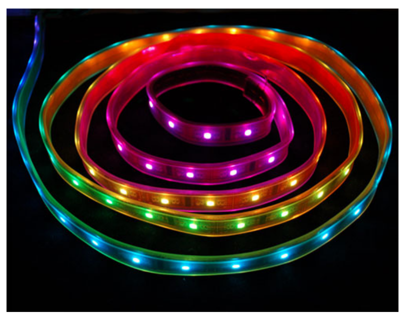

Figure 31: Controllable RGB LED for bubbles

Each 2.5" segment was capable of handling a maximum of 5V@ 120mA draw, which we knew would drain batteries quickly. However after reading about where and how the strips were used, most segments were never used at fully capacity and were generally run at 3V with a large draw range. With the Arduino capable of providing only 5V, we decided to also add a 9V wall-pluggable source to help power the lights. With the first bubble being small and our estimated average number of lit bubbles being 2.4, we felt that there would be adequate power to supply the board. If problems did arise, we had planned on reducing intensity and/or changing to color schemes which drew less power.

To begin the prototyping, the most significant aspect was hacking the sound module to output an immediate response to the decibels in the room. Since the module did not come with any schematic, we had to probe around the circuit with a digital multimeter (DMM) to figure out how the circuit functioned. It was found that the recording push button acted as a switch and when initiated closed the loop which sent 5V through the circuit to the microphone. The microphone recorded the sound and stored the digital input in a chip. The playback button functioned basically the same way however instead it sent power to the speaker, which drew a signal from the chip. The chip acted as the brain for the entire circuit by not only storing the digital input from the microphone but also converted the signal to analog which was read by the microphone. Initially the speaker was removed and the team read the output from the leads via the Arduino. The team tested the output readings by talking into the microphone and playing the sound back, which produced a noticeable voltage change on the serial monitor, which corresponded to the different intensities of our speech. The team proceeded to analyze the circuit for ways to automate the recording and playback. The first idea to output the signal was to jump the signal from the microphone straight to the speaker output. However without any specs on the chip, the team decided to keep the circuit as is. The team then decided to replace both push buttons with transistors, which would function as controllable switches via the Arduino. The recording transistor would close for 0.5s and once opened, the playback transistor would close, replaying the previously recording sound bite. Once the signal was read, the transistor would open. This process would be looped to run continuously resulting in an accurate reading of the environment (Fig).

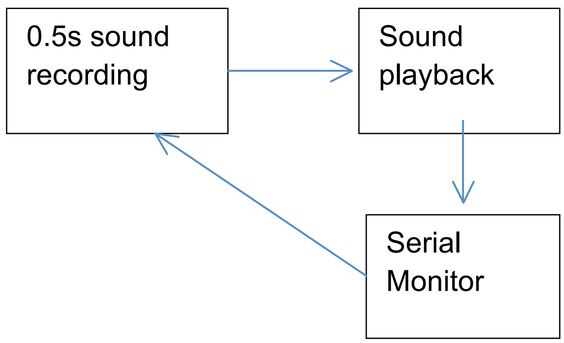

Figure 32. Box outline of how sound was recorded, replayed and read on Arduino

This process was used and accurate readings were repeatedly gathered. Unfortunately while attempting to modify a soldered joint, some solder fell onto the board and proceeded to short the board out. A surge of current was sent to the chip, which proceeded to overload the chip and render it useless. With such a short span to produce a working model for Kidspace, we were unable to acquire another sound sensor before we were to present our ideas. A model of how the system would function was implemented using high-output LEDs set on a timer. The first bubble was always lit, as we had planned, however the 2-5 bubbles were set to go off in sync with each other. The second bubble would light, and 0.5s later the third bubble would light, displaying the 1-3 bubbles being lit. After another 0.5s, the fourth bubble would light. This process was looped as to show what the actual Mr. Fish would function if there had been an actual sound sensor installed. Both a pseudo code of the original function and the actual code used for the presentation are included in the appendix.

The future work for Mr. Fish has a huge number of possibilities. Once an accurate sound sensor could be installed, the accuracy of a one-microphone sensor could be tested. Due to most microphones being directional and affected by the proximity of the sound, multiple microphones may have to be implemented in order to achieve an accurate result. With a schematic of the rooms, one could run acoustical tests in order to determine the best location for the microphones. The next iteration would also include the use of the RGB lights, which could be designed to achieve a wide array of colors which would correspond with the decibel levels. A power consumption analysis would also be conducted in order to optimize the circuit configuration to be most efficient. The team plans to continue work on Mr. Fish in order to present Kidspace with a finished product that would bring a fun and interactive way to help kids understand their audio outputs.

Conclusions

In conclusion, the team was able to develop three different designs in order to dampen sensory inputs at Kidspace. Finalized prototypes of each design were constructed and presented to the client at the end of the project. The partition design proved to be very successful and met the criteria established by the team at the beginning of the project. A full model was unable to be produced, however the working prototype provided the team with confidence that it would be an effective design if implemented in the space. It successfully reduced the transfer of sound, it was relatively inexpensive to construct, easy to assemble, sturdy in design, and safe for the end user. In addition, it proved to be a feasible alternative to building an entire wall to cover the space. Overall, the team was very happy with the design and is confident that the design or a variation of it will be implemented at Kidspace in the near future.

The transparent PVC door flap design was met with great success and a promising future at Kidspace. Overall, a final design was produced for the front gym doorway. In testing, the door proved to reduce sound transfer significantly, function as planned, light in load on the door frame, safe for patients and therapists, and showed potential to reduce visual sensory inputs. The team felt that it would be a viable alternative to using a conventional door, while also providing addition benefits to the facility. Moving forward, the team could see the design being altered to fit the space restrictions better and increase the longevity of the design. In general, the team was extremely satisfied with the working prototype and its effectives in the facility. Based on the response from Kidspace staff, there is no doubt that they will put this design into service for the facility.

In regards to the Sound Sensor, the team was very happy with the overall design and the potential it has at Kidspace. The idea behind the capabilities that this design has to impact the environment through the use of a visual sound meter really made the team excited for implementation. The design was very applicable to the treatment that goes on within the facility and would enhance therapy sessions through visual feedback. Additionally, the working prototype received a positive response from the Kidspace staff when presented to them. However, the complexity of the circuitry and short time frame made it difficult for the team to implement the full design. Had more time and all required resources been available, there is no doubt that the team would be able to implement the sound senor in its entirety. Overall, the team was pleased with the progress made and look to continue to develop this design further. It is the intention of the team that this visual sound meter be implemented in Kidspace in the near future. The team learned a great deal from the design process and working with a client in the context of a real world problem.

Resources

1. "A Senory Room the Best Space To Create For Some Awesome Relaxation Or Stimulation. Let's Start Building!" Sensory Room. N.p., n.d. Web. 15 May 2012. <http://www.sensory-processing-disorder.com/sensory-room.html>.

2. Abilities. "Therapeutic Listening." *Abilities*. 11 Apr. 2010. Web. 17 May 2012. <http://www.abilitiesinfo.com/therapy_listeningsensoryint.html>.

3. "About SPD." SPD Foundation. Sensory Processing Disorder Foundation, n.d. Web. 15 May 2012. <http://www.sinetwork.org/about-sensory-processing-disorder.ht

4. "Asperger's Syndrome-Symptoms." WebMD. N.p., n.d. Web. 15 May 2012. <http://www.webmd.com/brain/autism/tc/aspergers-syndrome-symptoms>.

5. "Audimate Absorption Sheets." *Audimate*. Web. 29 May 2012. <http://www.audimutesoundproofing.com/audimute-sound-absorption-sheets-materials-that-absorb-sound-soundproofing-blankets.aspx>.

6. "Autism." PubMed Health. U.S. National Library of Medicine, 26 Apr. 2012. Web. 15 May 2012. <http://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0002494/>.

7. "Autism Fact Sheet." : National Institute of Neurological Disorders and Stroke (NINDS). National Institutes of Health, n.d. Web. 15 May 2012. <http://www.ninds.nih.gov/disorders/autism/detail_autism.htm>.

8. "Beit Issie Shapiro." N.p., n.d. Web. 15 May 2012. <http://www.beitissie.org.il/eng/>.

9. "Best Practices in Approaching the Sensory Challenged Child." The Motor Story. N.p., n.d. Web. 28 May 2012. <http://www.themotorstory.com/The_Motor_Story/Best_Practices_in_Approaching_the_Sensory_Challenged_Child.html>.

10. "Brain Highways: The Proprioceptive System." YouTube. YouTube, 04 Aug. 2010. Web. 08 June 2012. <http://www.youtube.com/watch?v=b2iOliN3fAE>.

11. City and County of San Francisco. City and County of San Francisco Municipal Code. Building Inspection Commission. *Building, Electrical, Housing, Mechanical, and Plumbing Codes*. Cincinnati: American Legal Corporation, 2011.

12. Costello J. T., Donnelly A. E. (2010). "The effects of cryotherapy on joint position sense in healthy participants: A systematic review". *Journal of Athletic Training* **43**: 306–316.

13. Cohen, Sheldon, and Shirlynn Spacapan. "The Social Psychology of Noise." *Noise and Society* 9 (1984): 221-45. Print.

14. Crawford, Benna. "Calming Sensory Room Wall Colors." EHow. Demand Media, 09 Apr. 2011. Web. 08 June 2012. <http://www.ehow.com/info_8190025_calming-sensory-room-wall-colors.html>.

15. "Grainger Industrial Supply - MRO Supplies, MRO Equipment, Tools & Solutions." Grainger Industrial Supply - MRO Supplies, MRO Equipment, Tools & Solutions. N.p., n.d. Web. 29 May 2012. <http://www.grainger.com/Grainger/wwg/start.shtml>.

16. Hall, Leah, and Jane Case-Smith. "The Effect of Sound-Based Intervention on Children With Sensory Processing Disorders and Visual-Motor Delays." *American Journal of Occupational Therapy* 61 (2007): 209-15. Print.

17. Holtz, Gillian A., Andrea Castelblanco, Isabel M. Lara, Alyssa D. Weiss, Robert Duncan, and John W. Kuluz. "Snoezelen: A Controlled Multi-sensory Stimulation Therapy for Children Recovering from Severe Brain Injury." Informa Healthcare. N.p., July 2006. Web. 15 May 2012. <http://ubikproyectos.com/rehabilitacion/catalogos/Snoezelen_severe_brain_injury.pdf>.

18. "How To Design a Calming Room for Autistic Kids." How To Design a Calming Room for Autistic Kids (NY Metro Parents Magazine). NY Metro Parents Magazine, n.d. Web. 15 May 2012. <http://www.nymetroparents.com/article/How-To-Design-a-Calming-Room-for-Autistic-Kids>.

19. "Interior Design for Children with Autism | Autism Key." Interior Design for Children with Autism | Autism Key. N.p., n.d. Web. 15 May 2012. <http://www.autismkey.com/interior-design-for-children-with-autism/>.

20. "Miami Project Research Breakthrough." MEDICAL JOURNAL. N.p., n.d. Web. 15 May 2012. <http://www6.miami.edu/ummedicine-magazine/fall2004/journal.html>.

21. "Modulus of Elasticity, Average Properties of Structural Materials, Shear Modulus, Poisson's Ratio, Density - Engineers Edge." N.p., n.d. Web. 29 June 2012. <http://www.engineersedge.com/manufacturing_spec/average_properties_structural_materials.htm>.

22. Mosby's Medical, Nursing and Allied Health Dictionary, Fourth Edition, Mosby-Year Book 1994, p. 1285

23. "Noise Barriers." Industrial Noise Control. N.p., n.d. Web. 29 May 2012. <http://www.industrialnoisecontrol.com/materials/flexible-noise-barriers.htm>.

24. "NSPE Code of Ethics for Engineers." *NSPE Code of Ethics for Engineers*. Web. 04 June 2012. <http://www.nspe.org/Ethics/CodeofEthics/index.html>.

25. "Open vs Closed Cell Foam." Open vs Closed Cell Foam. N.p., n.d. Web. 29 May 2012. <http://getfoaminsulation.com/?p=142>.

26. "Overview of Materials for PVC, Transparent." N.p., n.d. Web. 29 May 2012. <http://www.matweb.com/search/DataSheet.aspx?MatGUID=68fa5d97c647420cbc5635034a6816bf>.

27. "PVC - Poly(vinyl Chloride)." PVC - Poly(vinyl Chloride). N.p., n.d. Web. 29 May 2012. <http://www.pslc.ws/macrog/pvc.htm>.

28. "PVC Mechanical Properties." EPI. The Liner Company, n.d. Web. 29 May 2012.

<http://www.geomembrane.com/techpapers/PVCMechanical.htm>.(stress strain curve)

29. "Sensory Integration Disorder." TheFreeDictionary.com. N.p., n.d. Web. 15 May 2012. <http://medical-dictionary.thefreedictionary.com/Sensory%20Integration%20Disorder%20>.

30. "Sound." Dictionary.com. N.p., n.d. Web. 15 May 2012. <http://dictionary.reference.com/browse/sound>.

31. "Soundproofing and Acoustical Materials." Acoustical Surfaces, Inc. N.p., n.d. Web. 29 May 2012. <http://www.acousticalsurfaces.com/>.

32. "SoundAway - Residential and Commercial Soundproofing." SoundAway - Residential and Commercial Soundproofing. N.p., n.d. Web. 29 May 2012. <http://www.soundaway.com/>.

33. "STRATEGIES FOR TEACHING STUDENTS WITH AUTISM SPECTRUM DISORDERS." Autism, PDD-NOS & Asperger's Fact Sheets. N.p., n.d. Web. 28 May 2012. <http://www.autism-help.org/education-classroom-strategies.htm>.

34. "Tear Strength." Tear Strength. N.p., n.d. Web. 29 May 2012. <http://www.rueylung.com.tw/home/site_index/Tear_Strength>.

35. "Top Aromatherapy Scents for Stress Relief." N.p., n.d. Web. 15 May 2012. <http://www.solveyourproblem.com/aromatherapy/aromatherapy-stress-relief.shtml>.

36. "UL 94, the Standard for Safety of Flammability of Plastic Materials for Parts in Devices and Appliances Testing." UL. N.p., n.d. Web. 29 May 2012. <http://www.ul.com/global/eng/pages/offerings/industries/chemicals/plastics/testing/flame/>.

37. "Ultimate Tensile Strength." The Free Dictionary. Farlex, n.d. Web. 29 May 2012. <http://www.thefreedictionary.com/Ultimate tensile strength>.

38. U.S. Fire Administration. "Clearance Around Sprinkler Pipe." *Coffee Break Training* 2006.49 (2006): 1-2. Print.

39. "Tear Strength." Tear Strength. N.p., n.d. Web. 29 May 2012. <http://www.rueylung.com.tw/home/site_index/Tear_Strength>.

40. "PVC MECHANICAL PROPERTIES." *PVC Geomembrane Mechanical Properties*. N.p., n.d. Web. 09 June 2012. <http://www.geomembrane.com/techpapers/PVCMechanical.htm>.

41. "PVC MECHANICAL PROPERTIES." *PVC Geomembrane Mechanical Properties*. N.p., n.d. Web. 09 June 2012. <http://www.geomembrane.com/techpapers/PVCMechanical.htm>.

42. "Standard External Trigger Piezo Sound Sensor." - *Connevans.co.uk*. N.p., n.d. Web. 09 June 2012. <http://www.connevans.co.uk/store/viewProduct.do?id=2566>.

43. "Effects of Traumatic Brain Injury| Effects of Brain Injury | Causes of Brain Injury." *Effects of Traumatic Brain Injury| Effects of Brain Injury | Causes of Brain Injury*. N.p., n.d. Web. 09 June 2012. <http://www.traumaticbraininjury.com/content/understandingtbi/effectsoftbi.html>

44. *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 15 June 2010. Web. 09 June 2012. <http://www.cdc.gov/TraumaticBrainInjury/causes.html>.

45. Staff, Mayo Clinic. "Definition." *Mayo Clinic*. Mayo Foundation for Medical Education and Research, 16 Sept. 2010. Web. 09 June 2012. <http://www.mayoclinic.com/health/traumatic-brain-injury/DS00552/DSECTION=symptoms>.

46. "By Illness." *NAMI*. N.p., n.d. Web. 09 June 2012. <http://www.nami.org/Template.cfm?Section=By_Illness>.

47. "ADHD Awareness." *ADHD Awareness*. N.p., n.d. Web. 09 June 2012. <http://adhdawareness.wordpress.com/2008/05/10/how-is-adhd-discovered/>.

48. "ADHD/ADD In Children: Symptoms, Causes, Types, Tests, Treatments." *WebMD*. WebMD, n.d. Web. 09 June 2012. <http://www.webmd.com/add-adhd/guide/ast_oneadhd-children>.

49. "What Is ADD." *About.com ADD / ADHD*. N.p., n.d. Web. 09 June 2012. <http://add.about.com/od/adhdthebasics/a/ADHDbasics.htm>.

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All of the School of Engineering and Applied Science faculty member and staff

Appendix

APPENDIX A – Photos of Kidspace

Figure 33. Front gym

Figure 34. Alternative view of front gym

Figure 35. Main hallway

Figure 36. Waiting Room

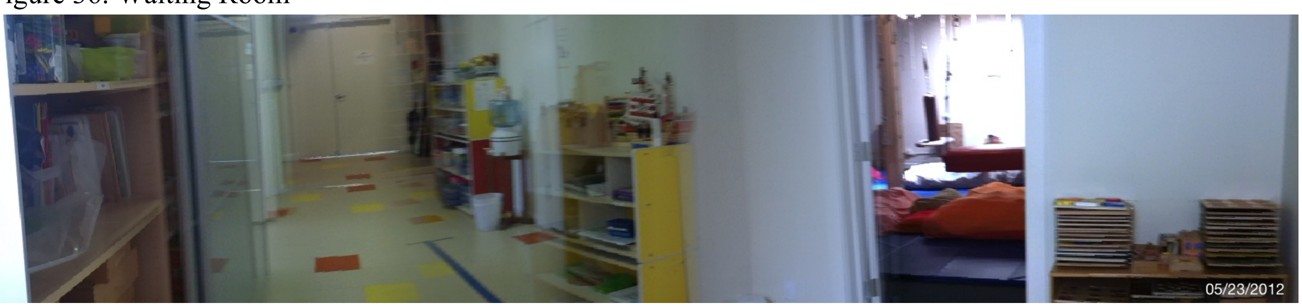


Figure 37. Main hallway with view into front gym

Figure 38. Back gym

Figure 39. Doorway leading from main hallway to waiting room. Also shows gap in wall

Figure 40. Main hallway

APPENDIX B – Alternative sketches and proposals

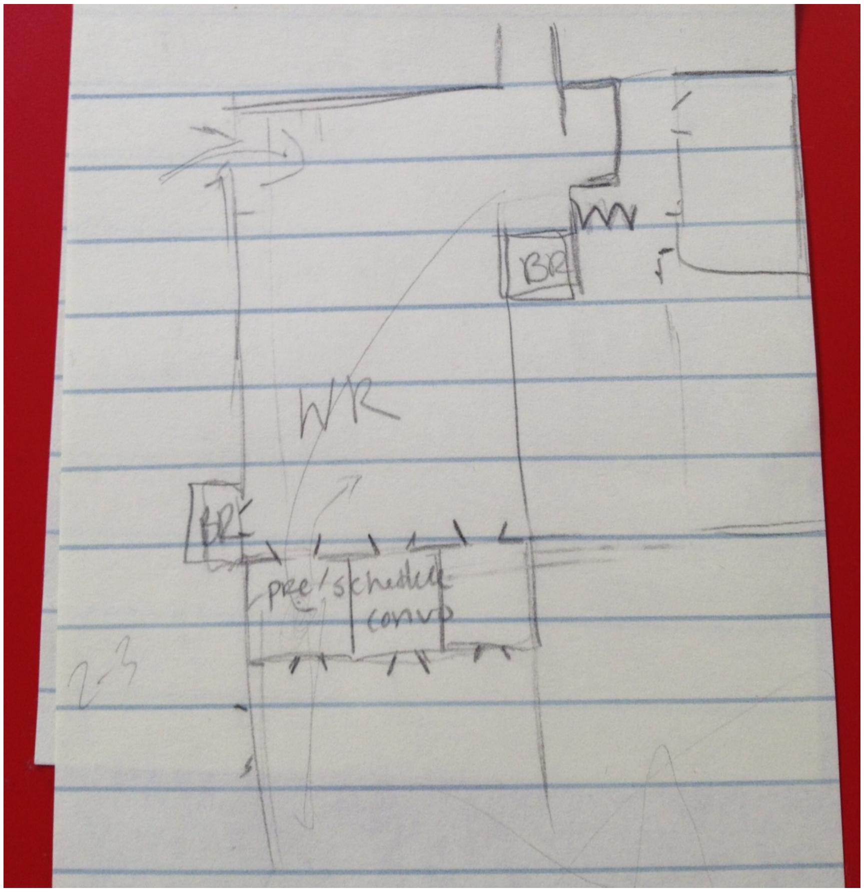


Figure 41. Waiting room with 3 intermediate cubicle rooms

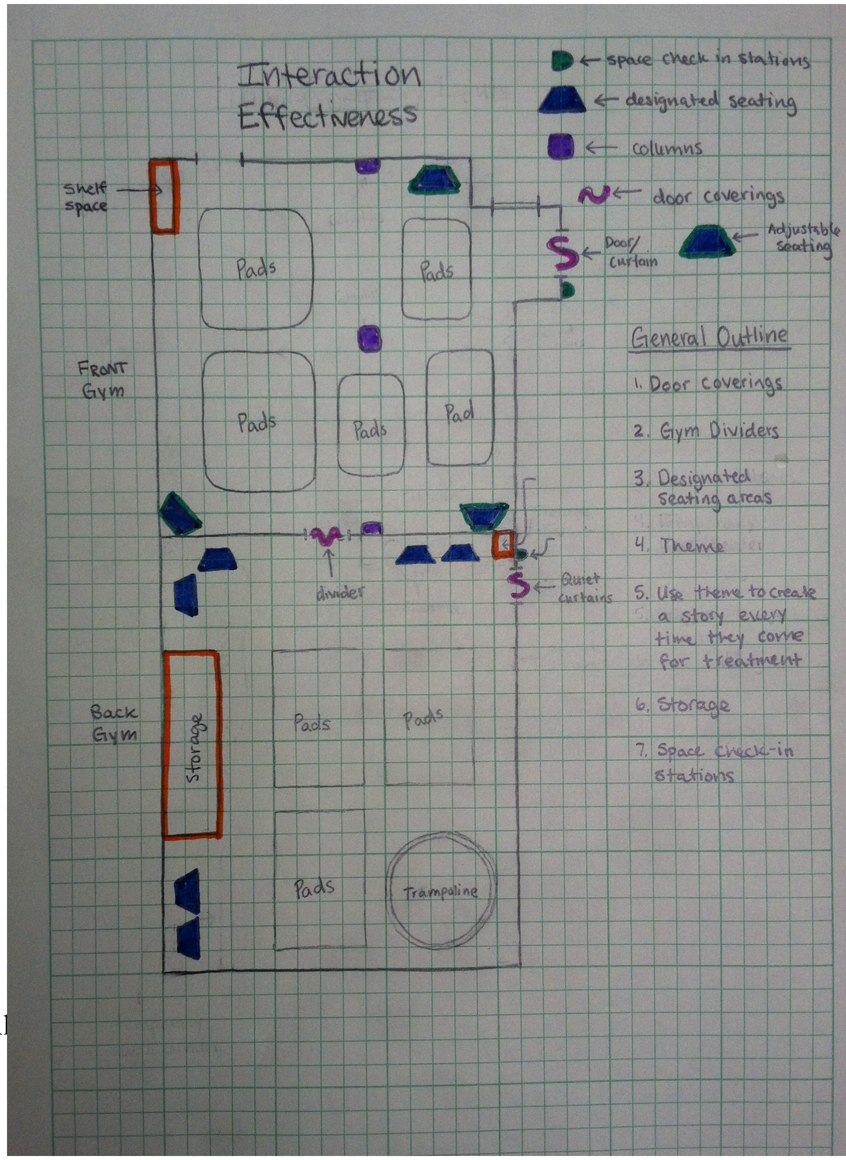


Figure 42. Al ffectiveness

APPENDIX C – Design process

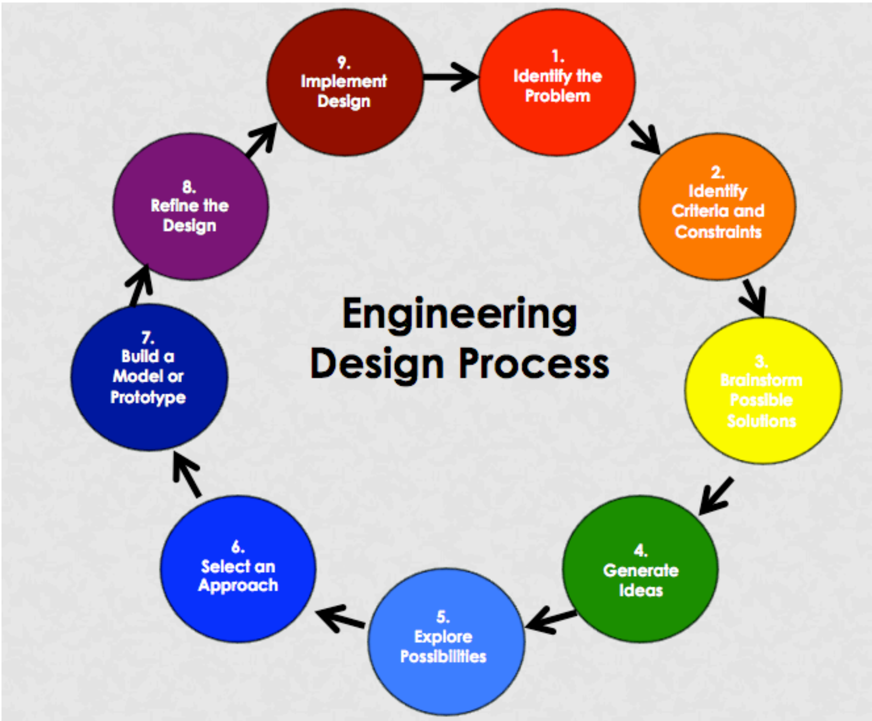


Figure 43. The engineering design process followed.

Figure 44. Sticky notes used throughout brainstorming.

APPENDIX D – Soundproofing materials

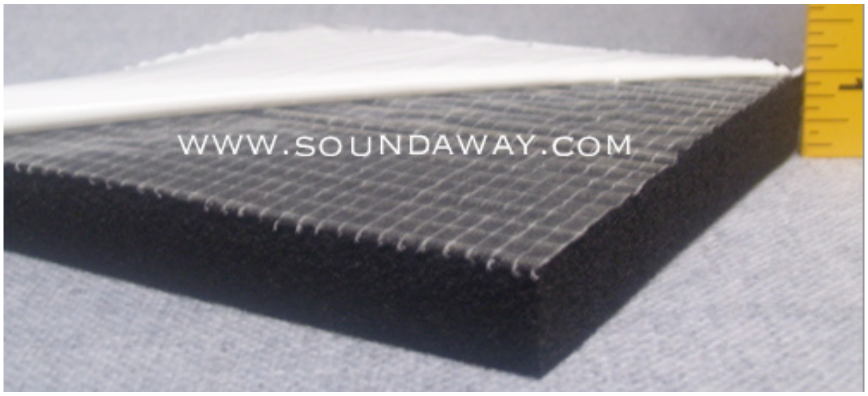
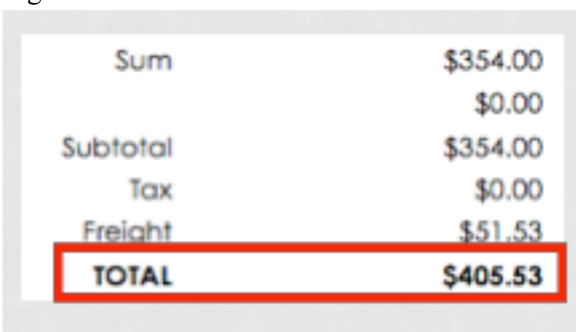


Figure 45. The closed cell foam offered from Sound Away



Sum	$354.00
	$0.00
Subtotal	$354.00
Tax	$0.00
Freight	$51.53
TOTAL	**$405.53**

Figure 46. The quote given by Bill Hagemann from SoundAway to purchase MLV and foam

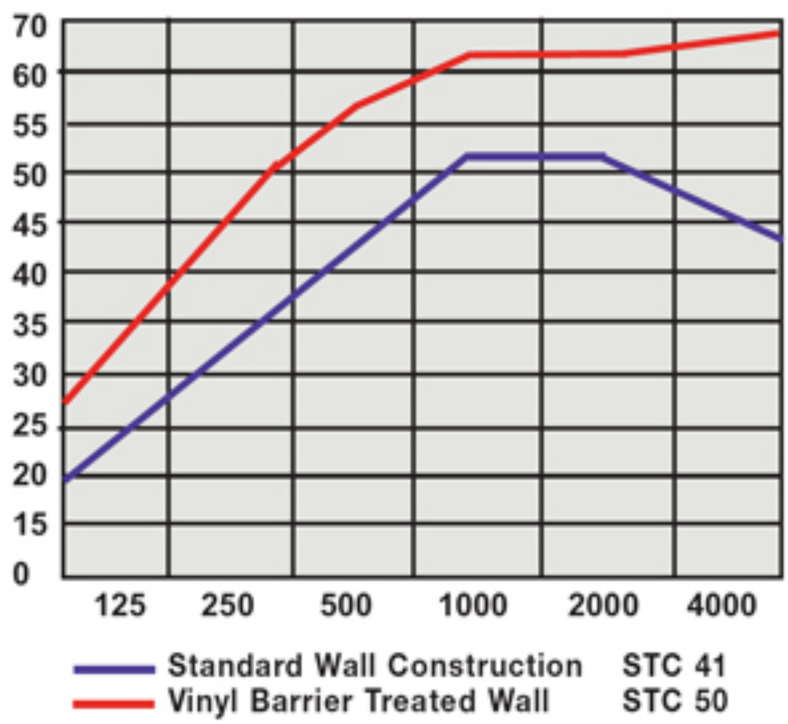


Figure 47. Results for decibel loss after treating a wall with mass-loaded vinyl

APPENDIX E – Prototypes

Figure 48

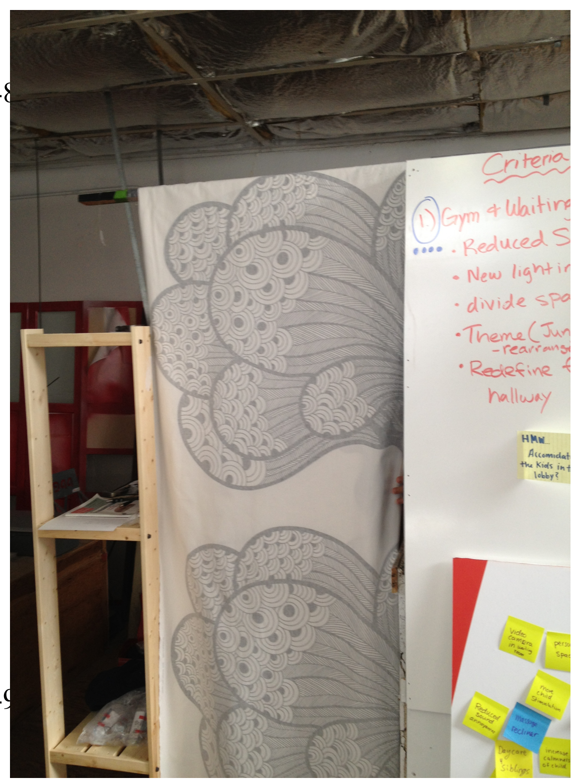


Figure 49

Figure 50. Prototype of the PVC door design

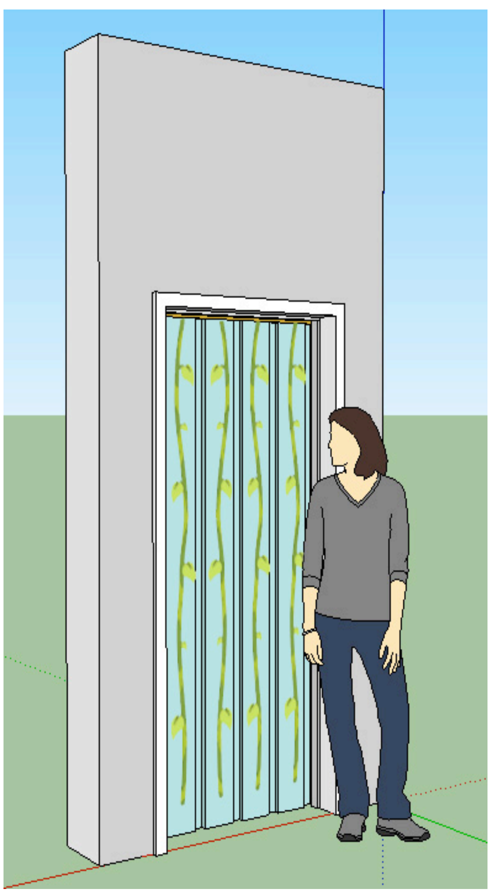


Figure 51. Proposed design for door with vine design

APPENDIX F – Sound Sensor Pictures

Figure 52. The speaker that had to be used due to the unavailability of the appropriate hardware.

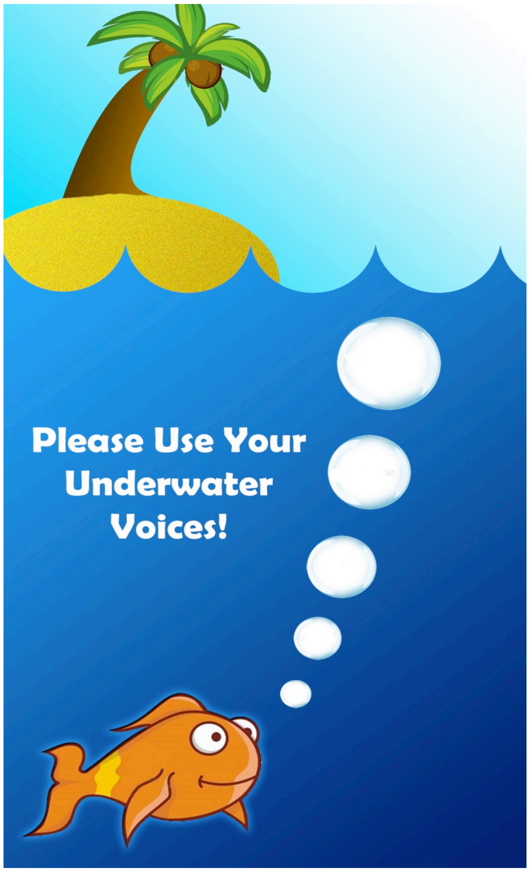


Figure 53. The design used on the faceplate of the sound sensor.

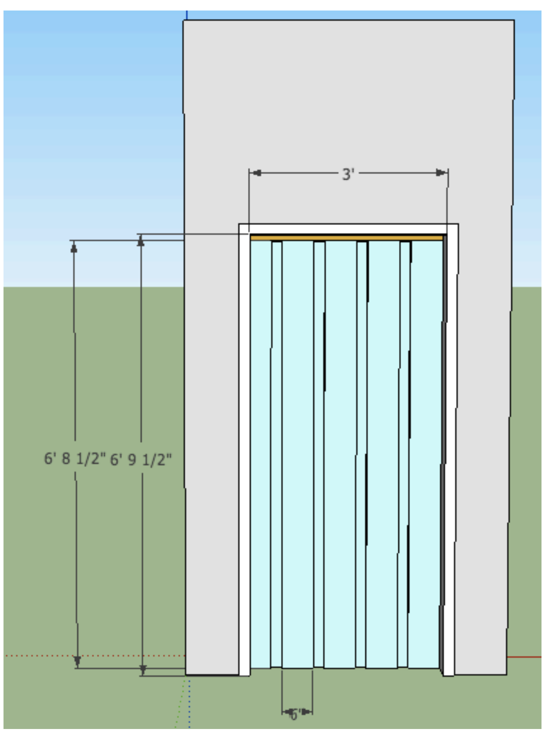
APPENDIX G – Bill of Materials

Bill of Mateirals					
Item	**Supplier**	**Product Number**	**Quantity**	**Cost**	**Total**
220Poly Closed Cell Foam	Grainger	5GDK3	3	$25.35	$76.05
TMI Vinyl Strip Roll, 150 ft	Grainger	6GJH4	1	$102.40	$102.40
TMI Vinyl Strip Roll, 300 ft	Grainger	6GJH5	1	$205.50	$205.50
SoundAway Barrier MLV	Sound Away	11001	3	$33.00	$99.00
Mr. Fish Viyll Sign	Budget Signs	2370	1	$49.00	$49.00
1/4"x100' DB POLY RPE CRTE	LOWE'S	349241	1	$8.48	$8.48
8 X 1 1/4 PH FL HD STL	LOWE'S	3373	1	$5.58	$5.58

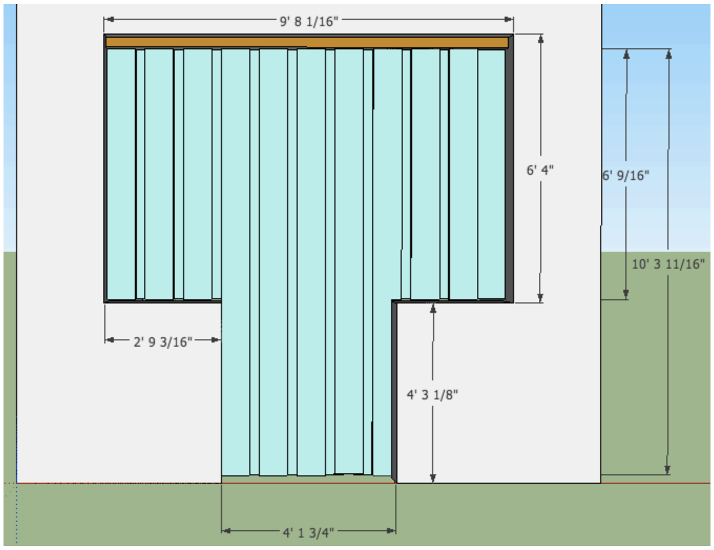
W/S					
1x4x8 Premium Furring STR	LOWE'S	4510	1	$3.22	$3.22
1/4 2x4 Birch	LOWE'S	6197	1	$7.94	$7.94
1/2 2x4 Birch	LOWE'S	6200	1	$13.67	$13.67
Flat Washers	LOWE'S	63306	10	$0.11	$1.10
Hex Nuts	LOWE'S	63301	5	$0.06	$0.30
Arduino Uno Rev 3	Radio Shack	276-128	1	$34.99	$34.99
Breadboard	Radio Shack	BRD	1	$19.50	$19.50
15x3mm LED	Super Bright LEDs	7261	1	$10.20	$10.20
HM 1/4 - 20x1 1/2 Hex B	LOWE'S	63312	5	$0.17	$0.85
				Total	**$637.78**

APPENDIX H – Door Design Dimensions and Calculations

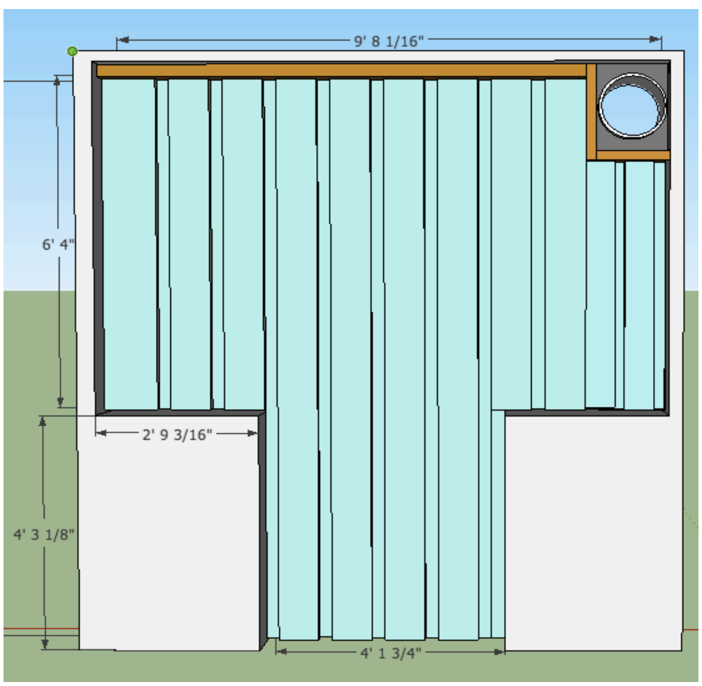
Front Gym Door Dimensions



Doorway Between Two Gyms Dimensions



Back Gym Door Dimensions



Mounting Brackets Load Calculations

$$Load\ per\ Unit = \frac{55lbs}{300ft} = \frac{0.1833lbs}{ft}$$

Front Gym Door:

81" in length
Nine 6" wide strips of transparent PVC

$$81.0"/12' = 6.75'$$

$$\textbf{Total Load} = (\mathbf{6.75'})\mathbf{x}(\mathbf{9})\mathbf{x}(\mathbf{0.1833}) = \mathbf{11.135\ lbs}$$

Gym Divider Door

Door Covering
8' in length
Nine 6" wide strips of transparent PVC

$Load = (8.0')x(9)x(0.1833) = 13.1976\ lbs$

Two Side Area Coverings
Length = 55"/12' = 4.583'
Six 6" wide strips of transparent PVC

$Load = (4.583')x(6)x(2)x(0.1833) = 10.081\ lbs$

$$\textbf{Total Load} = \mathbf{13.1976 + 10.081 = 23.2786\ lbs}$$

Back Gym Door:

Door Covering
9.42' in length
Nine 6" wide strips of transparent PVC

$Load = (9.42')x(9)x(0.1833) = 15.535\ lbs$

First Side Area Covering
6.33' in length
Six 6" wide strips of transparent PVC

$Load = (6.33')x(96)x(0.1833) = 6.9617\ lbs$

Second Side Area Covering
4.83' in length
Six 6" wide strips of transparent PVC

$Load = (4.83')x(6)x(0.1833) = 5.3157\ lbs$

$$\textbf{Total Load} = \mathbf{15.535 + 6.9617 + 5.3157 = 27.81\ lbs}$$

APPENDIX I – Arduino Code

```
int LED1 = 13;
int LED2 = 12;
int LED3 = 11;
int LED4 = 10;
int LED5 = 9;
int time = 500;

void setup() {

  pinMode(LED1, INPUT);
  pinMode(LED2, INPUT);
  pinMode(LED3, INPUT);
  pinMode(LED4, INPUT);
  pinMode(LED5, INPUT);
}
void loop() {
  {
    digitalWrite(LED1, HIGH);
    digitalWrite(LED2, LOW);
    digitalWrite(LED3, LOW);
    digitalWrite(LED4, LOW);
    digitalWrite(LED5, LOW);
    delay(time);
  }
  {
```

```
  digitalWrite(LED1, HIGH);
  digitalWrite(LED2, HIGH);
  digitalWrite(LED3, LOW);
  digitalWrite(LED4, LOW);
  digitalWrite(LED5, LOW);
  delay(time);
}
{
  digitalWrite(LED1, HIGH);
  digitalWrite(LED2, HIGH);
  digitalWrite(LED3, HIGH);
  digitalWrite(LED4, LOW);
  digitalWrite(LED5, LOW);
  delay(time);
}
{
  digitalWrite(LED1, HIGH);
  digitalWrite(LED2, HIGH);
  digitalWrite(LED3, HIGH);
  digitalWrite(LED4, HIGH);
  digitalWrite(LED5, LOW);
  delay(time);
}
{
  digitalWrite(LED1, HIGH);
  digitalWrite(LED2, HIGH);
  digitalWrite(LED3, HIGH);
  digitalWrite(LED4, HIGH);
  digitalWrite(LED5, HIGH);
  delay(time);
}
{
  digitalWrite(LED1, HIGH);
  digitalWrite(LED2, HIGH);
  digitalWrite(LED3, HIGH);
  digitalWrite(LED4, HIGH);
  digitalWrite(LED5, LOW);
  delay(time);
}
{
  digitalWrite(LED1, HIGH);
  digitalWrite(LED2, HIGH);
  digitalWrite(LED3, HIGH);
  digitalWrite(LED4, LOW);
  digitalWrite(LED5, LOW);
  delay(time);
}
{
  digitalWrite(LED1, HIGH);
  digitalWrite(LED2, HIGH);
  digitalWrite(LED3, LOW);
```

```
    digitalWrite(LED4, LOW);
    digitalWrite(LED5, LOW);
    delay(time);
  }
  {
    digitalWrite(LED1, HIGH);
    digitalWrite(LED2, LOW);
    digitalWrite(LED3, LOW);
    digitalWrite(LED4, LOW);
    digitalWrite(LED5, LOW);
    delay(time);
  }
}
```

Pseudo Code

```
float currentValue = 0.0

While serial >= 0.0

        if (currentValue < a)

                first light on

        else if (currentValue > a && currentValue < b)

                first light on

                second light on

        else if (currentValue > b && currentValue < c)

                first light on

                second light on

                third light on

        else if (currentValue > c && currentValue < d)

                first light on

                second light on

                third light on

                fourth light on

        else if (currentValue > d)

                first light on
```

```
        second light on
        third light on
        fourth light on
        fifth light on
record on
delay(500)
record off
play on
currentValue = serial
if (currentValue < a)
        first light on
else if (currentValue > a && currentValue < b)
        first light on
        second light on
else if (currentValue > b && currentValue < c)
        first light on
        second light on
        third light on
else if (currentValue > c && currentValue < d)
        first light on
        second light on
        third light on
        fourth light on
else if (currentValue > d)
        first light on
```

second light on

third light on

fourth light on

fifth light on

play off