Designing for Tranquility, Exploring the Cognitive Impact of Architectural Design

A Major Qualifying Project

Submitted to the Faculty of

Worcester Polytechnic Institute

In partial fulfillment of the of the requirements for the Bachelor of Science in Architectural Engineering and Computer Science

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Abstract:

This project developed a GUI in python to operate the Personal Emotional Augmented Controlled Environment or PEACE room designed in previous MQPs, as well as designed and performed experiments using the room. The PEACE room utilized an EEG, an O2 Ring, a webcam, and the Positive And Negative Affect Schedule (PANAS) survey to measure how different configurations of space, sound, and light affects stress levels. The results from these experiments were then used to create a design concept for "Heaven's Cloud", a mixed use eight story building consisting of retail, residential, and office spaces.

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Acknowledgments:

Capstone Design Statement:

The goal of this Major Qualifying Project was to continue the work of last year's MQP group and fully utilize the Personal Emotional Augmented Controlled Environment, or PEACE room that they developed. This project delivered Python code that can control the room remotely from the desktop outside, an experimental method on how to test different room settings on participants, how to collect and analyze the data collected from the O2 Ring device and EEG device, and an architectural plan for a potential 8 story multi use building that utilizes the PEACE room. To complete this project, the four basic architectural engineering disciplines were integrated through the design and application of structural, mechanical, and electrical building systems and construction elements.

This project demonstrates the fulfillment of design requirements set forth by the Accreditation Board for Engineering and Technology (ABET). The team of three architectural engineering majors and the one computer science major drew upon knowledge from prior courses and project experiences, as well as the skills and information gathered throughout the timeline of this MQP, in order to demonstrate proficiency across all architectural engineering curriculum areas. Collaboration among team members ensured that the project delivered satisfied set expectations.

Architectural Design

Architectural design was utilized to create a proposed 8 story multi use building that incorporates the PEACE room into its design. A model was created in Sketchup and floor plans were drawn in AutoCAD. Lastly a structural system was developed for the building that can withstand theoretical loads.

Computer Science

Computer science was utilized to create the interface that was used to control the PEACE room, as well as streamline the data collection process. First python was used to create the page for gathering information about participants, as well as allowing them to fill out the PANAS survey. Next the interface for controlling the room was constructed. This involved developing code to control the motors in the walls, adding presets to allow for easy wall configurations, adding buttons for collecting data, and allowing for sound to be played in the room using the interface.

Project Organization, Planning, & Communication

To ensure the success of the project, we researched similar experiments and reviewed the previous MQP groups research and development. We then designed an experiment that utilizes the O2 Ring and EEG, and started gathering participants to collect data. To meet the ABET design requirement, we considered the systems or processes from other architectural engineering

curricular areas, worked within the overall architectural design, communicated and collaborated with other design or computer science team members.

Marketability

In the future, the space can be further refined to streamline installation and could possibly be reproduced and marketed.

Licensure Statement:

Architectural engineering licensure is the next step in advancing an architectural engineer's credibility and career. Two licensure exams are needed, the Fundamentals of Engineering (FE) exam and the Principles of Engineering (PE) exam. To get the PE exam, one must have completed the FE exam and have worked 4 years under a credible engineering firm. Licensure benefits both the engineer and the profession. It promotes public safety, ensures code standard building will be signed off on and it improves consistency within the industry.

Executive Summary:

Stress in today's world can sometimes feel inescapable. Our lives are very complicated and filled with many things that can cause us stress. School, work, family life, etc. Our ways of relieving stress vary with each person, but what if there was a way to use room design to cause less stress. More specifically, can we use different room design aspects to relieve the stress of whoever sits in it.

There have been many different experiments whose goal is to find out if certain room stimuli can affect a person's stress levels. These stimuli include wall color, room size, and room sound. Many of these experiments only test one aspect instead of multiple. This experiment will instead use multiple stimuli at once to determine which combination is the most effective in reducing stress levels.

In order to perform the experiment, the Personal Emotional Augmented Controlled Environment or PEACE room will be utilized. The PEACE room is a space that can change its size, color and play any sound necessary. In order to test stress levels in a person while they are in the room, 3 measuring devices were used. A portable EEG to test brainwaves, a mounted camera to record movement, and an O2 ring that tests the person's heart rate. The experiment also utilizes the Positive and Negative Affect Schedule or PANAS test to record a person's emotions before and after the experiment as well as a questionnaire to receive more specific feedback on each of the rooms settings.

When taking a look at the PANAS results, participants felt less stressed and felt more positive emotions when they finished the tests compared to when they started it. When filling out the questionnaire, participants felt that the blue color, the rain sound and the large room settings were the most relaxing. The results from the o2 ring also indicated that the large, blue room also had the greatest impact in decreasing stress through comparing heart rates before and after the tests. The eeg data that was gathered needed to be discarded as there was too much interference resulting in the data becoming skewed.

While there was a lot of data gathered, the most useful knowledge gained from these experiments is how to run them properly. This MQP was more of a testing phase rather than full on data gathering. Improvements are already being made, like the use of a better camera, a new voice test, a watch that tests skin temperature and a new EEG headset are going to be used in the future. Different room setting combinations are also being tested. The experiments conducted in 2023-2024 will lay the groundwork for how experiments should be performed in the future and how the experiments can be expanded upon.

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1. Background

1.1 Motivation for The Project:

       As time progresses, mental health has become an increasingly important concern for humanity. Emerging theories propose that room design might contribute to stress reduction, encompassing factors such as lighting, color, size, and layout.

       Given how our school, Worcester Polytechnic Institute, likes to focus on addressing student's mental health, students thought it would be beneficial to look into this theory and try to see if the Built Environment plays a role in reducing stress levels. This particular project is continuing the work of previous students, who designed and built a room that can be manipulated at any time. The space is called the Personal Emotional Augmented Controlled Environment (PEACE Room). Through this, different room settings were tested on selected participants to test for stress level reduction.

1.2 Overview of Recent Studies of Neuroarchitecture:

       We experience five primary senses daily: sight, touch, taste, hearing, and smell. It's essential for each of these senses to feel comfortable to prevent strain.. There is only so much our eyes can see, our nose can smell, our tongue can taste, our skin can touch, and our ears can hear. Would you like to hear nails scratching on a chalkboard? Or do you want the smell of the dumpster invading your occupying space? Of course not - it's already a given that the typical human being wants nothing negative ruining the space they're occupying.

       Three of these five senses will be used to study human reaction to the built environment: sight, touch, and hearing. The factors that play into these senses include: the lighting used in this space, the size of the space, and the sounds that occur in this space. In every occupied space, lighting fixtures will always exist with the addition of windows to offer vision of the environment. In terms of touch, the size of the space will heavily determine whether or not the occupant feels comfortable. Do they feel comfort with a confined space in which they are able to touch the walls or the ceilings? Or do they want to feel the openness that allows them to move freely. In terms of sounds, noise will always exist whether it's indoors from other occupants or mechanical systems or from outdoors with the elements of weather or living organisms.

1.2.1 Lighting Overview

       The lighting and color of a room may not seem that important but studies have shown that they do seem to have an affect on human emotions and behaviors. The PEACE Room has about 6 LED's that can be manipulated at will. This allows us to change the brightness as well as the color of the lights. Because the LED's are so numerous and the walls by default are white, we can essentially change the room color to whatever we please. By going off of previous studies, we decided to examine two extremes when it comes to light. The color's we chose are red and

blue. Red appears to not have many positive effects on stress levels while blue light does. We would like to test whether or not this is true.

1.2.2 Space Overview

       Space is an important aspect when it comes to human comfort in the built environment. The main question that needs to be asked for an occupant is how big of a space do they need to do their task? The qualities of the room explored include changing the heights and widths of the ceilings and walls respectively. Is there a difference in productivity or comfort when it comes to a small, closed-in room or a large, pushed-out room? It would make sense for someone to have access to the openness as to not feel closed-in or claustrophobic. The emotion that evokes someone to feel like they have a vast amount of space can't be put to words. What purpose would an occupant have to need an amount of space? Or rather the free-will.

1.2.3 Sound Overview

       Steering away from the general white and pink noise planned from the previous experiment, there has been a shift to incorporate more specific sounds from nature. Recalling from the introductory paragraph, a lot of sound elements that come into the built environment come from the occupants themselves, the mechanical systems running throughout the building, the animal noises, or the spattering rain. For this experiment, the PEACE room will be small and comfortable enough to fit one person so the sounds will be skewed more towards the outdoor environment. According to Buxton et. al, soundscapes are an assortment of noises in an environment that can be categorized as biological (from animals), geophysical (from weather), and anthropogenic (man-made). Some of these soundscapes sources in question used for this project include splattering rain, running waterfall, rushing river, ocean waves, and birds chirping. With these sound choices made and data collected from participant reactions to them, this will segue into certain design choices by bringing these sounds to life.

       Substantial research was put into proving if these design incorporations exist and work effectively. The design question that needs to be answered is if the occupants feel a sense of comfort from this incorporation? Will this design incorporation prove to be sustainable in the long run? Are there intersecting concepts of reuse to preserve resources? The contributions that will help solidify the design will be using data from experiments that detail the reactions and behaviors from participants to certain room settings - which are inspired from previous experiment runs or real-world occurrences.

1.3 Lighting: Color Analysis, How Does Lighting Color Impact an Occupant's Behavior:

       Lighting plays an important role in everyone's life. Every room you enter, there are lights. There are lights outside, lights in cars, light from your phone, there is light everywhere. Do we ever think about how this light affects us? While the idea is still being explored by

scientists, light and especially colored lighting does seem to have some effect on human emotions (Minguillon, et al, 2017).

Studies have shown that pale short-wavelength colors like blue, violet, and green can cause increased relaxation and decrease people's heart rate (Minguillon, et al). In a preliminary study conducted by Jesus Minguillon and his fellow theorists, they tested how blue-lighting can affect post-stress relaxation. They used bio-signals such as EEG or ECG to test how people respond to blue-lighting. They used the Montreal Imaging Stress Task (MIST) to put participants under stress then placed them in a blue chromotherapy room and tested to see how they're stress levels were affected. They also had a control group that went into a plain white room instead (Minguillon, et al, 2017).

The results of the experiment proved that blue light did have a greater effect in reducing stress levels.
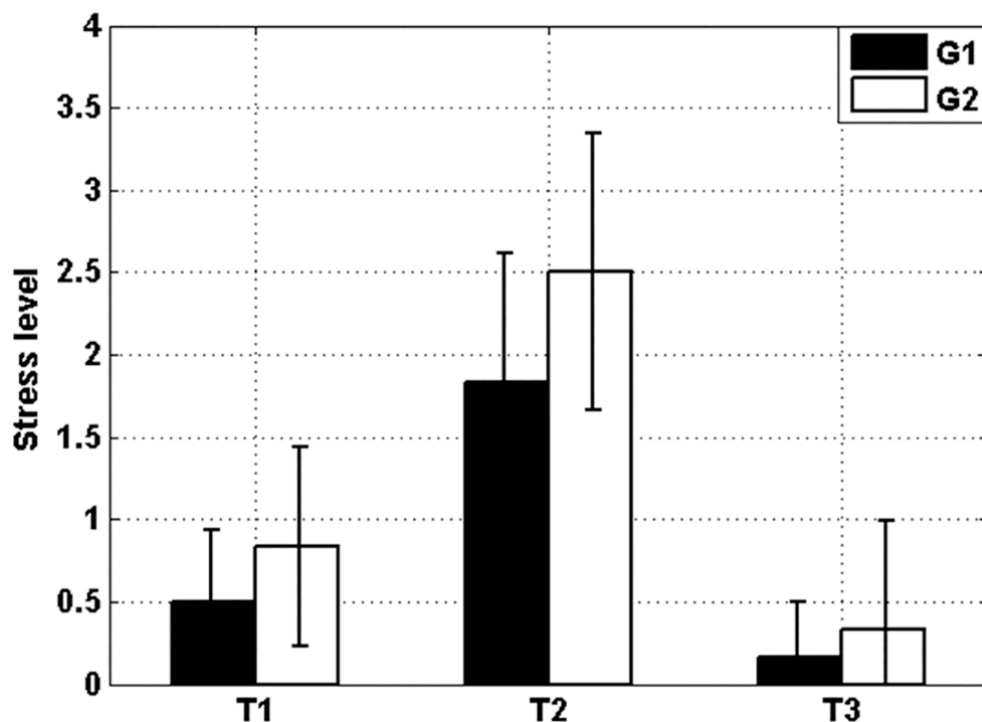
Figure 1: Mean (bars) and SEM (errorbars) of the subjective self-perceived stress level: G1 (black) and G2 (white). At each time (T1, T2 and T3) there was no significant inter-group difference. The intra-group analysis reveals significant differences of subjective stress level T1-T2 and T2-T3 for both groups. The latter proves that both the stress and relaxation sessions were satisfactory completed. (Description taken from "Blue lighting accelerates post-stress relaxation: Results of a preliminary study" article).

G1 was the group exposed to blue light. The chart shows that the G1 group experienced less stress compared to the G2 group who had to relax in the white room. While this is just one experiment it shows evidence that lighting, specifically blue-lighting, has an effect on human stress-levels.

1.4 Space: What Does Openness Evoke in the Occupant:

When one thinks about a comfortable place, is it usually associated with a vast amount or a tight amount of space? It's quite easy for someone to admit that they're claustrophobic, some taking it worse than others. What exactly is it that causes someone to feel claustrophobic? The lack of air, the lack of movement, the lack of openness and freedom. In a study conducted by Llorenz-Gamez et. al, the team investigated the impacts of design for learning spaces on the human mind through color and scale. In terms of spacing, there was a huge negative reaction when the ceilings were lowered and closed in. With their word verbatim, the lower ceilings made them feel "confined" but the higher ceilings gave "that sensation of freedom" (Llorenz-Gamez, et al, 2021). When associating a learning space, it's most evidently a classroom type that needs to fit at least 20 people. Imagine if there was a room with closed ceilings and walls, there wouldn't be enough space to fit many desks or tables, so everyone would be crammed together. This is a total nightmare for introverts and germaphobes alike, but those associations aside, it truly does not give the occupants the ability to move around or sit comfortably as they wish. They are restricted to the minimal space they have and need to share with their peers.

1.4.1 Home Sizes Increase as the Sign of the Times:

A study conducted in New Zealand found that each year since the 1980s, the floor area of houses have increased. The statistics showed that every ten years the square footage increased by over 20 m^2, with the years between '84 and '94 showing the largest amount of 41 m^2. The trend that Khajehzadeh and Vale found was that many homeowners felt the need to increase the amount of bedrooms, bathrooms, and miscellaneous rooms devoted to certain hobbies [most notably the games' room] (Khajehzadeh & Vale, 2017). To see this ever increasing rate of square footage makes sense, many couples start large families which constitute the need for additional bedrooms and bathrooms which make up a large amount of area. Khajehzadeh and Vale noted that the games' room was starting to popularize as well - where this serves as a hub for video games, board games, or other sorts such as pool or air-hockey. Similarly yet oppositely, the post-COVID times have also introduced more accessible remote work and learning so some people might find that an office must be included as well on top of the added bedrooms and bathrooms, along with the existing necessities such as a kitchen and living room. It's interesting to view this through a residential architect's point-of-view who constructs the design but also the client who shares their desires within the shape of the design. What does openness evoke within the space of these types of homes? The largeness of a home allows for its occupants to enjoy an assortment of rooms devoted to certain purposes: sleep, entertainment, dining, productivity, and grooming (in the cleanliness sense). Similarly on a smaller scale, the PEACE room at its peak potential can see largeness and openness as a sense to allow for the occupants to move freely and not feel closed in or limited.

1.5 Sound: Natural Sounds Familiar to the Human Ear:

In the overview, the sounds highlighted include splattering rain, running waterfall, rushing river, ocean waves, and birds chirping. Most of these sounds occur in our various biomes on Earth. These sounds also occur outdoors, so it may seem odd to bring them into the indoor environment. The sounds listed despite being commonly outdoors have the potential to improve the built environment's acoustical comfort. Looking further into the context of these specific sounds, previous studies must display how humans react to the assortment of soundscapes to help better predict this experiment and solidify hypotheses.

1.5.1 Biophilia: The Human Relationship With the Ecosystem/Environment:

Biophilia is the love that humans have for life. In his article about incorporating nature into the built environment, Browning implies that biophilia is the human need for the physical and mental connection to life's surroundings which help improve productivity, emotion, and wellness (Browning, 2015). Browning goes on to highlight many examples of biophilia being present, one example cited from Park et. al, detailing how studies in Japan show that taking walks through forest like areas helps improve moods and lowers stress and heart rate. Browning also goes on to briefly introduce the Attention Restorative Theory which is the theory in which nature provides the platform to manage stress, promote healthy living, and lower disease contraction (Browning, 2015). As a forewarning, it should be known that not every participant will be a biophiliac, in fact some might even hate nature. Instead of going into these experiments with the idea that the participant is a biophiliac, it's important to note which ones grow to love the natural aspect and those that oppose it. Biophilia also shows the potential in which humans can relate or react to nature since it can occur throughout the daily life cycle. People's senses are constantly in contact with nature - the breeze against our skin, birds chirping, or the aromas of flowers wifting in the air. What are some of the ways in which this experiment can incorporate biophilic design into the PEACE room?

1.5.2 Testing the Effectiveness of Bird Sounds in Urban Cities:

A study conducted by Hedbloom et. al documented a soundscape study in an urban setting. There are various factors that were taken into account such as the age and gender of the participants and this was used to further draw conclusions. The argument in question was that most Euro-urban areas have constant noises from construction or traffic that disrupt city life: raising stress levels and messing up sleep patterns (Hedbloom et. al, 2017). In this study, there was a prevalent bird motif in the sounds being played. This motif helped them further develop and prove the "heard biodiversity" hypothesis in which higher rates of bird song increase the symbiosis of natural sound in the urban setting (Hedbloom et. Al,2017). The most evident point to note is that bird song (or chirping) in the urban setting proves to be an effective soundscape as it helps sound out the disturbing traffic or construction that cannot be controlled. In addition to this discovery, it highlights the effectiveness of combating negative noise with positive noise - in which both don't overpower each other nor do they intersect and cause further disruption. To

further the impacts it had on gender, women were more influenced and swayed by bird song than men. In terms of age, older ages saw more effectiveness in the various bird songs. The relevance of age and gender in this study helped the investigators draw conclusions that older people had more experience due to age in an urban setting and were then able to feel that the calmness in the birdsong was needed to make their living conditions better (Hedbloom et. al, 2017). In this current PEACE room experiment, gender and age aren't the factors at the center of focus. But with the effectiveness that all groups were able to experience, the bird sounds prove to be a good soundscape to test. With the data collected, comparisons can be drawn between the PEACE room and an urban building - whether or not they both face similarities and to further draw conclusions of the sound's impact.

1.5.3 Effectiveness of Natural Sounds in National Parks:

Another study conducted by Buxton et. al synthesized the effectiveness of natural sounds in national parks. Though this study was conducted for national parks and not so much the built environment, it's still important to note what sounds were used and how people reacted to them. The main purpose of this study was to analyze the health benefits that natural sounds offer to the park visitors. The results indicated that these soundscapes were able to improve moods and lower stress and annoyance to the visitors which in turn lowered heart rate and blood pressure (Buxton et. al, 2021). The soundscapes used in this experiment were between natural and urban sounds. The results expected a 52% increase in groups that were exposed to calmer natural sound while a 48% decrease due to groups being exposed to the noisier urban sounds. The results also showed that when one participant was exposed to both natural and urban sounds, there was an overall improvement in mood of 184% when going from urban sounds to natural sounds (Buxton et. al, 2021). With this existing study, the use of natural sounds further proves to be effective and can therefore be a central focus in the PEACE room experiment. To dig deeper into the natural sounds used, this study included the use of water, birds, and a mix of both. The results showed that water sounds were skewed in favor compared to the bird sounds - which gave more annoyance and stress to the participant. Regardless of these two extremes, the investigators were able to conclude that natural sounds evoked a sense of safety from the calmness and simplicity of the sounds that is contrary to the likes of the urban setting. This study of natural sounds helped further support the testing of bird sounds and now add water sounds into the mix.

1.6 Design Concept: Case Studies of Interest for Inspiration:

For this project, a design concept must be completed to begin the assimilation of this PEACE room concept into an everyday living space - whether that be in the classroom or the office, or even living spaces such as apartments or homes. Some case studies were found to help direct the design direction of this updated "PEACE" room that incorporates elements of the outdoor environment into the built environment.

1.6.1 Jewel Changi Airport, Singapore: Rain Vortex Waterfall:

A particular design of interest was the indoor waterfall. Many of the soundscapes used in this experiment have water motifs - one of them being quite literally a running waterfall. The design will evidently be subject to change based on the experiment results but it's still important to note if there are any existing incorporations of the indoor waterfall and how effective it is in the built environment. An example of a recognized indoor waterfall is an airport that was built in Shanghai called the *Jewel Changi Airport*. What makes this indoor waterfall renown is that the water flowing through is rainwater reuse, this same rainwater is used to function other services in the building as well. The waterfall itself also serves as a passive cooling system which in turn preserves HVAC use in the summer (Safdie 2019). The multipurpose use for this waterfall system is efficient in many ways: improving building aesthetics, practicing sustainable living through water reuse, and providing indoor environmental quality comfort. In another article from Dezeen, India Block further describes the climate situation of Singapore and how the airport is able to retrieve the rainwater. Built with a roof dome, the retrieval of rainwater falls through an oculus and flows for seven stories. The reason why this system is also efficient is because Singapore experiences frequent thunderstorms due to its tropical climate, so the water is able to flow through at a rate of 10,000 gpm (Block 2019). Though the design concept won't be as specific and detailed with thorough consideration of climate and sustainability, nor would it be on a similarly large scale, taking inspiration from the Jewel Changi airport can help formulate what an indoor waterfall could look like for a PEACE room variant to bring the soundscapes to life.

1.6.2 Ecological Architecture: Indoor Bird Sanctuary:

In their research of Van der Laan's study of ecological architecture, Gonzales-Diaz and Garcia-Navarro recounts nature inspired within architecture in the Stonehenge temples and the Baroque, both buildings in which their respective architects redefined architectural bounds (Gonzales-Diaz et. al, 2016). To add a twist into the upgraded PEACE room, an animal ecosystem would further the inspirations of nature in architecture. Many spaces in the built environment have begun to allow dogs or service pets alike to enter them. These service pets provide protection for those who suffer from severe anxiety or depression, while also providing passerbys the opportunity to pet and play with them as well. Overall, there is an increase in mood when animals come in to play in terms of presence. The same can be said for other animals that can be seen outside in parks or neighborhoods - such as birds, squirrels, chipmunks, and rabbits, all of which are small, harmless critters on the same level of domestic pets. A study conducted in England showed that a majority of bird species such as thrushes that disappeared in farmlands have begun to thrive and adapt to the urban setting like their human counterparts (Mason, 2006). With these bird species essentially losing their habitats to urbanization, it would be fitting to allow these built environments to have a space that allows them to co-exist as well. But how does the incorporation of a symbiotic ecosystem fit into this design narrative based off of the PEACE room? To recall from the previous section about soundscapes, bird song is a factor that can bring

comfort to humans in the built environment. The reactions that want to be tested are if the participants can react positively to the sounds of birds chirping - and translating that into a design that allows birds to enter the premises unscathed and find a comfortable landing.

1.6.3 Santiago Calatrava: Blending Artistry With Engineering:

Santiago Calatrava is a world-renowned architect who studied architecture and structural engineering at the Polytechnic University of Valencia and Federal Institute of Technology in Zurich. He is most well known for his ability to combine elements of artistry and engineering for his architectural works, as seen in the iconic Quadracci Pavilion in the Milwaukee Art Museum, the Turning Torso in Sweden, and the Alamillo Bridge in Spain. Calatrava drew inspiration from nature, most notably with "interest in zoomorphic forms" Zoomorphism is defined as a representation of animal forms or gods of animal forms - such forms are common in ancient Egyptian and Hinduist imagery (Britannica, 2023). The Britannica Encyclopedia also states that the Turning Torso in Sweden represents that zoomorphic ideology. The Turning Torso is a residential building that stands 623 sq. ft. with each level being 21,500 sq. ft. The building itself is made up of 9 units with 6 of them containing 147 apartment rooms This building is also named the second highest building in all of Europe (Calatrava, 2005).
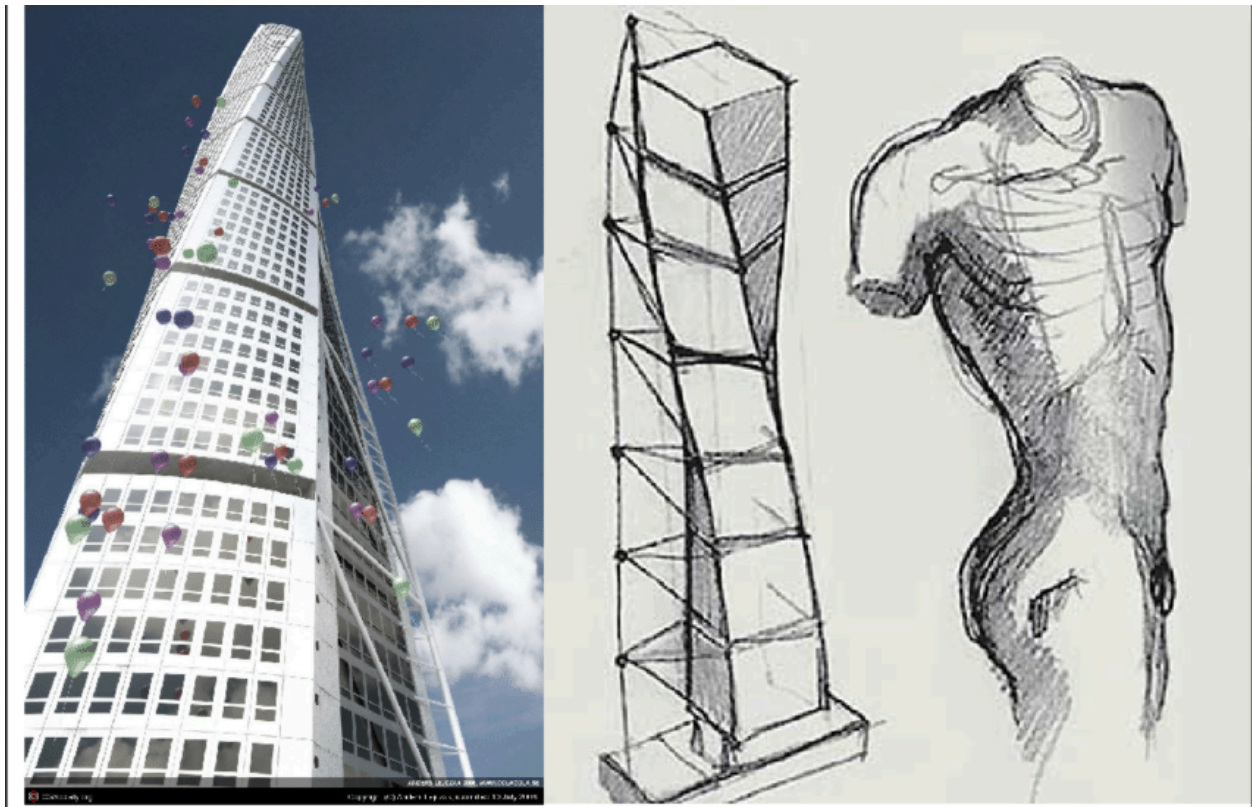
Figure 2: A reference of Calatrava's drawing inspiration process for the Turning Torso in Sweden. First by looking at the human body's capabilities of turning and then digging deeper into the anatomy and pointing out images of the spine.

Based on the image of the Turning Torso above, cross referenced with an actual human torso shows how he drew inspiration with the human body and its rhythmic movement. The use of nature and life in his inspirations proves to be not only an interesting concept but also his abilities to bring these concepts to life through his skills in engineering. In terms of the concept, drawing artistic inspiration from the human body shows that he is very unconventional in imagining his architectural forms - separating him from his brutalist predecessors of the post-WWII times. Calatrava's process first was to draw the human form and how it is able to turn, then dug deeper into the anatomy beneath to see what bone structure would peak his interest - notably the spine (Britannica, 2023). What makes the Turning Torso seem most interesting is Calatrava's ability to model the human spine as a fully functional building. Referring back to Image X, the lines on the drawing of the building most resemble a twisted spinal cord but how can a building of this caliber stand on its own without any structure on the outside interfering with the overall design? Calatrava incorporates his knowledge of structural stability by connecting the spine-like structure to a reinforced concrete core at the top of each unit; supplementary structural stability points include the elevator shafts and staircases placed in the core of the building (Calatrava, 2005). The Turning Torso is a strong concept that continued to fuel Calatrava to his peak due to his abilities to bridge engineering with his artistry. He was able to develop a residential building that looked unconventional and brought it into reality through the concept of the human spine. Calatrava was able to incorporate the concept of the human spine in the structural studies as well - the center core acts as the spine for the building similar to the function within humans. The Turning Torso is an iconic project that Santiago Calatrava created with a strong design development from the structural aspect by bringing it to reality to the artistic aspect in which it was unconventional and interesting.

Santiago Calatrava has many other famous works that were highlighted by Britannica. For instance, with the Lyon Airport Railway station, in which he used the bird's skeletal form as a basis and used its pose of spreading its wings. The design narrative in using a bird shows his inspirations and interests in zoomorphism while also using the "symbolic meaning since the station served as the end point of the route from Lyon to the airport" (Britannica, 2023). It's interesting to see how Calatrava was able to connect birds with an airport because even though airplanes fly as birds do, the passengers on the railways making their way to the airport can be symbolized as the birds preparing to take off by spreading their wings. Then once the passengers arrive at the airport and board, the plane will take off, flapping its wings towards the sky as a bird would. Drawing inspirations from Calatrava's process of relating two different entities and connecting them can help redefine an architectural form that is relative to the PEACE room and its experiments. One potential topic derived from the PEACE room is to create a built environment that allows its occupants to feel comfortable and be accessible, so the next step would be to find symbolic images of comfort to connect to and develop a form. Many architects building towards modernity have begun to reimagine buildings in unconventional forms and shapes. Although the extent of this project does not want to complicate or be on the grand schemes like famous architects such as Santiago Calatrava, it is still important for the team to

make the effort to follow in their footsteps and create a meaningful space that is visually appealing while also being functional.

1.7 Virtual Reality: Studying the Process and Effectiveness of Occupants in a Virtual Setting:

With the field of technology seeking new heights in the quality of life, virtual reality is at the forefront giving the platform to provide people a live, what-if scenario through a video screen. VR proves to be efficient in time and materials as these what-if scenarios often take time and resources to construct, costing heavily even before its final and fleshed form. VR already lowers the cost by a large amount and allows for trial and error to occur before spending on resources to develop the scenario. There are essentially no bounds to these scenarios as well, one can be given a prompt and run with it as they wish (so long as it fits to real world application). In architecture, there is already a large price in coming up with the materials and the labor time to develop a space. With the help of VR, architects are able to design the space digitally then take it and apply it through technology. In a study conducted by Bower et. al testing the impacts of the built environment on human emotion, the investigating team put participants in the VR setting and in the session morphed the room's geometry to various sizes from linear to curvature (Bower et. al). There are many other ways outside of changing the room's geometry. VR can test the color theory in which participants react to certain colors with various emotions; it can also test interior designs and furniture placements that are likable to the general public. In their study of using colorful graphics in healthcare centers, Kalantari et. al was able to use VR to make a game to test participants' eyesight against signs for direction. On top of making readable signs for direction, the healthcare center also plans to make the stoic, plain hospital space into a lively area for kid patients with various motifs such as deep sea or fairytale (Kalantari et. al, 2021). Using VR as a method of experimentation for architecture is very helpful in alleviating costs, resources, and physical labor while also being able to expand on creative solutions and alternatives that help improve the state of architecture as well. Although it's not real, it still allows for interaction and gives potential and a gauge to whether a project can go through or still seek improvement.

1.8 Research Questions:

The objective of this experiment and project is to be able to develop an idealistic architectural form that includes optimal elements that evoke comfort from the common human. In order to do so, data must be collected from experiments that test participant's reactions to the various components of the built environment. The use of this data from the participants' reaction will help to establish a common trend in desired forms of comfort and in turn help develop a creative, yet feasible, architectural building. The research questions that needed to be answered were which sounds are most effective at reducing stress in a person, what room sizes are the most effective at reducing stress in a person, what light color is the most effective at reducing stress, and how can the PEACE room be incorporated into a larger architectural form?

For this project, the expectation lies in being able to incorporate the answers to these research questions in an architectural form that helps human beings react better to the built environment while being able to enhance lifestyle and performance. Architectural spaces need to better address human comfort to carry out their life functions. It lies within the building's size, shape, and personality that ultimately shapes an occupants reaction and whether they prefer to use the space in their day-to-day lives.

2. Methodology

The two experiments used in this project were the VR Experiment and the PEACE Room Experiment. For the VR experiment, participants wore a VR headset and were tested for their emotions and reactions to a straightforward clicking game. For the PEACE Room experiment, participants were put into a room with an activity of their choosing, then tested for their emotional reactions to various room settings in 1-3 sessions. Both of the experiments had data collected through electroencephalogram (EEG). The EEG headset was used to monitor brain frequency, the O2 ring to monitor pulse rate and breathing, and a camera recording to cross-reference the participants movement or actions with the other forms of data. Once the data is collected, from the EEG's companion software, the data will be sent to written folders named after the participant. The naming convention for each participant will be known as PEACEVRx, with "x" representing the number order in which a participant goes through the experiment. The folders were named as PEACEVRx_time in which the participant took their test_date in which the test took place (i.e PEACEVR01_1100_03032024).

2.1 VR Experiment Procedure:

For the virtual reality (VR) experiment, data collection relies on the DSI Streamer software and the VIVE controller. Participants generate five files: #All and #Focus, conveying their game scores and interaction data, and three additional files—.dsi, raw.edf, and accel.csv—capturing EEG recordings and related metrics. The #All and #Focus files provide participant scores and interactions, while the DSI Streamer records EEG data in .dsi format, with associated metrics in accel.csv. Additionally, raw.edf files offer graphical representations of EEG data.

2.1.1 Equipment Setup:

The participant will be using an EEG headset and VR goggles to run through a series of tests in two different room colors. First and foremost, the cameras in the corners of the room were connected, along with the controllers fully charged and the computer laptop plugged in. The experiment started with the testers launching the testing app to make sure that the two rooms being tested (white walls, red walls) were in the correct order. Then the DSI Streamer collecting

the EEG data was opened and ensured that the headset was connected to the computer. The connectivity status was denoted by a green light that read "streaming" on the app and a collection of graphs with black lines fluctuating up and down. With the headset resting on the participant's head, it's now time to make sure that nodes are aligned. To check for node alignment, click on the "Diagnostic" box and a setup of nodes will pop up, green and yellow meaning that there is a connection, red meaning that there is no connection.

2.1.2 Game Process:

To access the game in which the participant was tested with, SteamVR and UnrealEngine was opened. The game should be taken to an empty room with a table and white board. The default color of the room should be red, and the next room after the first session was blue. Keep in mind that each session is five minutes. The objective of the game is that the participant must click whenever they see a number that isn't "3" pop up onto the white board.

2.1.3 Data Collection:

Before the participant starts the test, make sure that the DSIStreamer software is recording the EEG headset. Create a folder with the participant's name and follow the naming conventions to make sure that the data returns to that folder. Once the game is complete, click on the button with three lines on the controller to send the data all into that folder.

2.1.4: VR Experiment Conclusion:

There was a short questionnaire upon the completion of the VR experiment created by the student investigators to gather any feedback that can be done to improve the game. The series of of 8 questions were:
1. *What did you think of the game/test?*
2. *In what color room did you feel most comfortable in?*
3. *In what color room did you feel most frustrated in?*
4. *Did this test feel too long?*
5. *At any point did you feel like giving up on the game and wanted to just spam the clicking?*
6. *Was there anything distracting you? (I.E outside noise)*
7. *Would you play this game again?*
8. *Any other notes or feedback?*

The purpose of this experiment was to test the participants' reactions to the game in tandem with the room colors. Since the game was meant to evoke frustration due to the fast-pace run of each number which may overwhelm the participant's mind, it was important to note whether the red or the blue either heightened or alleviated the frustration. The overall portion of this experiment

helped fuel the research completed in the background and drew conclusions for a potential theme in the architectural design and improved the PEACE room's efficiency.

2.2 PEACE Experiment Procedure:

The PEACE experiment commences with participants completing a pre-PANAS survey, reflecting their current emotional state relative to the experiment or their personal lives. Following survey completion, participants are fitted with an EEG headset and an O2 ring on a finger. Unlike the VR setup, the PEACE EEG configuration is simpler, comprising three nodes—two on the forehead and one behind the ear. Participants are then guided into the room and instructed to engage in a 15-minute activity, either provided or personal, while experiencing different room settings

2.2.1 PANAS Survey:

PANAS (Positive and Negative Affect Schedule) is a survey used to help a person determine their emotions at varying levels at any point in their life. The use of the PANAS survey is used to monitor the participants' emotions before and after the PEACE experiment. The PANAS survey includes twenty questions - 10 of which are positive emotions and the other 10 of which are negative emotions. The participants will have 5 options ranging between very slightly, a little, moderate, a bit, extremely; very slightly is the lower levels of the emotion while extremely is higher levels of the emotion. The PANAS survey before (better known as pre-PANAS) allows participants to answer either their emotions about the room or their emotions in their lives in general. The PANAS survey after (post-PANAS) then asks for the participants to answer based on their experience of the room.

2.2.2 PEACE Room Activity:

Upon completion of the PANAS survey, the participant was escorted into the room to sit and engage in an activity of their choice. Activities provided by the testers include Lego building blocks, an adult coloring book, 500-piece puzzle, and zen garden simulation. The participants themselves were able to bring their own activities as well, these included handheld gaming consoles, crochet/knitting, reading, or simply using their phones or laptops. The participants were forbidden to wear headphones - this is due to one of the factors being implemented into the room including sound. For the 15-minute duration, the room settings were chosen at random, the lights had an assortment of colors, the rooms were able to change size and shape, and the sounds were assorted from a nature collection. Most of the activities completed were stationary to accommodate the participant's limited space in the PEACE room and also to allow the participant to minimize their stress.

2.2.3 Data Collection:

The data being collected in this experiment was through video recordings, the EEG headset, and the O2 ring. There was an interface compiling these data collections called the PEACE.GUI, in which there was access to a camera, the EEG software, and the O2 Ring software. The camera capture was done using the OpenCV python library, which allows for the capture of frames from a camera and the collection of them into a video. To control the camera, it was placed in a corner that showed the participant's face and the visual features of the room such as the light or whether the walls were pushed in. When accessing the camera through the PEACE.GUI, the recording automatically starts and to stop it, press the "Q" key. Keep in mind that there is no time watermark so it was the tester's job to time the experiment on their own. For the EEG headset, the software called "OpenSignalsflux" was used to collect and record the data for graphs that depicted the participant's brainwaves. For the O2 Ring, their companion software titled "O2Ring" is able to compile graphs of the participant's oxygen levels by connecting the ring through a USB adapter and clicking download.

2.2.4 Peace Room Experiment Conclusion:

Lastly for the PEACE experiment, a questionnaire created by the student investigators was created to ask for participant's partial and honest opinions and feedback for the room settings they experienced. There was a series of seven questions:

1. *Do you believe the lighting color changed your mood in any way?*
2. *Do you believe the room size was suitable to your needs?*
3. *Was the noise too distracting for your experience?*
4. *Rate from 1-5 (one being terrible, five being great) for each element for your session:*
    a. *Color:*
    b. *Sound:*
    c. *Size:*
5. *Why did you rate each the way you did?*
    a. *Color:*
    b. *Sound:*
    c. *Size:*
6. *What would you do to improve this space given the parameters?*
7. *Would you come back for a follow-up experiment (with the same/different settings)? If not, please state what you would change to make the room more suitable?*

Each of the room settings only changed one factor in the variants so the questionnaire was shortened and tailored towards what setting was changed. For instance, if the room's sound only changed, then the participant was asked to give opinions and ratings on the sound only.

The purpose of the PEACE Room experiment was to gather the participants' feedback and opinions on the various settings independently. Not only will their opinions help to better shape the generally preferred comfortable lights, sounds, and space but to also help guide the architectural concept and form developed for the AREN portion of the project.

2.3 PEACE.GUI:

For the PEACE room, an app that controls the room's settings was created. There was a wide range in variety of changes that can be made for the lighting color, the space size, and the soundscapes. For the lighting color, the use of the smartphone GOVEE Home app allowed for the LED lights to change to any color on the spectrum. The space size, soundscapes, data collection, and PANAS survey were included in the PEACE.GUI app. In the app buttons can be pressed to pull up pages for each wall of the room as well as the ceiling, which allows for individual adjustments to the motors controlling them. This lets the space size be manipulated by pushing the walls inwards and outwards, as well as being able to make them diagonal or curved. The app also includes presets to set the size of the room to a predetermined state. The soundscapes initially included the use of pink noise and white noise, but evolved into a collection of natural sounds: ocean waves, rain splatter, morning birds chirping, calm river dropping, and waterfall crashing. The data collection page allows for recording of the camera in the room, as well as EEG data collection which requires the data acquisition to first be started on the opensignals PC app. The participant page of the GUI brings up a consent form as well as two PANAS surveys for the participants to fill out.
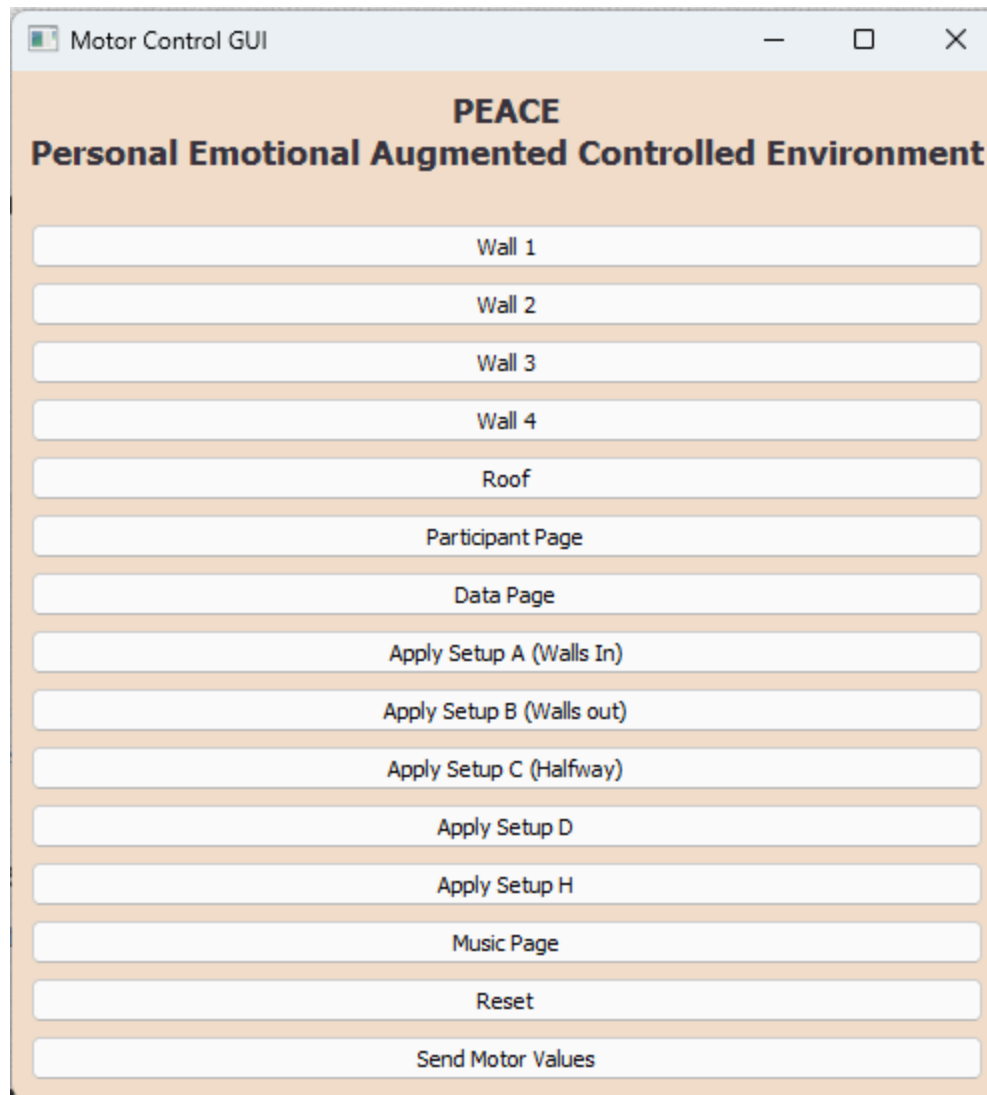
Figure 3: Picture of PEACE GUI: Pictured above is a screenshot of the PEACE GUI through which the PEACE room is controlled. Each wall button controls a specific wall, the participant page opens an interface for participants to enter their information and fill out the PANAS forms. The data page allows for gathering of EEG data as well as O2Ring data. Each setup button allows for users to apply premade setups to the room. The music page allows for control over the sounds played in the room.

2.4 Code Development:

The code development began with forming the participant page of the GUI. This part of the app was created using tkinter in python through consulting the documentation on the python docs site. Through the use of this package the creation of windows with common GUI features such as labels, entry boxes, and buttons is possible. The first page for participants is a login page, which upon entering the participants ID and session number into entry boxes a folder is created to store all of the data for that participant. After the next button is clicked the consent form page is brought up, which contains the consent form as well as entry boxes for the participant to enter

their initials and the date. These are saved in the participants folder after the next button is clicked, and the first PANAS survey is brought up. This survey was made using the radio button feature of tkinter which creates check boxes which can be assigned labels and values. This survey requires the participant to click one of 5 check boxes corresponding to how much they feel the given emotion and then click a submit button to go to the next. After the survey has been completed for all 25 given emotions the results are saved into a csv file in the participants folder and a page is brought up prompting participants to enter the experiment room. After the experiment has concluded the participants are given another identical PANAS survey to gauge how their emotions have changed because of the experiment. After this second survey has been completed the participants are finished with the experiment.

The PEACE GUI itself was started with a template using the python PyQt5 library that allowed for control over the motors in the walls, but it still needed the ability to begin data acquisition as well as play sounds and pull up the participant page. In order to pull up the participant page threads were used which allowed for the participant page to run at the same time as the PEACE GUI.

3. Results

For this experiment, 15 participants were gathered. These participants mainly consisted of colleagues and friends of the experimentees. The participants were mostly college students with the occasional adult. The participants did not not need any accommodations and all participants signed a consent form before participating in the experiment.

Every participant did all three settings that were tested. Setting 1 was blue light, large room, and river sounds. Setting 2 was blue light, small room, and river sounds. Setting 3 was blue light, large room, and rain sounds. Before and after each test participants were asked to fill out the Positive And Negative Affect Schedule, and during each test, the participant had to wear an O2 ring, a wireless electroencephalogram (EEG), and were recorded using a camera located in the room. After the test participants were asked to fill out a questionnaire to better understand what they liked about the room. The data of the EEG and the camera will not be shown in the results.

The EEG and camera data could not be interpreted because of issues with the equipment. While the camera was able to record properly, because the lights in the PEACE room were too bright to allow for great quality and the camera was not a depth camera a proper posture analysis was not able to be done. The EEG was not able to be processed because the signal was interrupted by electromagnetic interference. This could have been caused by a variety of sources, but the most likely cause is from cell phone usage by participants, as "Alterations in human EEG induced by mobile phone emitted EMFs have been reported for all common frequency bands

(delta, theta, alpha, beta, gamma) of the EEG" (Henz, et al., 2018). Because of this the participants should not be allowed to use their phones in future iterations.

3.1 PANAS Analysis:

Recalling back from the methodology, before entering and after leaving the PEACE room, the participants were required to fill out a PANAS survey. Before entering, the participants filled out the pre-PANAS in which they answered the questions based on how they were feeling - whether it be about life in general or about their experiment. After leaving the PEACE room and completing their session, they filled out the post-PANAS in which they answered the questions based on how they were feeling upon their experiments. The PANAS survey itself has a list of 20 emotions - half of which are positive and the other half being negative. The answers in which the participants had to give (with their description and number code) were: very slightly (denoted as 1), a little (denoted as 2), moderate (denoted as 3), a bit (denoted as 4), and extremely (denoted as 5). With very slightly being the lowest amount of the emotion felt and extremely being the highest amount. The PANAS data is one form of collection which was used to determine any trends or changes in select emotions, and was used to cross-reference with other forms of data - most notably the questionnaire. In determining what emotions to select for a deeper analysis, the participants had to have drastic changes between the pre-PANAS and post-PANAS. For instance, if a majority of participant's anxiety went from very little to extreme in one session, then the anxious data was put into a deeper analysis. The emotions that noticed these preliminary trends were: interested, distressed, excited, irritable, alert, attentive, and active.

3.2 Emotional Responses to Different Room Settings:

3.2.1 Interested:

When a participant is said to be interested, it means that curiosity is evoked and their focus is invested on the topic. Some important points to notice in the context of this experiment is that the PEACE room has the ability to change size, color, and sounds which is a factor in the participant's interest level. In terms of the results of the PANAS based on the three settings provided, they all have more or less the same impacts of interest. Refer to Figure 1 below, the results of the control settings saw 13% positive change, 53% neutral change, and 33% negative change. Variant 1 settings saw a 40% positive change, 53% neutral change, and 6% negative change. Variant 2 settings saw a 13% positive change, 67% neutral change, and 20% negative change. Interest is one of the positive emotions in this survey.

Interested: Percentage Score of Mood Change
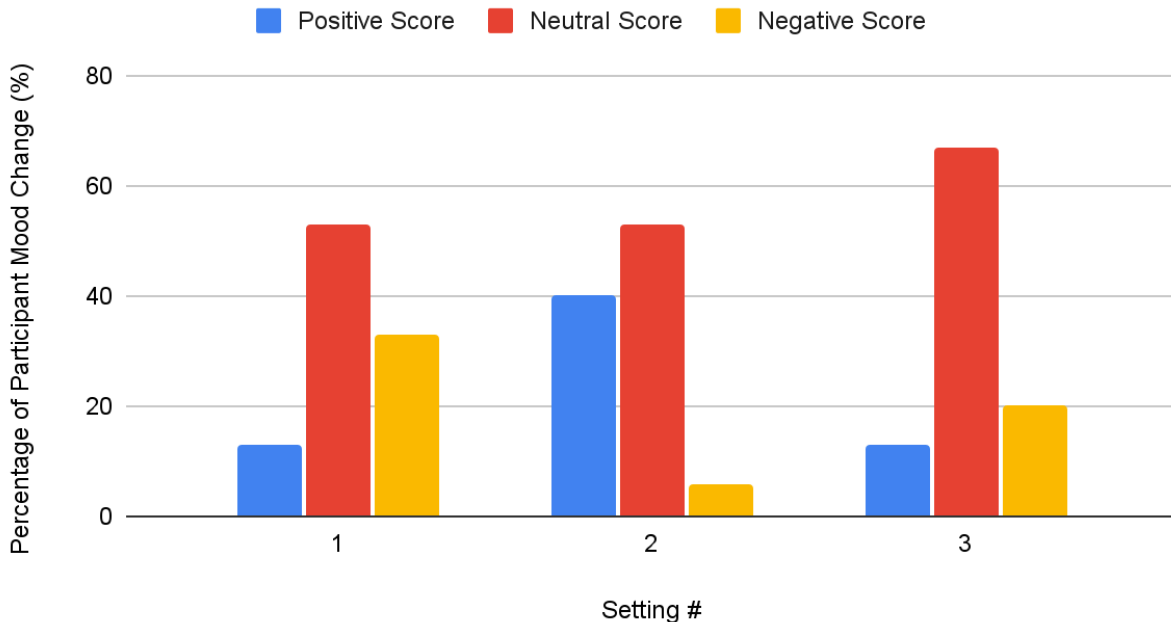
Figure 4: Percentage Score of Mood Change: Interest: This graph here depicts the mood change of the "interest" emotion for the 15 participants after experiencing all settings of the PEACE room. The scores are gained after subtracting the pre experiment scores from the post experiment scores. A positive score means that the post experiment score was higher than the pre-experiment score, the neutral score means the pre and post scores were the same, and the negative score means that the post score was lower than the pre score. There were 3 settings tested. Setting one used blue lights, large room, and river sounds, setting two used blue lights, small room, and river sounds, and setting 3 used blue lights, large room, and rain sounds.

The percentage score of the mood change tells more about how the room and its respective settings impacted the participant and their interest. Seeing as how there was a majority of neutral changes in the participants interest, there are still some notes to be made for the positive and negative changes that occurred. For instance, the positive score from setting 1 to setting 2 increased by 27% and then dropped down by another 27% when back to setting 3. An interesting context point to note between Setting 1 and 2 was that only the room size had changed from large to small. When going from Setting 2 to 3, the room size went back to large, but the soundscape changed. What this says about the room settings in invoking interest was that the size factor was more compelling to keep the interests of the participants. Since Setting 2 was the participants' first exposure to the room changing size, this compelled interest levels to increase despite it being smaller and presumably more uncomfortable. The reason why size is potentially more impactful than sound was probably because the participants experienced the room changing with their vision. It's harder to notice any change with sound, especially given that the sounds are somewhat similar in frequency and type. The next question to ask now is what if the sounds were sonically different, would that still have had more of an impact than the

size visibly changing? A potential conclusion to grab from this experiment data was that interest is closely related to the participant's ability to see rather than ability to hear.

3.2.2 Distressed:

In examining the emotion of distress, participants' levels of discomfort or unease were assessed across the different room settings. Despite the diverse experiences offered by the PEACE room, the baseline distress levels remained relatively consistent across settings. Notably, participants exhibited a preference for larger room sizes, with Setting 3, characterized by spaciousness and ambient rain sounds, demonstrating a slight reduction in distress levels compared to other settings. However, the impact of sound variations on distress levels was less pronounced, suggesting that room size may play a more significant role in alleviating participant discomfort. Moreover, while the majority of participants reported neutral or negative changes in distress, a small subset experienced heightened distress in response to specific environmental cues, such as the confined space of Setting 2. These findings underscore the complex interplay between room design elements and emotional responses, highlighting the importance of considering individual differences in designing immersive environments.
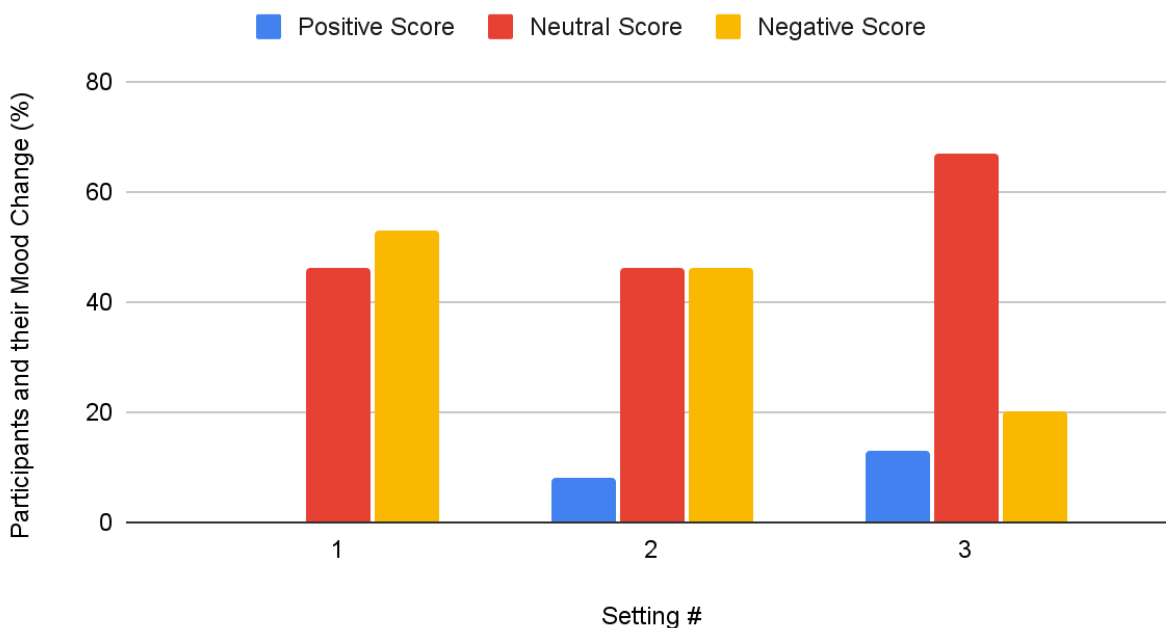
Figure 5: Percentage Scores of Mood Change: Distress: This graph here depicts the mood change of the "Distressed" emotion for the 15 participants after experiencing all settings of the PEACE room. The scores are gained after subtracting the pre experiment scores from the post experiment scores. A positive score means that the post experiment score was higher than the pre-experiment score, the neutral score means the pre and post scores were the same, and the negative score means that the post score was lower than the pre score. There were 3 settings

tested. Setting one used blue lights, large room, and river sounds, setting two used blue lights, small room, and river sounds, and setting 3 used blue lights, large room, and rain sounds.

The percentage of scores are able to tell that this section of the data can determine more of the participants' preferences in room settings rather than to the factors like it did with Figure 1. For instance, all of the Setting 1 scores were mostly neutral or negative which showed that it was able to help in alleviating participant distress. When changing to Settings 2 and 3 though, there seem to be some moods that saw positive scores which meant that some participants felt more distress, despite it being significantly lower amounts of participants. When discussing the participants' feelings of distress in the other settings, some participants must have felt unsafe in the smaller size rooms and the rain sounds must have had no effect on calming some participants down. In terms of the room size and its impacts, the participants were mostly working on stationary activities such as coloring books, building blocks, or the most common, swiping on their smartphones. With most participants being the majority scoring negative or neutral scores, it meant that the room had no effect on them doing the stationary activities. For the small number of participants who felt more distress, it must have been due to the fact that the space felt closed in and they didn't feel comfortable in completing the activities that they wished to do - presumably the ones who did the coloring books since they had no wiggle room to move their arms freely as they're shading with their colored pencils. Similar situation with the sound changes. Since the two sounds being changed went from river droplets to rain, a majority of the participants had no preference since both had soft water motifs, with the rain only having periodic thunder rumbles. For the participants who felt more distress, the thunder rumbles must have been off putting and ruined the cadence of the rain's movement. Across all three settings, a majority of participants had scored a neutral or negative score in the changes of their distress which meant that each room had a positive impact on their emotions and showed that there was necessarily no preference due to the fact that the participants were not doing active or taxing activities that required them to move around. Also because the sounds were somewhat related and had little-to-no changes to help fully determine what sounds were more preferred.

3.2.3 Excited:

Excitement can be classified as similar or exactly alike to interest. Both are positive emotions that exude that curiosity in wanting to learn more about a topic. Another avenue to view excitement is that a majority of the participants completed the experiments in the beginning of the day so they have something to look forward to in the later parts of the day. In the experiment across all 3 settings, Setting 1 had mood change scores of 13% positive, 40% neutral, and 46% negative. Setting 2 had 27% positive, 46% neutral, and 27% negative. Setting 3 had 33% positive, 40% neutral, and 26% negative. Refer to Figure 3 for visual representation of how the data trends throughout all 3 settings.

Excited: Percentage Scores of mood change
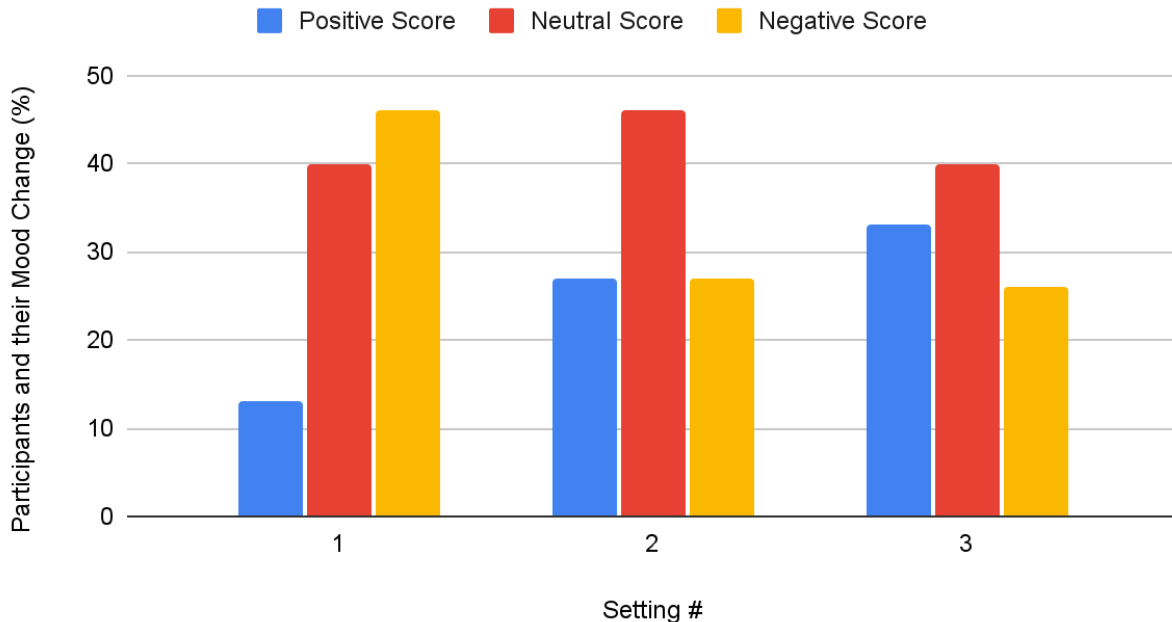
Figure 6: Percentage Scores of Mood Change: Excitement: This graph here depicts the mood change of the "excitement" emotion for the 15 participants after experiencing all settings of the PEACE room. The scores are gained after subtracting the pre experiment scores from the post experiment scores. A positive score means that the post experiment score was higher than the pre-experiment score, the neutral score means the pre and post scores were the same, and the negative score means that the post score was lower than the pre score. There were 3 settings tested. Setting one used blue lights, large room, and river sounds, setting two used blue lights, small room, and river sounds, and setting 3 used blue lights, large room, and rain sounds.

What the percentage scores of the excitement data tells is that the general excitement of the participants slowly increased. Taking a closer look at the specific positive (blue) bars, the participants in setting 1 had the lowest score in terms of change, but as Setting 2 and Setting 3 occurred, the positive bars were slowly increasing. The negative (yellow) bars saw the opposite changes. Similarly to almost all the emotions, there was mostly no change in emotion that occurred throughout the 3 settings. The potential reasons could ultimately still point to the previous remark where most of the participants who participated in the earlier parts of the day had excitement for something that occurred later. It could also be the excitement of experiencing the PEACE room and participating in some of the mystery activities that weren't disclosed until they entered the room. A more grim reason could also be that the participants were excited that the experiments were almost over, which is why setting 3 (the last played setting most of the time) experienced the highest score of positive change. In terms of the negative scores, most of the potential reasons align with the interest. Since excitement is rather so building anticipation for the participant's experience in the PEACE room, it's expected for their excitement to go down upon experiencing it. There is essentially no incentive in the room that could raise their

excitement since there are only three factors that are able to change and for this experiment's sake only two of the factors change. In terms of neutral changes, the reason depends more on how the participant answered. If the participant answered extremely or a bit then conclusions can be drawn that the participant was able to keep their excitement at a higher rate. If the participant answered a little or very slightly then the excitement was kept at a lower rate. Based on the trend described, it's safe to say that Setting 3 was able to raise the excitement of participants. In the context of the setting, the lightning and thunder rumbles in tandem with the rain splattering must have lifted the spirits of the participants and thrill that resembles excitement - which is why it seemed to be the most effective setting for this data set.

3.2.4 Irritable:

Irritable in the context of this experiment is describing the participant's levels of annoyance. To bring back the participant demographic, a majority were college students or young adults starting out in work. It's expected for these types of participants to be irritable or annoyed - whether it be about classwork, about professors or bosses who are being difficult and piling work, or it could even be about their peers who do not cooperate well with them. Not to devalue the project either but some participants must have found it to be a chore to participate in the PEACE room experiment (though all first 15 participants definitely enjoyed it and were more than likely to come back for leisure time). In the end, the irritable mood changes scored in Setting 1: 13% positive, 53% neutral, and 33% negative. In Setting 2, 6% positive, 53% neutral, and 40% negative. In Setting 3, 0% positive, 80% neutral, and 20% negative. Refer to Figure 4 to see graphic depictions of the scores.
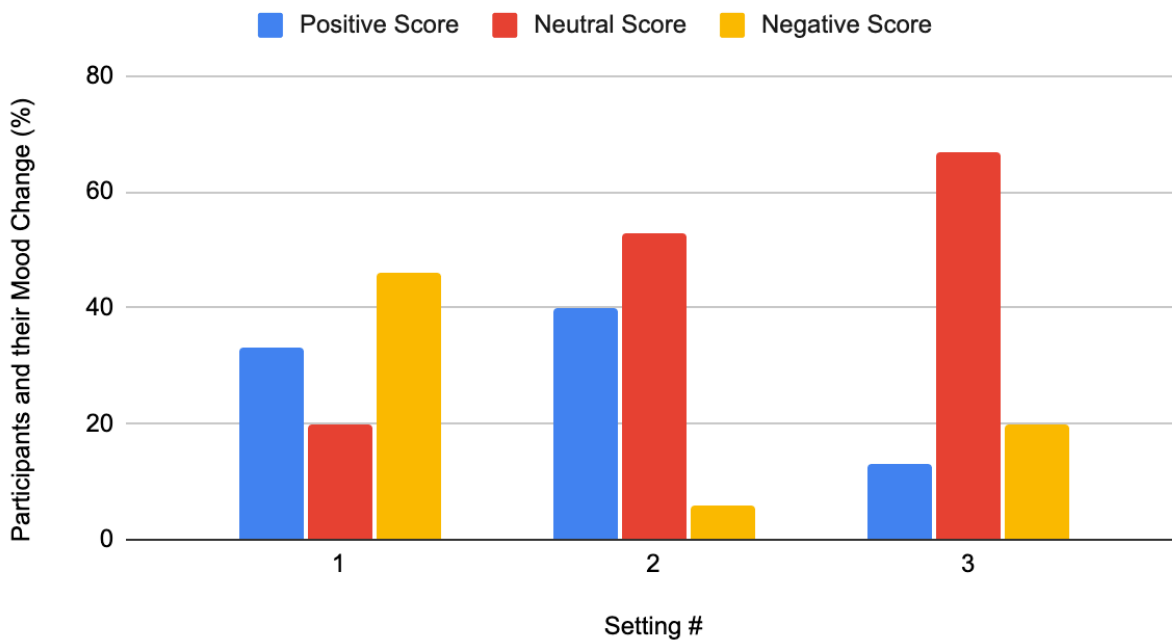
Irritable: Percentage Scores of mood change
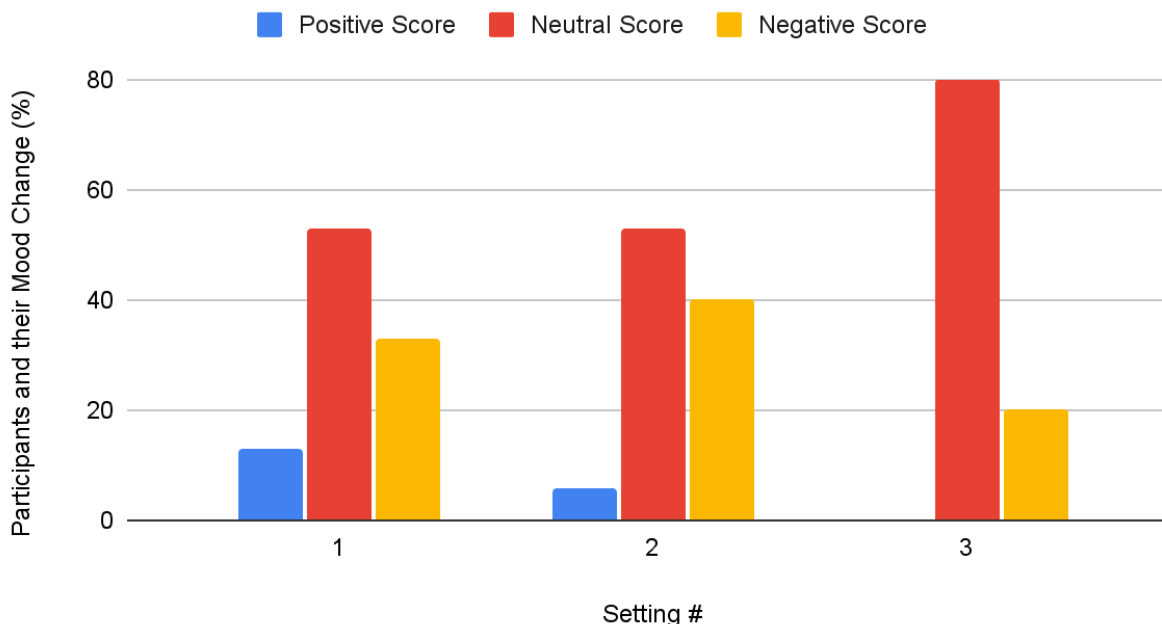
Figure 7: Percentage Scores of Mood Change: Irritable: This graph here depicts the mood change of the "irritable" emotion for the 15 participants after experiencing all settings of the PEACE room. The scores are gained after subtracting the pre experiment scores from the post experiment scores. A positive score means that the post experiment score was higher than the pre-experiment score, the neutral score means the pre and post scores were the same, and the negative score means that the post score was lower than the pre score. There were 3 settings tested. Setting one used blue lights, large room, and river sounds, setting two used blue lights, small room, and river sounds, and setting 3 used blue lights, large room, and rain sounds.

An interesting trend to note is that the irritable scores were reminiscent of the distressed trends. A majority of the participants were able to keep their irritability constant or alleviated, with a select few who had increased annoyance in the first two settings. The only thing that separates it from the distressed data is that there is a clear preference for Setting 3 in terms of alleviating irritability. Some potential reasons for the participants to be irritable amongst these three settings is if the space was too tight or too big for their activity, or if the sounds being played were grating to the ear. It seems that for Setting 3, a lot of the participants were able to decrease or keep their irritability at lower levels due to their enjoyment of the rain sounds. As for the participants in the other settings, the size of the small room must have made it difficult for the participants to sit comfortably or do their activities properly. Another thing to note is that even though all the settings had blue colored lights, some participants must have been annoyed with the color beating down, ruining their line of vision or even distracting and deceiving them. In terms of the sound, it all boils down to preference, but it seems that some of the participants did not enjoy the river sounds as much as they did with the rain sounds. Overall, Setting 3 was the most effective in lowering or keeping the participant's annoyance levels at lower levels.

3.2.5 Alert:

Alert in the context of this experiment is whether or not the participants were able to keep their senses heightened throughout their experience. Although alertness is important to the participant demographic of students and workers. Students must be able to keep their alertness for any event within the classroom. One thing to note is whether the teacher or professor calls on them to answer a question, or to sit through class presentations and the students are required to provide feedback. For workers, they must remain alert whether it be discussing matters with their bosses, their clients, or collaborators so they can address various topics and commit to their work. In this experiment, however, alertness levels are expected to be low since the participants had stationary activities and required little-to-no attention or focus as they would in the classroom or office setting. Throughout all 3 settings, Setting 1 had 33% positive, 20% neutral, 46% negative. Setting 2 had 40% positive, 53% neutral, and 6% negative. Setting 3 had 13% positive, 67% neutral, 20% negative. Refer to Figure 5 for further representation of the trends in data.

Alert: Percentage Scores of mood change

Figure 8: Percentage Scores of Mood Change: Alert: This graph here depicts the mood change of the "alert" emotion for the 15 participants after experiencing all settings of the PEACE room. The scores are gained after subtracting the pre experiment scores from the post experiment scores. A positive score means that the post experiment score was higher than the pre-experiment score, the neutral score means the pre and post scores were the same, and the negative score means that the post score was lower than the pre score. There were 3 settings tested. Setting one used blue lights, large room, and river sounds, setting two used blue lights, small room, and river sounds, and setting 3 used blue lights, large room, and rain sounds.

An interesting afterthought is that a good handful of participants were able to become more alert depending on the settings of the room despite the other factors such as activities that are not taxing to their mental health. But there are also a handful of participants who also experienced a loss of alertness. Setting 1 saw the most for loss of alertness, this could mean many things. For one, and almost for all the settings, the room's purpose was to let the participant's relax and be comfortable so the participants truly felt comfortable in that sense. Another reason could also be that the room must have worn them out - could be from the intensity of the blue room, or even the soothing sounds of the river droplets. For Setting 2, there was more of a neutral change and an increase in positive change. This could explain how the small room's tightness might have made the participants have heightened senses due to them not being able to sit comfortably as they would have liked, or the sense of the room being closed on them compelled them to feel more awake than dozed. In Setting 3, the positive scores however decreased and the negative scores increased. The same argument for Setting 1 can be said in this case as well, since in the other datasets, Setting 3 proved to be the more comfortable one for most of the participants due to the rain sounds. Based on this data, Setting 2 was able to retain and increase the alertness levels of the participants.

3.2.6 Attentive:

The participants' capacity to maintain focus and attention during their PEACE room experiences was examined to show the impact of environmental stimuli on cognitive engagement. Contrary to expectations, the presence of blue LED lighting, a predominant feature of all room settings, appeared to hinder participants' attentiveness, particularly in tasks involving color recognition and visual processing. Setting 1, serving as the control with standard room configurations, elicited a mixed response, with some participants reporting increased attentiveness while others struggled to concentrate amidst the ambient lighting. Conversely, Setting 3, characterized by the calming presence of rain sounds, exhibited a slight improvement in attentiveness levels among participants. This suggests that auditory stimuli may have a more positive influence on cognitive performance compared to visual cues alone. However, the overall neutral or negative trends observed across settings underscore the multifaceted nature of attentional processes and the need for further exploration into the nuanced effects of room design on cognitive functioning.

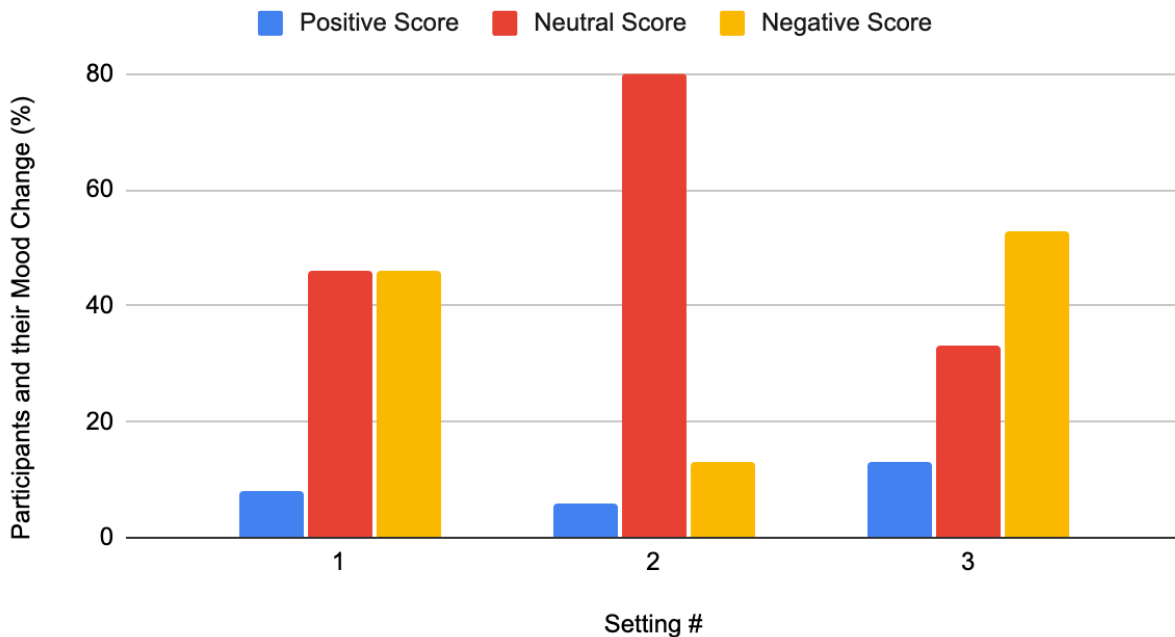## Attentive: Percentage Scores of mood change

Figure 9: Percentage Scores of Mood Change: Attentive: This graph here depicts the mood change of the "attentive" emotion for the 15 participants after experiencing all settings of the PEACE room. The scores are gained after subtracting the pre experiment scores from the post experiment scores. A positive score means that the post experiment score was higher than the pre-experiment score, the neutral score means the pre and post scores were the same, and the negative score means that the post score was lower than the pre score. There were 3 settings tested. Setting one used blue lights, large room, and river sounds, setting two used blue lights, small room, and river sounds, and setting 3 used blue lights, large room, and rain sounds.

Unfortunately with a majority of all three settings, the participants seemed to dencrease their attentiveness. A potential reason for why there was more alignment to neutral or negative change is possibly due to the previous argument where the blue light may have been overpowering to the participants - making it harder for them to do activities that involve identifying other colors. What's interesting is that there were outliers that did find the room's settings to increase their focus levels. Starting with setting 1, there was more negative and neutral change within the participants. Since this was the control room, it is safe to use the argument of the blue light preventing them from being able to focus well on their activities. Potential factors that may help increase their focus is if the activities they were doing did not involve identifying colors. Light in general is helpful in providing heightened vision and given that the room had no windows to allow for natural lighting, then that source of blue LEDs was able to help the participant focus on the activities that did not require coloring. In setting 2, there's a decrease in the positive score however, but also a decrease in negative change. A potential reason for this change could be due to the fact the participants have identified the issues of the blue light and decided to do other activities that did not require coloring. The smaller size

of the room must have had no effect at all since the neutral scores were at an all time high. In setting 3, the positive and negative scores increased while the neutral scores decreased tremendously. The potential reason behind this occurrence is possibly due to the sound allowing the participants to calm down - in the positive sense, it allowed the participants to calm down and keep their focus regardless of the activity they were working on. In the negative sense, the participants felt too much comfort so they may have decided to just scrap the activity as a whole and decided to rest or do a less taxing activity. Overall, the best setting in enhancing attention could either fall between setting 2 or setting 3, in favor of setting 2 if the participant's answers were a bit or extremely.

3.2.7 Active:

The active emotion is an interesting one to take note of not only for the trends found in the experiment but for the context of this experiment. A lot of the participants who experienced the PEACE room were mostly stationary and did tasks that required little-to-no movement. Even though the purpose of the experiment is to test for how comfortable the participants feel, the controls of the room might compel them to feel active and physically move around. Across all three settings, setting 1 had a score of 20% positive, 46% neutral, 33% negative. In setting 2, the scores were 20% positive, 40% neutral, and 33% negative. Refer to Figure 7 for graphical representation of the trends in the active data.
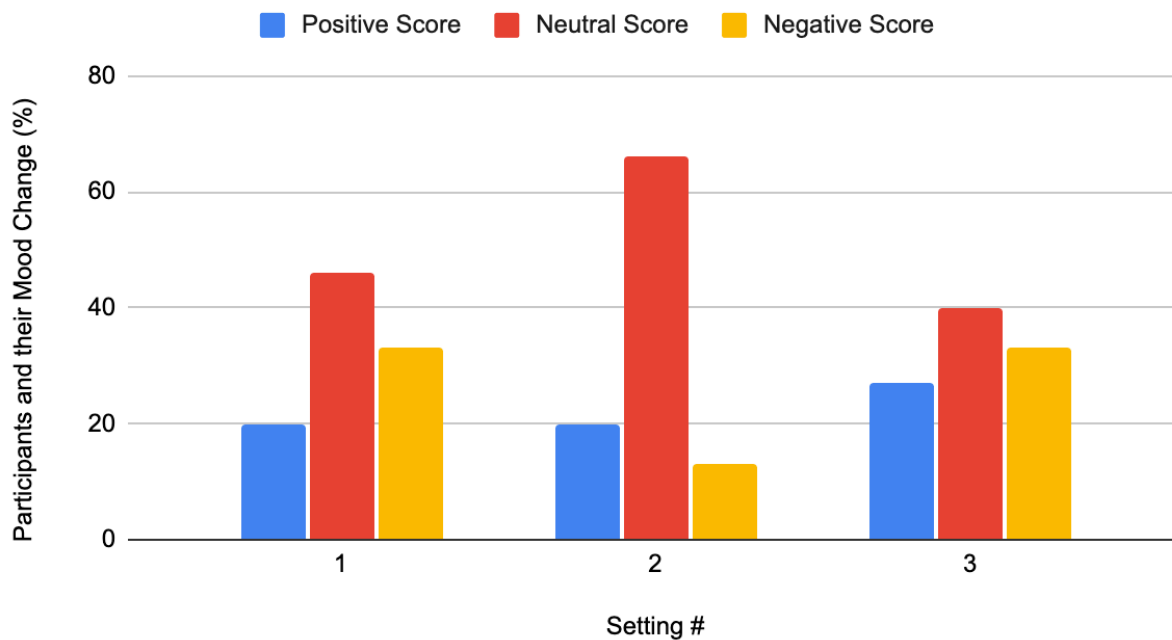
Figure 10: Percentage Scores of Mood Change: Active: This graph here depicts the mood change of the "active" emotion for the 15 participants after experiencing all settings of the PEACE room. The scores are gained after

subtracting the pre experiment scores from the post experiment scores. A positive score means that the post experiment score was higher than the pre-experiment score, the neutral score means the pre and post scores were the same, and the negative score means that the post score was lower than the pre score. There were 3 settings tested. Setting one used blue lights, large room, and river sounds, setting two used blue lights, small room, and river sounds, and setting 3 used blue lights, large room, and rain sounds.

The trends of the graph were quite interesting since a handful of participants were able to feel more active across the three settings. But it's also still safe to say that the other handful of participants were also fine with sitting in place, or even in another context - making the participants feel the opposite of active which is tired. Starting with setting 1, the participants must have been able to feel a positive change in their activity because of the larger space. Although the activities were stationary, the participants had the option to move around freely within the space. In terms of setting 2, there was more neutrality and less negative changes in scores. It is surprising to see that the negative scores of activeness decreased since the room size changed into a smaller size, not allowing the participant to move around freely as they could have in setting 1. In setting 3, to see the increase in positive scores for activeness makes it seem contradicting to the previous arguments above in which setting 3 was able to alleviate many stresses and alertness that allowed participants to feel comfortable. But comfort is not necessarily tied to sitting in place and rest, comfort can be tied to activeness and movement as well. Are the participants comfortable moving around in the room? Do the participants have access to move to any part of the room and sit any way they'd like? Based on the data, setting 3 does prevail in the argument of activeness but the other settings do pale in comparison so the data may as well be inconclusive in this context.

3.3 Questionnaire Response Analysis:

At the end of each session, participants were asked to fill out a questionnaire. Refer back to section 2.2.4 to see the list of questions asked.

The purpose of these questions is to get feedback on each setting to see how participants react as well as determine which settings are the most effective. Questions 1-3 ask the participants how they felt about the lighting, size, and sound in one or two sentences. Question 4 asks the participants to rate each setting and then in question 5 they are asked to describe why they rated each the way they did. The 6th question asks for general critiques of the experiment and question 7 asks if they are willing to come back for another test. These responses were then compiled and the results on each setting are shown below.

3.3.1 Lighting:

Majority of experiments used blue light only. This was so different sounds and room sizes can be tested.
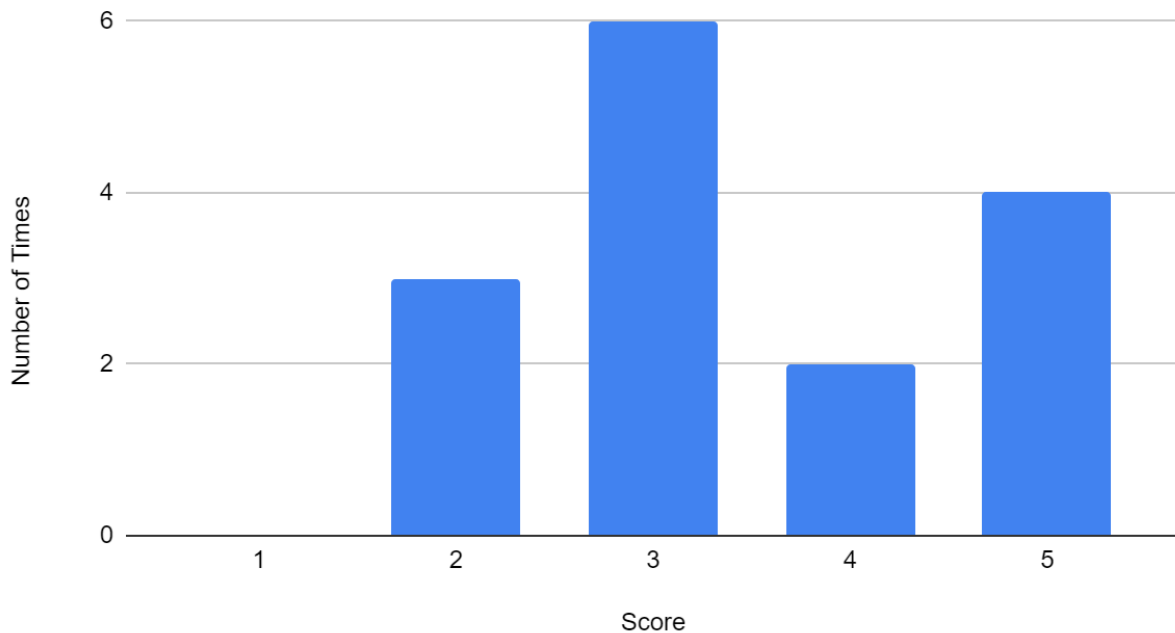
Blue Light Scores

The questionnaire still asked for opinions on the blue light. 40% of participants gave the blue light a 3 out of 5. Most of the participants that gave it a 3 felt indifferent about the color, with many either tuning it out or complaining that it made it hard to see. 26.67% gave the setting a 5 out of 5. Participants that gave the blue setting a 5 claimed it helped them relax, with some even saying it made them feel tired. Refer to figure 10 below.

20% of participants gave the setting a 2 out of 5. These are the participants who had the biggest problems with the light. Most of the responses repeated what participants who gave a 3 said with some outliers saying the blue made them feel stressed. The biggest complaint is the light's intensity making it hard to see or do anything in the room. Refer to figure 10 below.

Only around 13% of participants gave the setting a 4 out of 5 and 0% of participants gave it a 1 out of 5. A large number of participants were not affected by the light but there were still some who appreciated it. Refer to figure 10 below.

3.3.2 Sound:

Two different sounds were tested. The river sound uses recordings of rushing water as well as ambient nature sounds.

River Sound Score
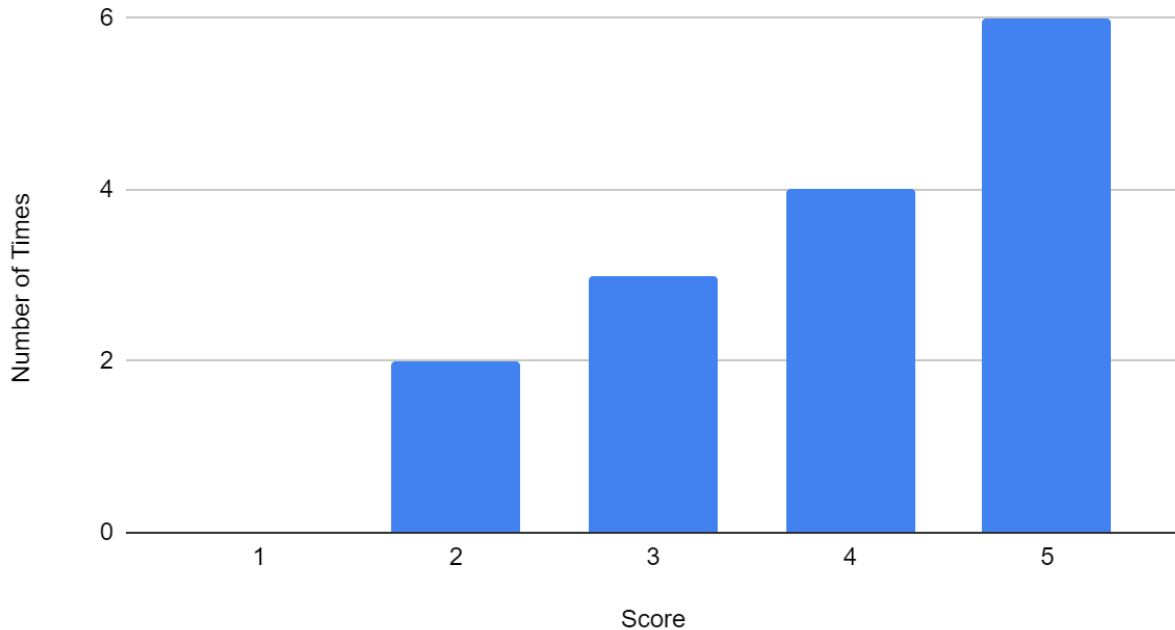
Figure 12: River Sound Scores: This graph here depicts the number of times a participant scored the river sound setting either a 1, a 2, a 3, a 4, or a 5. The Y-axis shows how many times that particular score was given and the X-axis shows what the score was.

When asked about the river sound, 40% gave the sound a 5 out of 5. Many described the sounds as being soothing and relaxing. 26.67% gave the sound a 4 out 0f 5 and 20% gave the sound a 3 out of 5. The reasoning for both of these scores mostly came down to the participant preferring the rain sound over the river sound. The 13.3% who gave the sound a 2 out of 5 did not enjoy the sound. They either found it too distracting, too loud or didn't notice it at all. Refer to figure 11.
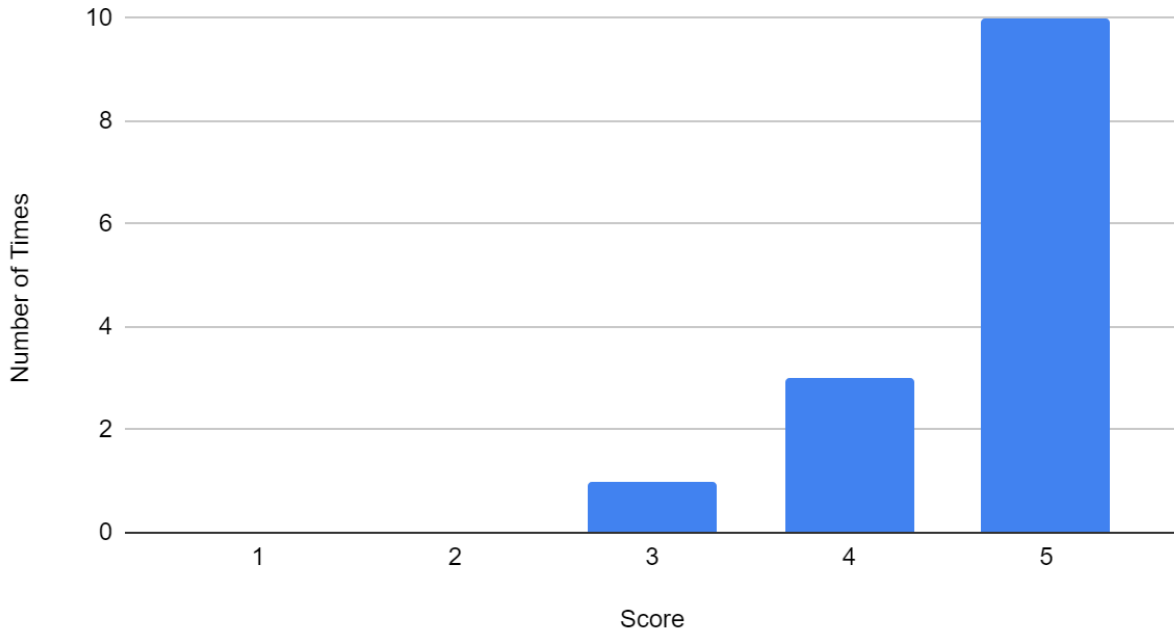
Rain Sounds Scores

Figure 13: Rain Sound Scores: This graph here depicts the number of times a participant scored the rain sound setting either a 1, a 2, a 3, a 4, or a 5. The Y-axis shows how many times that particular score was given and the X-axis shows what the score was.

The second sound that was used was the rain sound. The sound emulates a thunderstorm. Compared to the river sound, the rain was much more well received. Around 66.67% of participants gave the rain sound a 5 out of 5. As a reminder, only 40% of participants gave the river a 5. Most found the rain relaxing and cozy. Some didn't prefer one over the other but would still give the rain a 5. The 20% of participants who gave the rain a 4 out of 5 only did so because they liked the river sound just a bit more. Only 1 participant gave the rain a 3 out of 5 claiming that they tuned it out. Based on the data, rain sounds are the most popular choice. Refer to figure 12.

3.3.3 Size:

Two room sizes were tested. One where the motors were pushed all the way in (large), and one where all the motors were pushed out (small).

Large Room Scores

Figure 14: Large Room Scores: This graph here depicts the number of times a participant scored the large room setting either a 1, a 2, a 3, a 4, or a 5. The Y-axis shows how many times that particular score was given and the X-axis shows what the score was.

When asked to rate the large room, 40% of participants gave it a 5 out of 5. When participants were asked to describe why they rated it the way they did, most didn't give a specific reason. Most felt indifferent but slightly preferred the large over the small. The 20% that gave it a 4 out of 5 felt indifferent and would rate the small a similar rating. The 26.67% of participants that gave 3 out of five flet the most indifferent. They would also give the small a 3 out of 5. The 13.3% that gave the large room a 2 out of 5 actually preferred the small room over the large. They claimed they felt more cozy and secure in the small room compared to the large. Refer to figure 13.
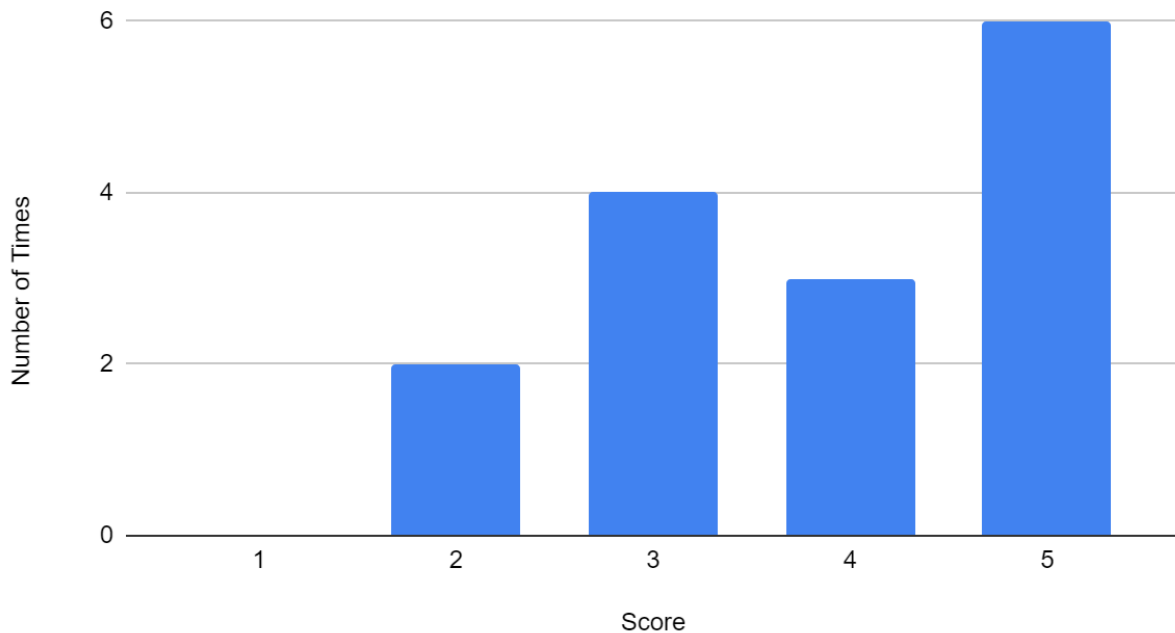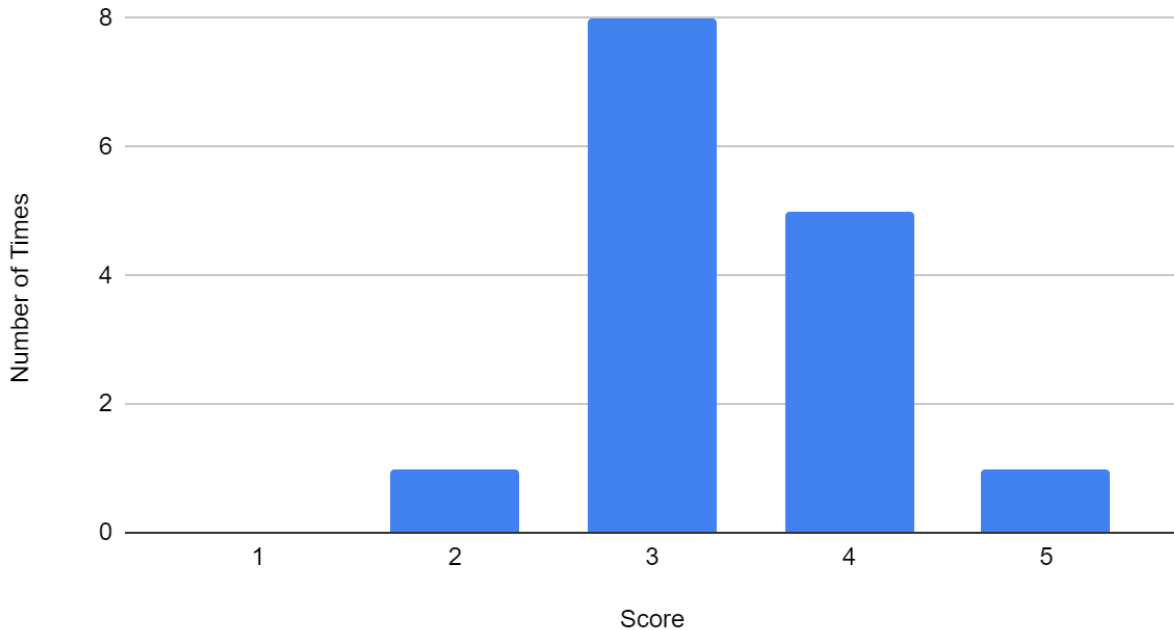
Small Room Scores

Figure 15: Small Room Scores: This graph here depicts the number of times a participant scored the small room setting either a 1, a 2, a 3, a 4, or a 5. The Y-axis shows how many times that particular score was given and the X-axis shows what the score was.

When asked about the small room, once again many felt indifferent. Only one participant gave it a 5 out of 5, only noting that they preferred it over the small. The one participant that gave it a 2 out of 5 also gave the large a 2 saying that they didn't prefer either. 53.3% gave a 3 out of 5 and 13.3% gave a 4 out of 5. Once again these participants mainly felt indifferent, with the majority preferring the large space compared to the small. Refer to figure 14.

Based on the data, participants preferred the large room over the small, however many didn't notice much of a difference and claimed that the rooms did not affect them that much. A big reason as to why is the way the experiment is performed. Participants are told to sit in a chair and do whatever they wish to feel relaxed. Because the participants are stationary, they don't get to feel the full effects of the room since they don't need to worry about feeling cramped. However, making the participants move around might not lead to useful data. It can be assumed that the small room would be disliked due to it restricting movement. Based on this we can assume that room size doesn't have as big of an effect on stress levels compared to sound and color. Further study can be performed to test this theory.

3.4 O2 Ring Analysis:

The O2 ring was primarily used to monitor participants pulse rates as pulse rate is a good indicator of stress. The pulse rates of participants were graphed to decide whether there was a general increase or decrease, with an increase corresponding to an increase in stress, and a decrease corresponding to a decrease in stress. The rooms which most often caused a decrease in

pulse rate were the blue rooms with the river sound, with the blue large river setting causing the greatest decrease in pulse rate.

Pulse Rate Over Time
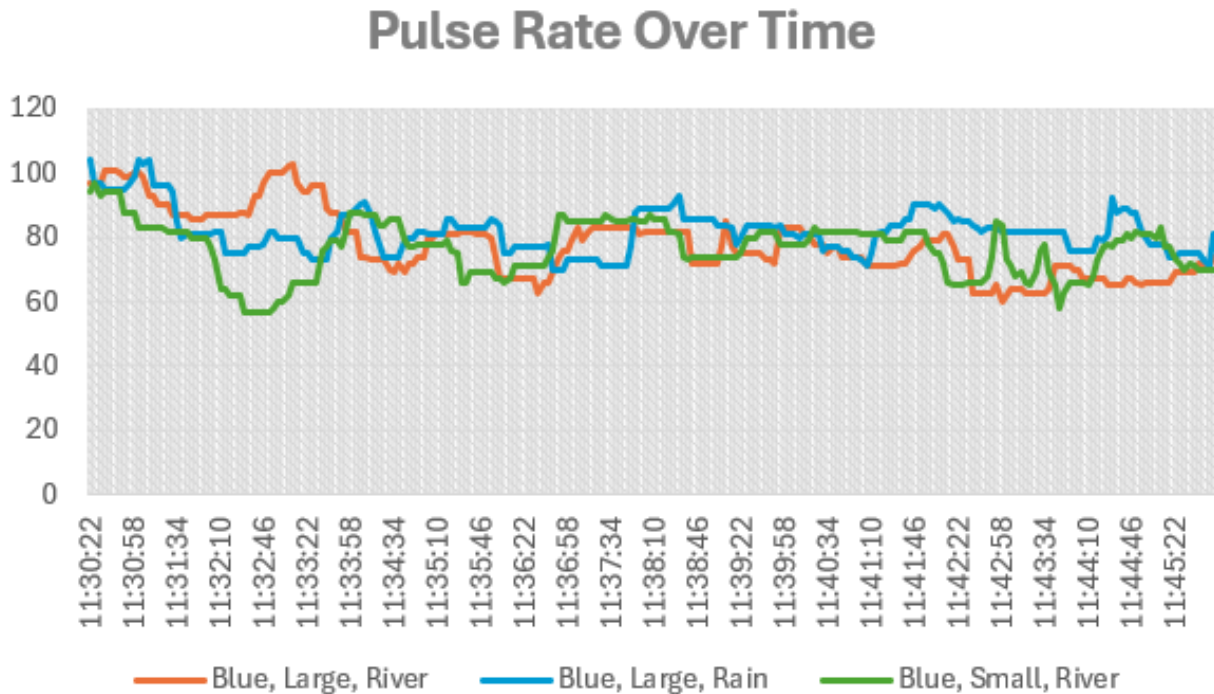
Figure 16: Pulse Rate Over Time: This graph here depicts change in pulse rate over time for one of the participants. The orange line represents the Blue, Large, River setting, the Blue line represents the Blue, Large, Rain setting, and the Green line represents the Blue, Small, River setting. The Blue, Large, River setting had the greatest decrease in stress levels over the course of the experiment.

4. Architectural Design

4.1 Design Concept Heaven's Cloud:

The concept of the building's design is *Heaven's Cloud*. Heaven defined by all can be closely tied as a sanctuary that exudes comfort, peace, and happiness for one and all to enjoy. The PEACE room itself can be described as a process in creating this sanctuary of comfort and peace - in fact the whole purpose of the experiment using this room was to gather data on what made people feel most comfortable.

Though Heaven is heavily tied to many of the core religions, it has found itself in the secular context amongst most of the universe. Heaven defined by all can be closely tied as a sanctuary that exudes comfort, peace, and happiness for one and all to enjoy. The PEACE room itself can be described as a process in creating this sanctuary of comfort and peace - in fact the whole purpose of the experiment using this room was to gather data on what made people feel most comfortable. The "Cloud" is an association to the participant's enjoyment of the rain sounds. There are a variety of interpretations of the cloud - for instance, clouds are in the sky and

can come in many shapes and sizes; as a favorite pastime for young children, they like to lie down in the grass and pick out clouds that resemble animals. The obvious implication of how clouds relate to rain is that rain simply comes on a cloudy day. With rain comes thunder and lightning. With rain passing and clouds disintegrating, rainbows often appear. These are two strong examples of relation to clouds in the similar context to rain.

With "Heaven's Cloud" combined into one singular concept, the building's form can take an abnormal form with incorporations of elements that visually relate to images of lightning and imagery that symbolizes peace, happiness, and comfort such as a rainbow. The architectural form will appear as dynamic as a lightning bolt, whilst serving as an iridian sanctuary.

Now that enough data has been collected and analyzed, how can the PEACE room be incorporated into a fully functioning architectural form and plan. Based on the data from the PANAS, Questionnaire, and EEG monitors, the participants resonated more with the larger size and the rain sounds. The concept of the building's design is derived from these participants' preferences and finalized as *Heaven's Cloud*.

The architectural form will appear as dynamic as a lightning bolt, whilst serving as an iridian sanctuary. The design of a "Heaven's Cloud" must also keep with its inclusive concept by creating a space that allows people of all cultures and backgrounds to feel comfortable and to use the space as they would like. In public spaces, it's important to have enough room to allow a large number of occupants. Openness is an important quality to insure this goal. For more private spaces, the theme of openness in the building's form should insure the comfort of the singular occupants to fully express themselves and give them a sense of homeliness.

Figure 17: The final iteration of the project building. The lightning shapes wrap around the building in a downward movement. On top of the thunder shapes, there is potential for green beds that are filled with vibrant and various flower types to serve as a green space and improve the rainbow connection and aesthetic.

Using the 3D modeling software Sketchup, the Heaven's Could concept was brought to life. The design had to be simplified into a more square like shape. The design incorporates a facade that emulates lighting bolts to fit with the cloud aesthetic. Refer to figure 17. More information on the drawing can be found in the appendix.

4.1.2 Design's Narrative

The building will be of mixed-use occupancy to allow for diversity in its use while blending together various cultures and a variety of purposes for different occupants.

The retail space idealistically will consist of a variety of retail clothing, novelty, and furniture stores along with a supermarket, convenience/drug, and few restaurants. The retail space resembles a shopping mall that gathers the human population and unites them through their shared interest in consumerist culture. In general, many teenagers like to spend time at the mall with their friends. In this stressful and ever changing world, people can cope with "retail-therapy" to ease their anxiety and seek comfort for a fleeting moment (in proper ration).

Recalling back to the purpose of creating office spaces, the target would be for small companies who are in need of a space for their roster. With additional lease revenue for the building owner, the smaller companies will have access to newer spaces with diverse uses for retail and food spaces, along with residency. To break free from the brutal, cubicle office life in which every person keeps to themselves for eight hours a day, this office space takes on a more open approach in which desks are connected with computers readily available. The openness and connected tables will promote the employees to work together more often, it's always better to have multiple minds thinking at once to come up with an innovative solution. The openness of the office also allows participants to feel the need to roam freely and do some hourly stretches, or change their scenery and work style to improve their productivity.

The call for more affordable residential spaces is a constant issue faced in current society for younger adults who are starting out their career, sometimes in foreign lands. So there will be three levels of housing types that are accommodating to all sorts of groups such as singles, families, and those alike. The variety of these housing types increases the demographic when looking for habitants. The variety also allows for many social opportunities. In these residential spaces, there are many gathering areas that are accessible to all the residents. Some examples of a social aspect is that families with young childrens can mingle as they would be attending the same school or making nice with one another similarly to suburban neighborhoods. The union of these young children can help to promote the idea of inclusivity and peacefulness, allowing them to build on their own social skills and develop lifelong connections. For the older crowds, fostering connections based on more complex topics such as sharing their different cultures and fueling the "melting-pot" that enriches one's knowledge and exposure to different parts of the world. In being able to deal with each other, this "suburban" idea of neighborly relations helps to calm the bustling city life and allow for people to expand their comfort zones and try out new things.

4.1.4.1 Peaceful Lightning, an oxymoron:

How exactly can lightning be peaceful? Lightning and thunderstorms are often noisy and dangerous. In fact, being "struck-by-lightning" though at a very low chance has a negative connotation to it as it can evidently bring about one's death but also evokes a sense of fear from its danger. Like with most things in life, there is always a silver-lining. The common phrase "the calm after a storm" essentially connects the lightning motif to the architectural concept and narrative in evoking comfort. After a lightning storm, the sun comes out and reflects the puddle with a rainbow. The sight of a rainbow symbolizes happiness and brings out the joy in many people as they can peacefully walk out and enjoy the fresh air and ambience of nature. In the sense of the building form, the lightning shape being filled with colorful flower-beds represents that calm after a storm where the strong lightning shape and motif is complemented by the variety of flowers blooming throughout the building's facade. The flower-beds are also an effort to make the occupants more attracted to the aesthetics and to take interest in the form through simplicity.
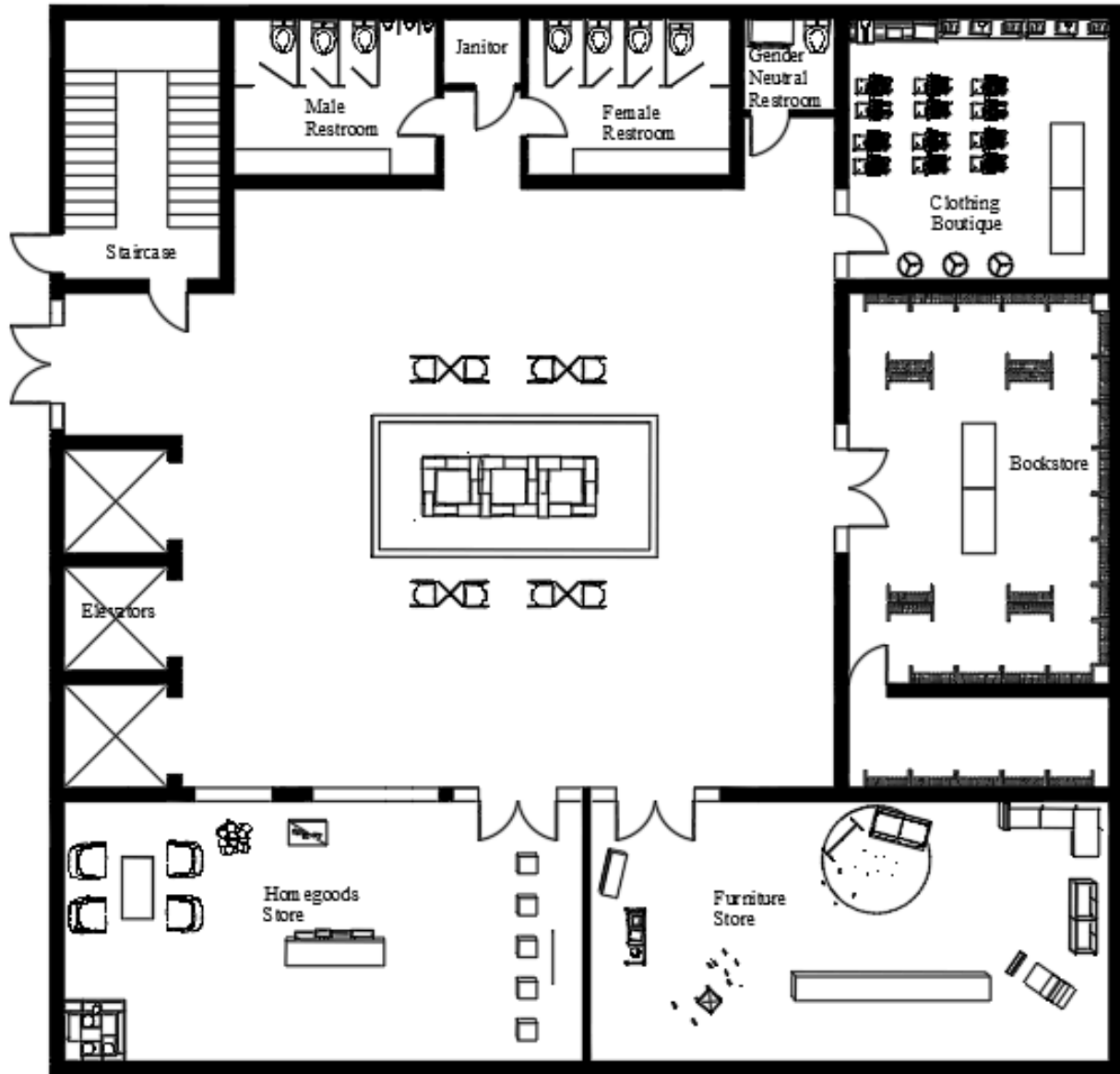
4.1.5 International Building Code Restrictions:

Before going into detail how the floor plan appears in the different mixed-use spaces, it is important to highlight code compliance used within this project and form. The assumption made was that the building would be built in Boston, Massachusetts, and Massachusetts follows the International Building Code (IBC) 2015. The important components to check for building code compliance is if the types of the building have a maximum set of dimensions such as height or width, if the building's corridors allow enough comfort for occupants to roam freely without feeling tight, egress requirements such as staircase dimensions and quantity of doors that take occupants to a convenient exit. When picking the criteria for the building to follow, the building is classified as a mixed-occupancy of A-2, M, and R-2 with Type 1 Construction. The buildings ' heights are unlimited for Type 1A, meanwhile for Type 1B, 160-180 feet (IBC Table 504.3). First, going over the requirements for the minimum corridor throughout the building, any space must have at least 44 inches of space for occupants to traverse throughout the building (IBC Table 1020.2), and each corridor cannot have a dead-end spanning over 20 feet (IBC 1020.4). Stated in the IBC 1003.2, the egress corridors must have a height of at least 7.5 feet. For means of egress, the path should not span more than 75 feet to allow for occupants to escape in an orderly and quick path (IBC 1006.2.1) and based on certain occupant loads, there must be approximately 2-4 exits (IBC 1006.3.1). Moving onto stairways, the width must be greater than 36 inches and ample headroom spaced at 80 inches (IBC 1011.2-.3). The depths of each stair must be in between 4 to 7 inches (IBC 1011.5.2). A special case for spiral stairways as stated in IBC Section 1011.10, the space the stairway can take up is up to 250 square feet, the stair depth must be 7.5 inches minimum, and headroom space must span at least 78 inches.

4.1.6 Building Layout:

  Recalling back from the design concept, the building has three different occupancy types in which it's separated by retail, office, and residential. The building is broken up by the first two floors being retail, the next two are offices, and the remaining four are residential spaces. Before going into further detail, please note that the spaces in the retail and office follow the same style in which the rooms are throughout the perimeter with a large open space in the center. The bathrooms are at the bottom end of the floor plan, including a male, female, and gender-neutral room along with an ongoing staircase. The residential spaces on the other hand switch out the open space and include a recreational space and additional apartments.

4.1.6.1 Retail Level:

  The retail space was visualized to resemble a mall, but on a smaller scale. On the first floor, the retail is more focused on material goods including: a bookstore, a furniture store, clothing store, homegoods and decor store, and lastly a clothing boutique. In the middle of the space there is a small pond and tables seated for any occupants to sit by. Where the pond and tables are placed, above it includes an open atrium that can be viewed from the second floor. Refer to Figure 18 for a closer look at the layout of the first floor.

Male Restroom

Janitor

Female Restroom

Gender Neutral Restroom

Clothing Boutique

Staircase

Bookstore

Elevators

Homegoods Store

Furniture Store

(1) First Level: Shopping Mall
Scale: $\frac{1}{8}" = 1'-0"$

Figure 18: First floor: Retail floor for material goods. Includes an open gathering space with a pond, staircase, restrooms, clothing boutique, bookstore, furniture store, homegoods store, elevators. This layout follows the same suit for the second floor except that for the second floor there is an open atrium.

For the second floor of the retail space, it is focused more on food retail. There is a restaurant including a waiting area, tables and seats, and a kitchen. The other space is a supermarket including produce, deli, and various other products from cold to hot. In the middle of the space is the open atrium to allow for occupants to overlook the pond and the lively view beneath them. A future thought for enhancing the building is adding a waterfall flowing into the

atrium. This was based on participants' reactions to the rainfall sounds in the PEACE Room. If a soft trickling waterfall were flowing into the pond beneath the atrium, it could enhance the aesthetics of the building and create a peaceful ambience for the occupants sitting idly. Refer to Figure 19 for a closer look at the size of the atrium.
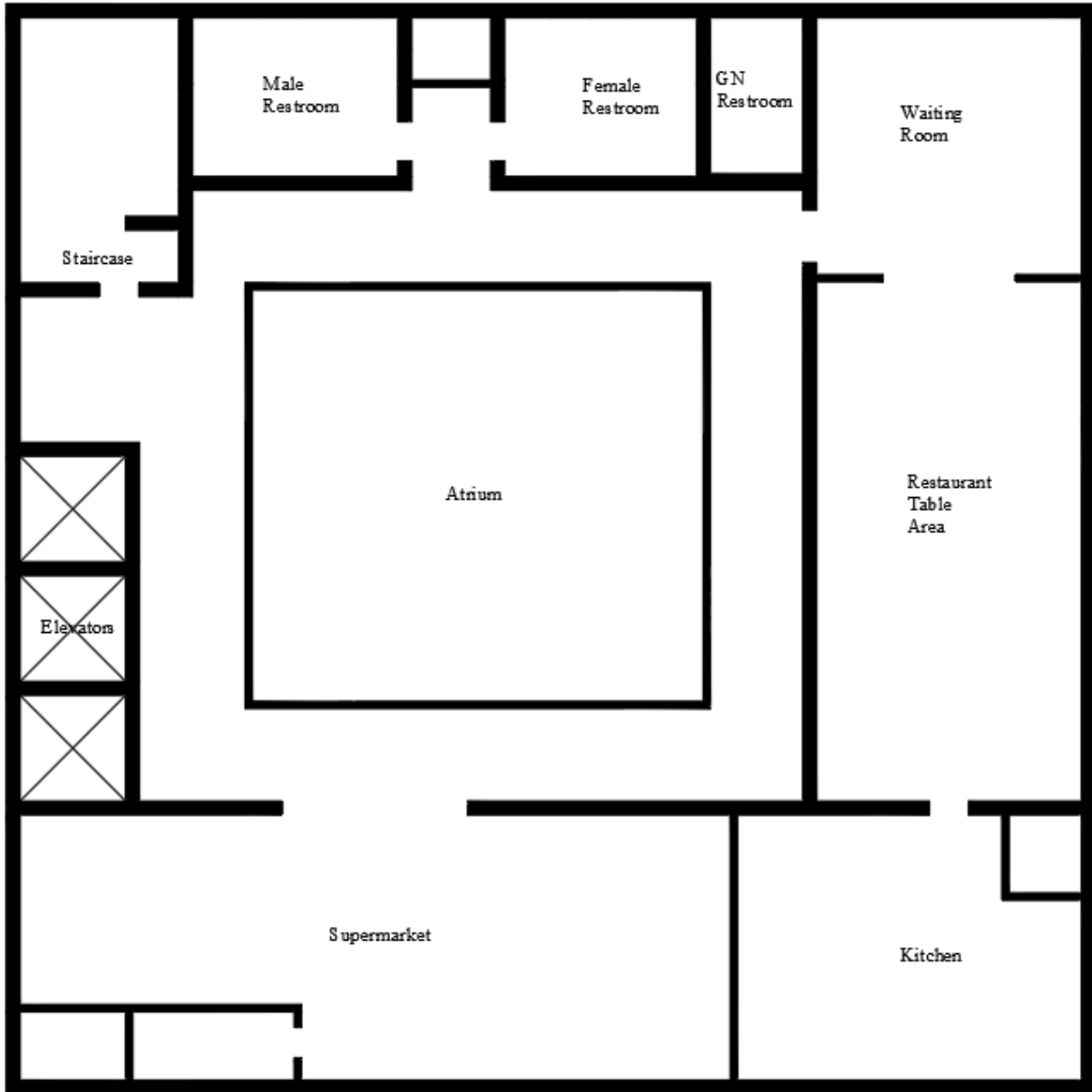
Second Level: Supermarket & Restaurant
Scale: ¼" = 1'-0"

Figure 19: Second floor: Food Retail. The atrium is a large open space in the middle sized at 31 ft. by 34 ft. This provides a good view of the space beneath found on the first floor while providing ample corridor space for occupants to pass through.

The convenience of these retail spaces is to allow for residential occupants to just take an elevator down to do shopping. Residents are able to purchase clothes, furniture, and decor for

their newly purchased homes. They can also purchase groceries to cook dinner or even spend the night out at a luxury restaurant. The overall purpose of including retail into the mixed-space is to serve a convenience and incentive factor for the prospective residents of the building, offering ready options for any employees working in the offices, and for any other occupants that are staying within the city.

4.1.6.2 Office Level:

The next two floors (floors three and four) are office spaces. The main target for this type of office is targeting small companies with 10-20 employees with frequent attendance. This office space follows a modern take with an open space in the middle filled with a common area and computer desks to not only allow the employees to work but to also promote taking breaks and resting on the couches. There is also a collaboration factor with the open space in which the employees are not tied down to their individual cubicles but allowed to speak to one another. What separates these two floors is that the third floor office has conference rooms and a cafe to help jumpstart the working day. The fourth floor has 3 executive/manager offices and a pantry/cafeteria for employees to have lunch. There is also a meeting room on this floor similar to the 3rd floor. The two office spaces are also crucial to this project as the PEACE rooms will be incorporated in the bottom left corner of each of their levels. Refer to Figure 20 for a closer look at the fourth floor, a reminder that the third and fourth office floors are variations of each other. On the third floor, the pantry would be swapped with a cafe and the executive offices swapped with conference rooms.
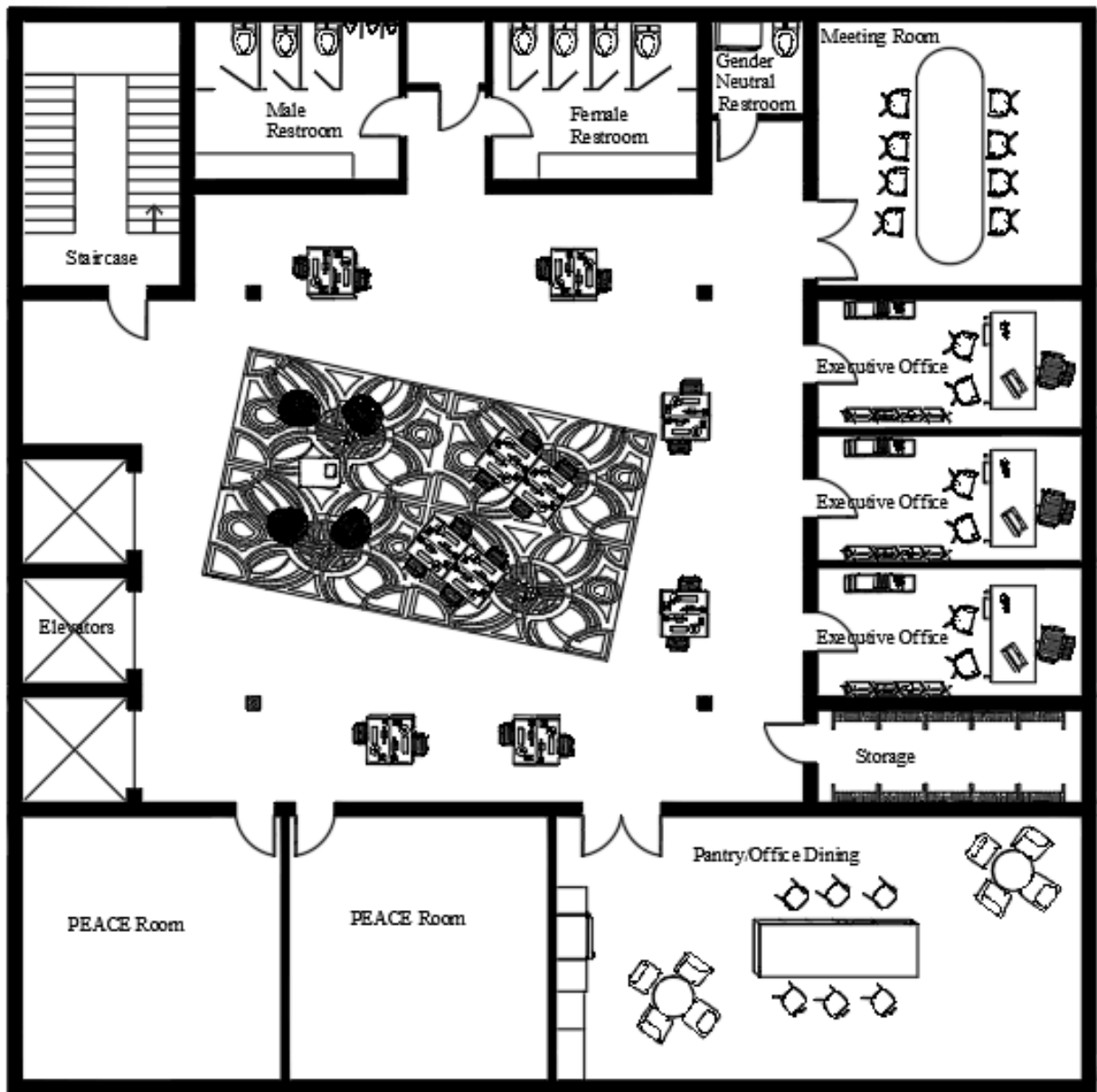
Fourth Level: Office
3
Scale: $\frac{1}{8}" = 1'-0"$

Figure 20: Fourth floor: Office space. There is the open space in the middle with the collaborative and modern office with a relaxation area and scattered desks - breaking away from the closed-off, traditional cubicle.The executive offices are broken into three, downsizing the executive and adding storage and a meeting room.

The prospective PEACE room will be split in half. Since the PEACE room only allows one person at a time, it would be more efficient to have a total of four rooms throughout the two floors to allow employees to maximize their break times with a peaceful meditation or calmness

to break free from the stresses of work life. It goes without saying that the PEACE room is basically fitting for the office spaces as most of the employees and workers can maximize the use more than the residents in the building who are possibly outside of their apartments during the day or the occupants who are mostly lounging in the retail spaces.

4.1.6.3 Residential Level:

There are three residential floors each with separate styles. The first style is the Single's apartments where there consists approximately five studio apartments fit for one person and a deluxe multispace apartment for multiple people. There is also a gathering space with a game room consisting of an arcade, board games, and consoles. Each of these apartm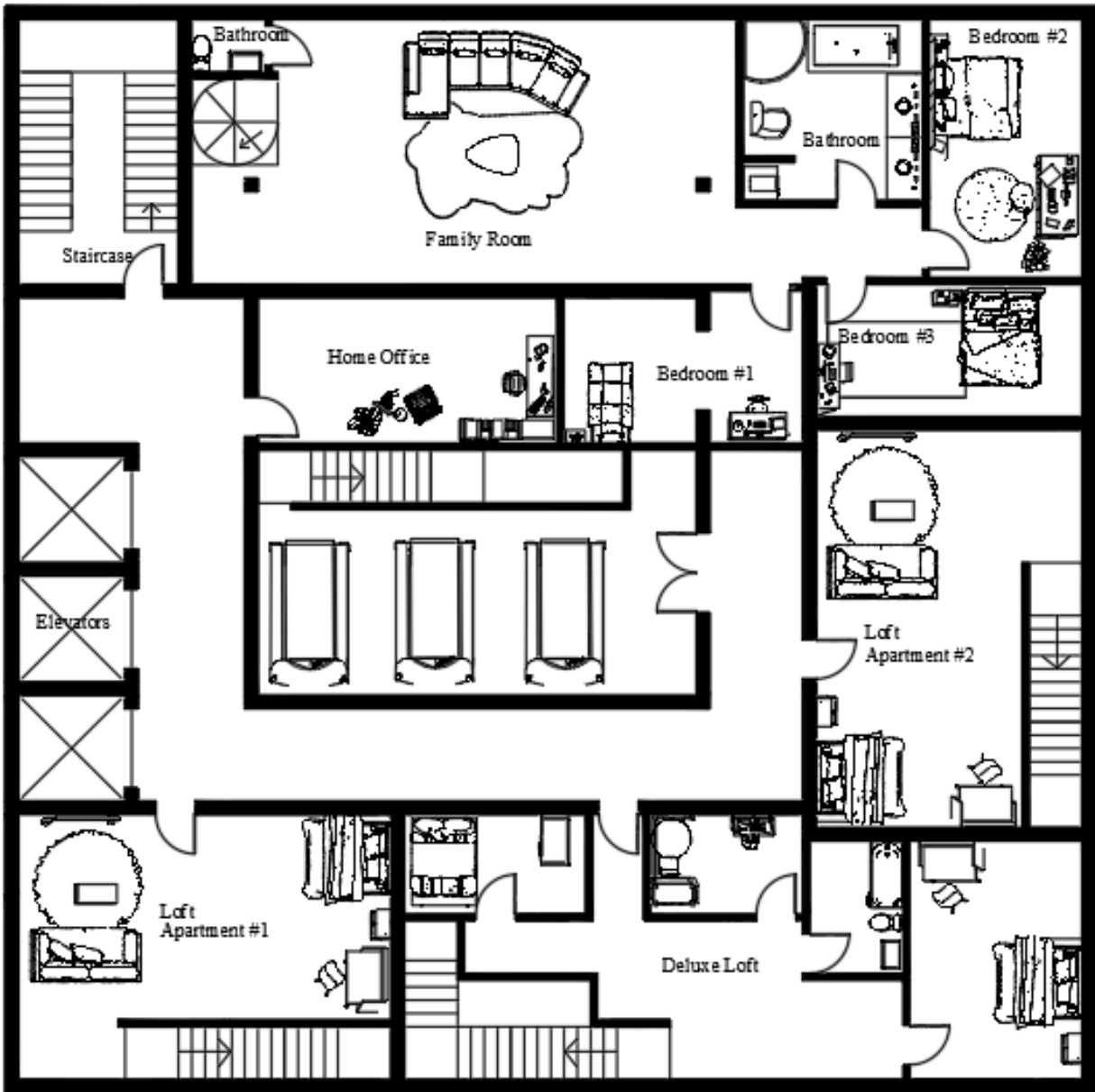ents include a living room, kitchen, bathroom, washer and dryer, and bedroom; with the deluxe having two extra bedrooms. The second style is the Family apartments where there consists of four multispace apartments and one studio apartment. These apartments follow the same suit and style as the studio and deluxe apartments (as applicable) and consist of a daycare for residents to leave their young-ones under supervision. The third and final style of the residential floor is the loft apartment. This space consists of an extra level to allow for the apartments to have an upper level and extra space. The loft apartments have a layout with a kitchen, dining room, washer and dryer, and bathroom on the first floor while the living room and bedroom are upstairs. On this loft style level, there is also a luxury penthouse consisting of three bedrooms, two bathrooms, washer and dryer, kitchen, dining room, and two living rooms on each level. Initially when developing the layout of the residential floors, each level only followed a single studio apartment layout consisting of seven apartments each floor with one of the apartments being a deluxe. Seeing as to how having only a studio apartment with one bedroom lowers the target audience in which the space is being marketed to.

Bathroom

Living Room

Walk-in Closet

Master Bath

Staircase

Master Bedroom

Kitchen

Elevators

Gym/Recreational Center

Loft Apartment #2

Deluxe Loft
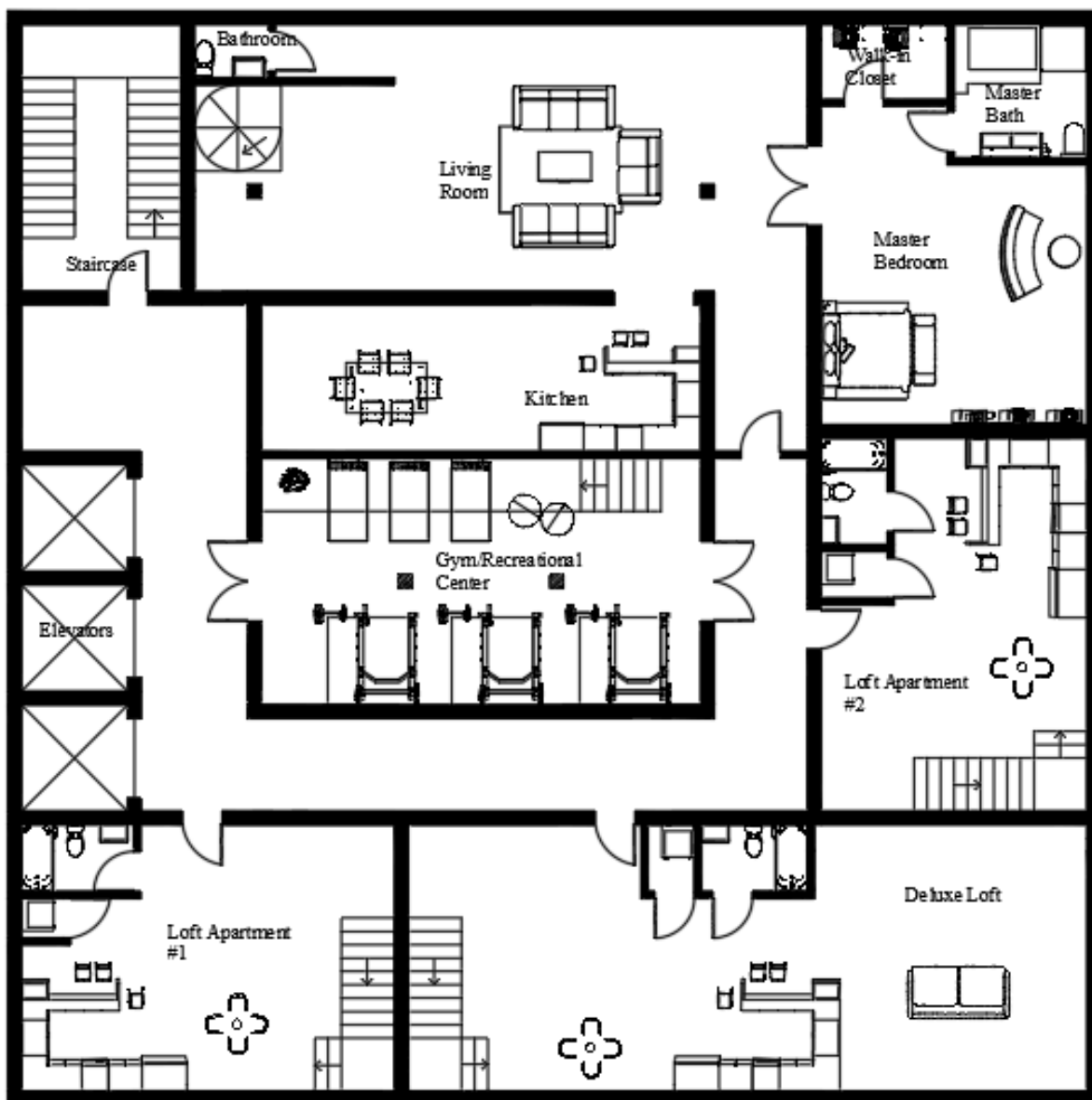
Loft Apartment #1

④ Seventh Level: Loft Apartment (Lower)

Scale: $\frac{1}{4}" = 1'-0"$

Bathroom

Family Room

Bedroom #2

Bathroom

Staircase

Home Office

Bedroom #1

Bedroom #3

Elevators

Loft
Apartment #2

Loft
Apartment #1

Deluxe Loft

⑤ Eighth Level: Loft Apartments (Upper)
Scale: $\frac{1}{4}'' = 1'\text{-}0''$

Figure 21-22: Loft apartments: There are three loft apartments and one large penthouse. These images are meant to provide the viewer a visual of how the stairs are incorporated and how the two levels of the loft apartments will connect.

With the variety in loft, multi, and studio apartments, there is an increase in audience as people have different tastes. An important component in an architectural building from a marketing standpoint is incentive. Now with the variety of the apartment types included, there is

also the variety and convenience of the recreational space. The first type having a young adult target audience provides a gathering space for them to mingle with one another. The second type has a majority of families who have young kids who can use a daycare while the parents head to work, or for young kids heading from school to have supervision in case the parents are unable to come home. Lastly, the third type has a gym that allows for residents to be active, should they not have to purchase a gym subscription, they will have access to bodybuilding, cardio, and various other sessions at their own convenience.

For the building layout, a mixed-use building type would provide solutions to many issues such as offering more housing, providing more office leasing space, and the convenience of retail to the residential occupants of the building all in one space. Given the parameters of each of the office spaces, the PEACE room can integrate well into the space without interfering with the current layout.

4.2 Structural System:

The final part in the design process was to add a basic structural system. This would include girders and columns. The first step was to place the girders and columns on to the first floor. The biggest challenge with this design was the fact that the first floor has an atrium that only extends to the second floor. This means the building can't have a central core and instead must rely solely on columns and girders.
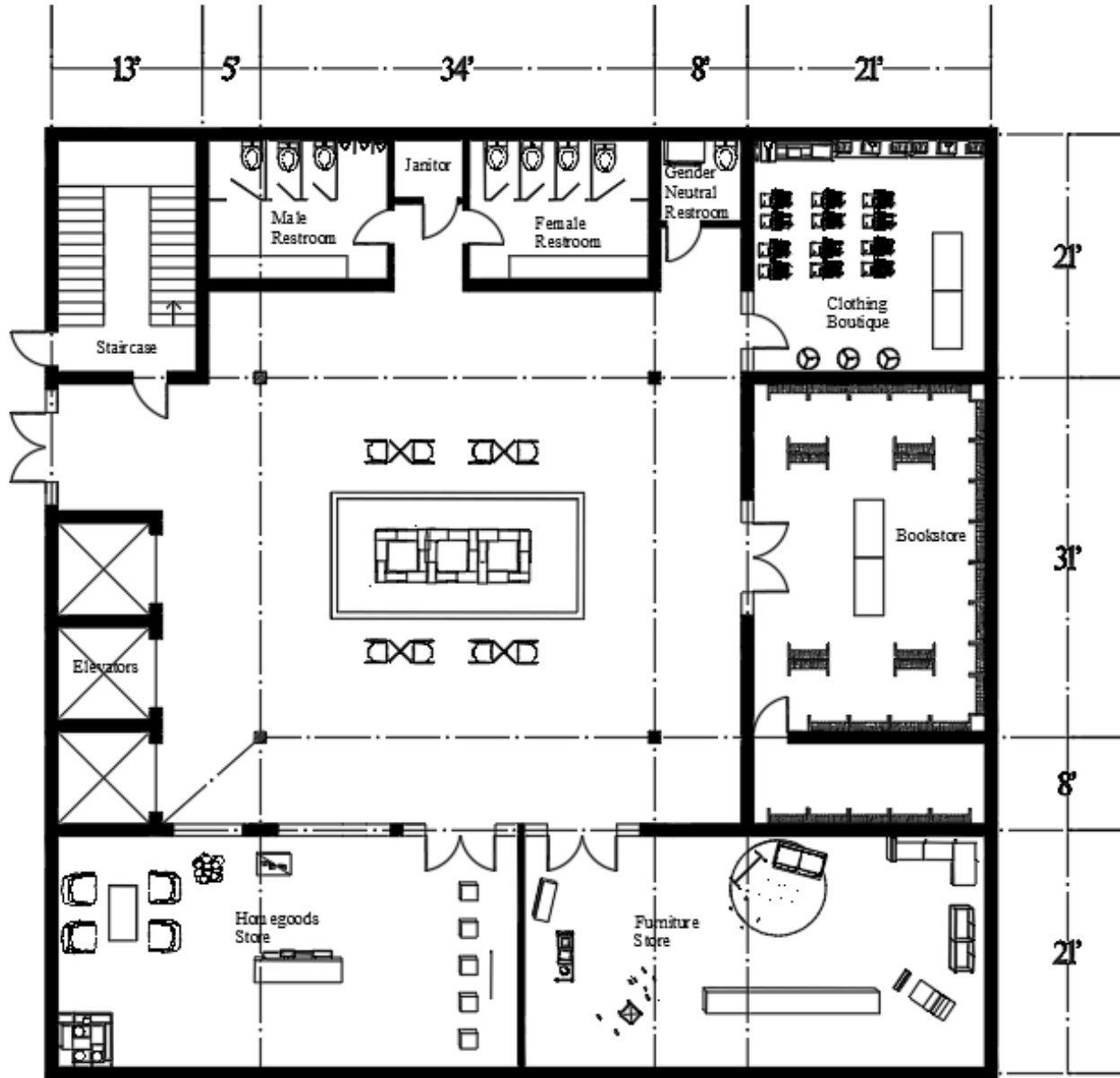
Figure 23: Revision of the ground floor. New additions include the new columns, clothing boutique and library revisions and changes to the bathrooms.
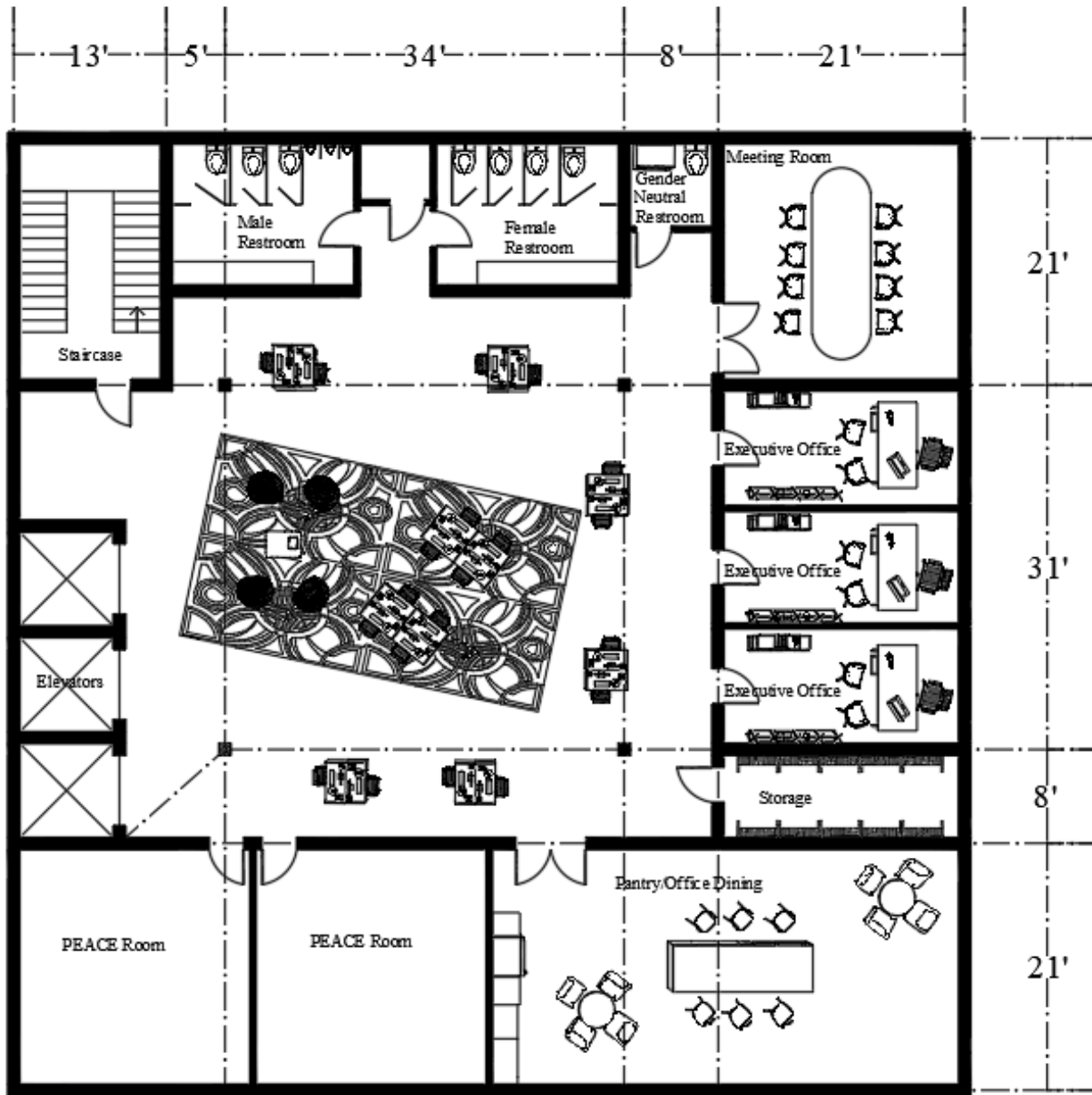
Figure 24: Revision of the fourth floor. New additions include the new columns, addition of the meeting room, changes to the executive offices and changes to the bathrooms.
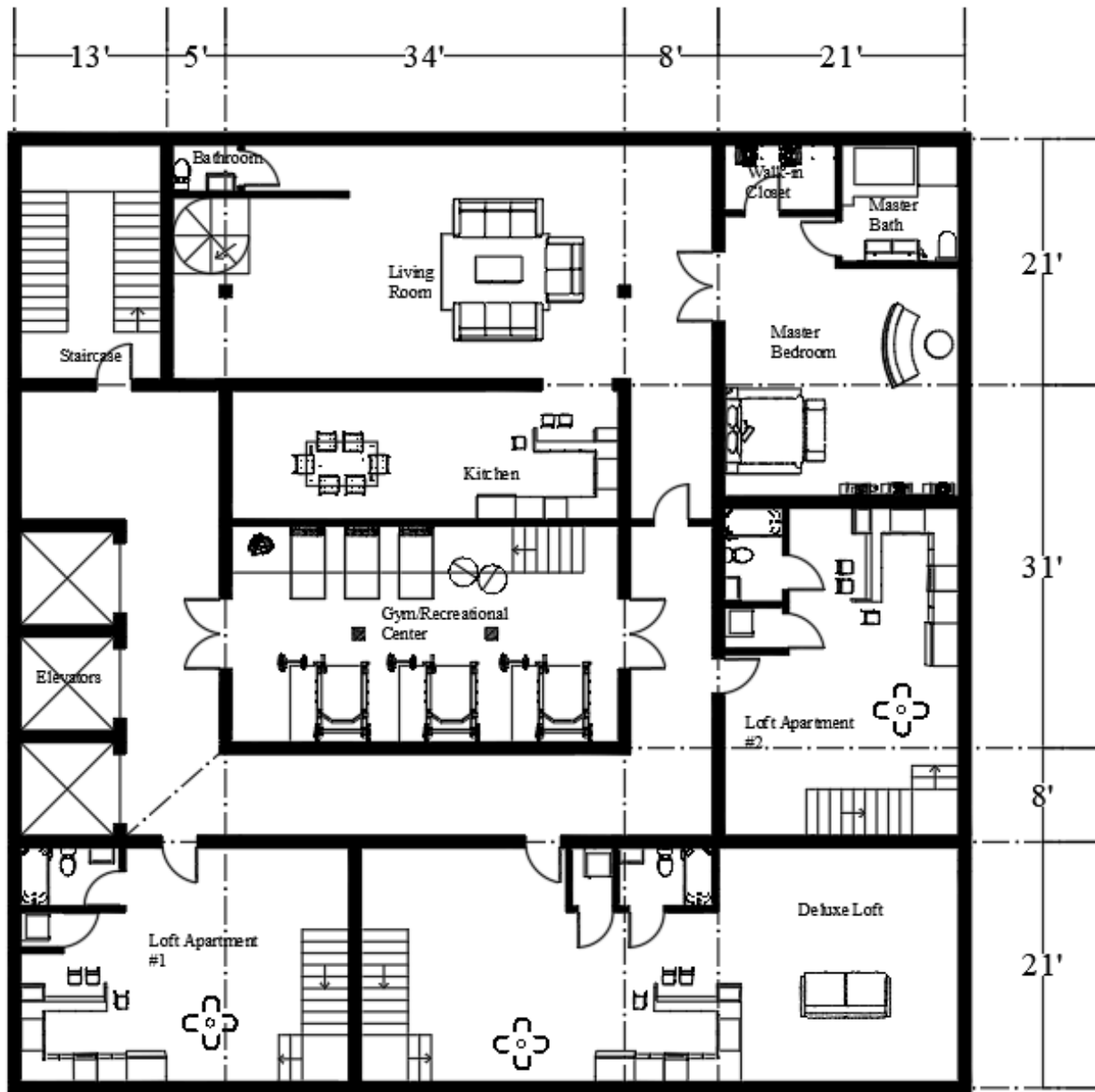
Figure 25: Revisions to the 7th floor. The revisions include the gym, luxury apartment size/layout, and addition of columns in the gym.
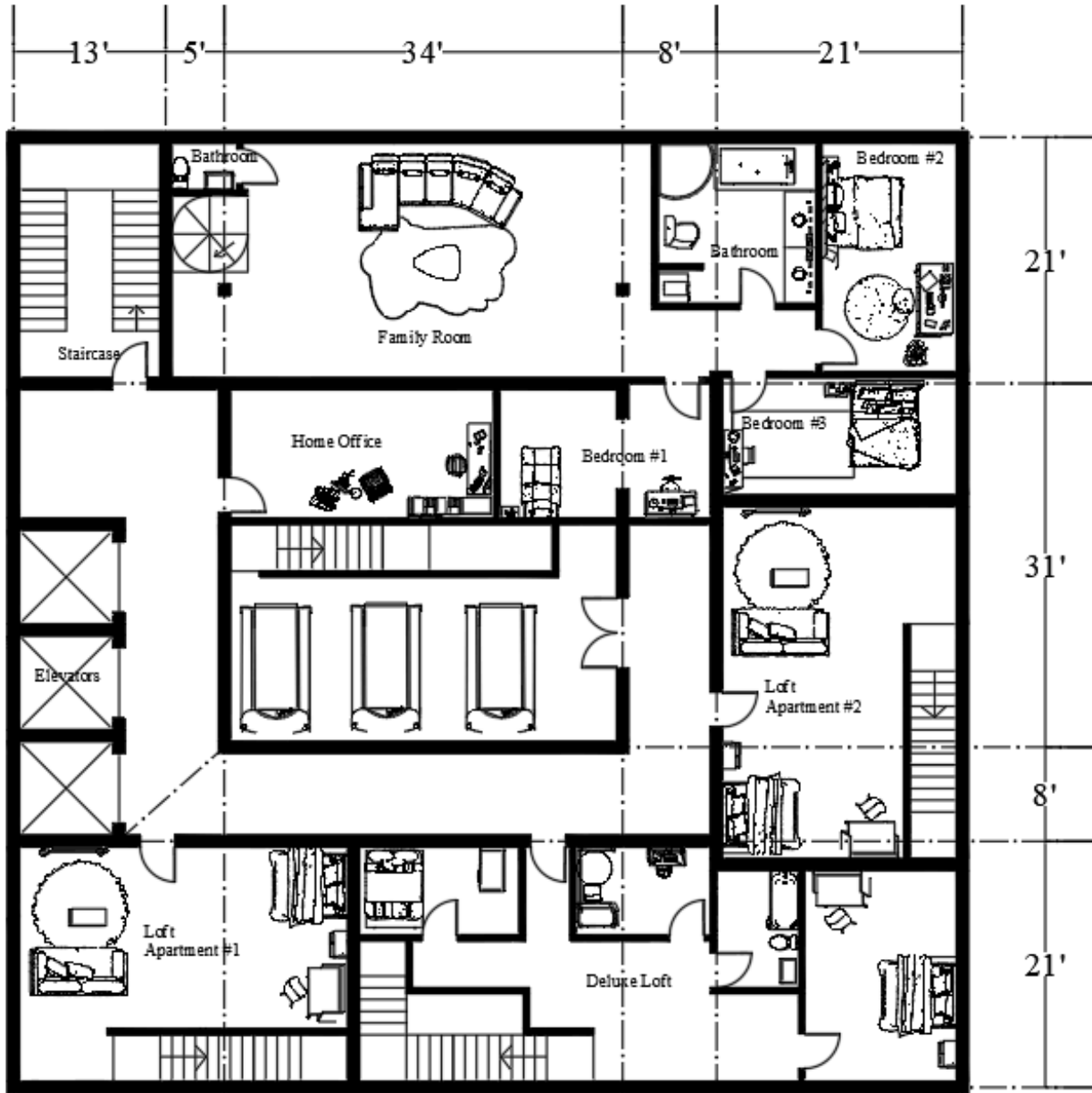
Figure 26: Revisions of the 8th floor. The revisions include the gym, luxury apartment size/layout, and addition of columns in the gym.

In order for the structural system to function, many walls needed to act as structural walls. The original floor plans had to be changed in order to account for this. Places like the library, 4th floor executive offices and the 7th and 8th floor penthouse had to be redesigned. The biggest obstacle was the atrium. In order to accomplish this a transfer needed to be placed on the third floor. This girder can handle the forces of the upper floors while still having an atrium. Refer to figure 27 for more details.
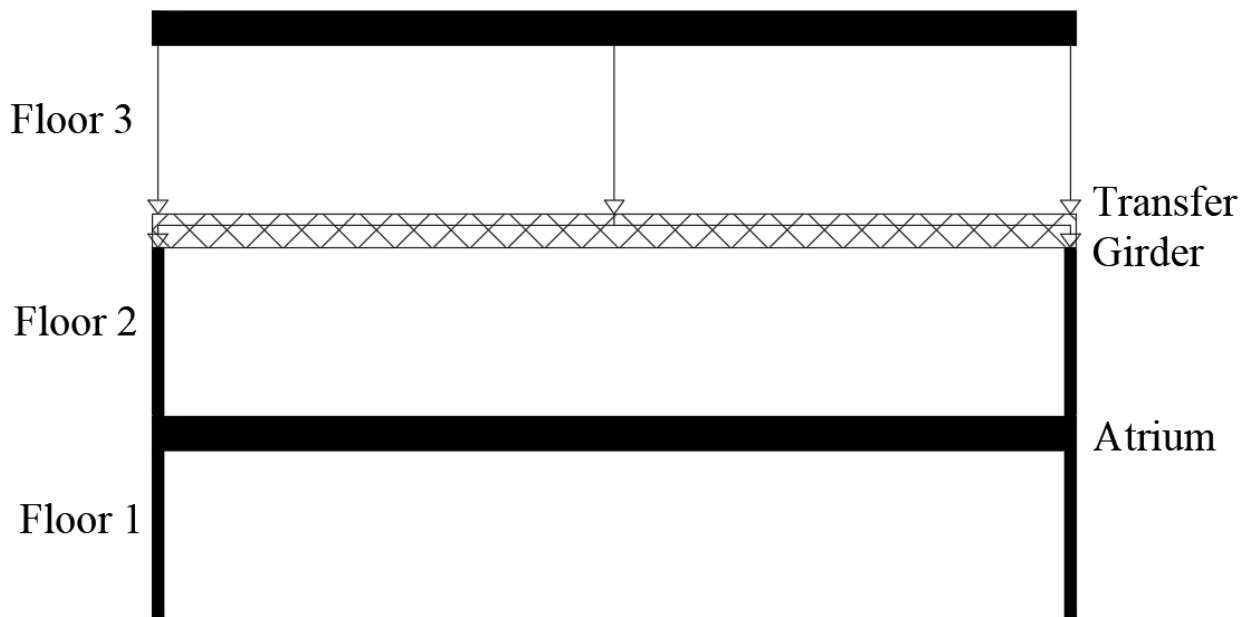
Figure 27: Second floor transfer girder. This is an initial sketch that shows the idea of the transfer girder and how it will absorb the loads on the upper floors.

Another challenge was the gym on the 7th and 8th floor. Due to there being a gym in the middle of both floors, something needed to be done about the vibrations. The AISC design guide 11 explains the idea and provides a solution to the vibrations. The guide has equations and tables that are used to determine what type of columns can be used in this situation. For this example we would look at the running category in table 1-1 and the aerobics category in table 1-2. Refer to figure 28 for the proposed solution.
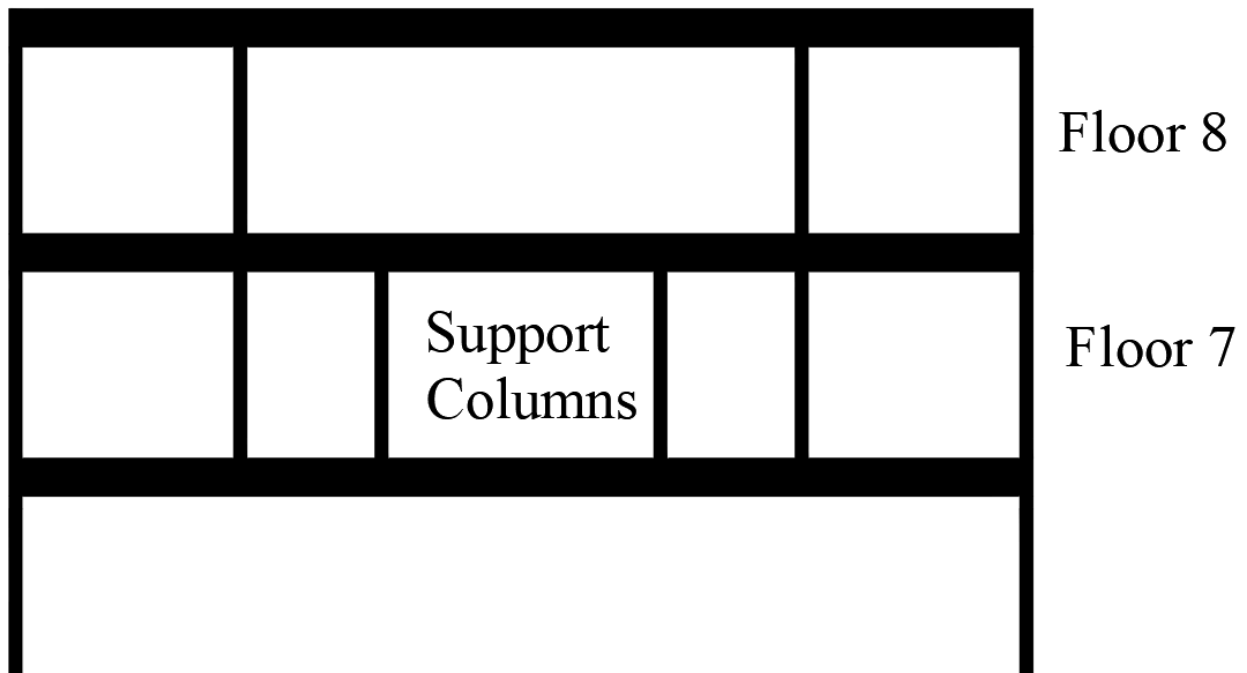
A full structural plan was not done for this project. If given more time, all columns and girders would be calculated. To show what this would look like, the top right support column and surrounding girders on the ground floor were calculated. The sizes and values for the girders and columns were taken from the American Institute of Steel Construction (AISC) 16th edition manual. First the loads had to be determined. The loads were found using the 2024 International Building Codes (IBC). The building has a total live load of 1210 Psf, the total dead load is 664 Psf, and the snow load is 45 Psf. It is to be assumed that the building will be constructed in Boston, hence why snow loads are used instead of roof loads. Refer to Figure 33 for more information on the loads.

After performing the calculations, the column was determined to W12x50 or a W14x53. Both sizes can support the loads. The W12x50 would be the smarter choice since it will cost less compared to the W14 column. The girder was determined to be a W10x12 girder. The reason why it is so small is due to the fact that the distance between this column and the next is only 10.5ft. This means there is less of a load being placed on the girder. It can be assumed that all columns can be W12x50. The girders would need further calculations to determine their sizes. Refer to the appendix for more information on the calculations.

5. Conclusions and Future Work

PANAS and Questionnaire Conclusions:

When looking at the PANAS results, certain conclusions can be drawn. Based on how participants reacted when transitioning from one setting to another, it can be concluded that the room size changing caused the most changes in participants' emotions. Unfortunately, after looking at the data, the majority of participants felt neutral between tests. There were some who did experience change but not a lot. This could just be because of the low sample size but it also could be due to the experiment set-up and how the PANAS test works.

For every test, participants were stationary and would either use their phones or play with one of the activities offered. None of these required the participant to get up and move which in turn didn't really allow them to truly notice the changes in the room. Same can be said about the sound. With both being water based there isn't a big difference between the two and it could cause the participant to feel indifferent.

Then there is how the PANAS was handled. The participant would fill it out before and after the test. This could get monotonous, especially if the participant is doing all three tests in one sitting. If the tests were spaced out more or if the PANAS wasn't required twice per test, it could potentially improve the data. It would give participants more time to reflect and less time to remember what their past answers were.

Greater conclusions can be drawn from the questionnaire. Feedback from the questionnaire was more direct and allowed the group to see how participants felt about each setting. After looking at all of the results, participants preferred the larger room setting and the rain sounds the most. Participants also were fond of the blue light. This also is somewhat reflected in the PANAS data. For example, participants felt more distress after they switched from large to small.

The questionnaire data does show a lot in terms of people's preferences. There is also potential for this to expand even further. Future groups can test different lighting, sizes, and sounds and use the questionnaire to get good and consistent data. The PANAS will need to be revised. Due to the amount of times participants complete the test as well as the length of time in between tests, it results in participants just putting what they put in last time. In order to get more reliable data from the PANAS, future groups must space out the tests more.

Tone Recognition:

One future goal for the room is to use machine learning to derive tone from voice recordings of questions posed to participants before and after entering the room. Through gathering information on participants' tones further insight can be gained on their stress levels. In order to develop a machine learning model more data must be obtained and then labeled. This data would short voice recording and would be labeled with the proper valence and arousal values to indicate emotion.

Camera:

Towards the end of this year the camera was upgraded to allow it to read depth, which in turn made doing posture analysis on participants possible. Through combining the regular camera with the depth camera posture analysis can be done which provides further insight on participants stress levels through their posture.
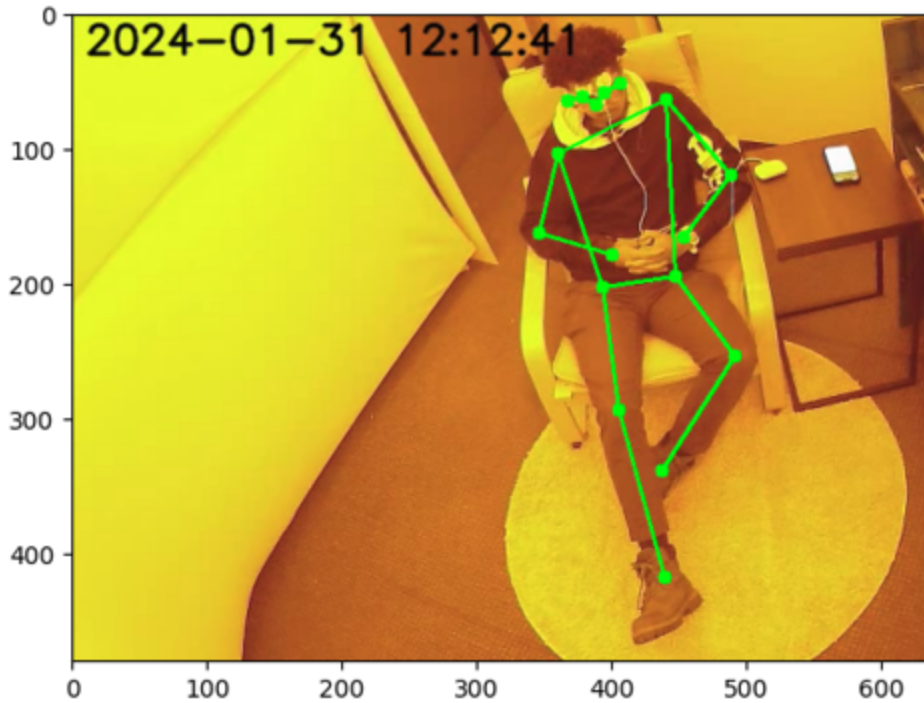
Figure 29: Demonstration of Posture Analysis: The image above depicts a participant undergoing posture analysis. The green lines are vectors mapped to the participants limbs, and through analyzing the positioning and length of the vectors the participants posture can be estimated.

Watch Data:

In order to process the watch data it must first be pulled from the bucket using a program such as Cyberduck as well as the access key and secret access key. Through Cyberduck the .avro files can be accessed which hold heart rate and electrodermal activity (EDA) data for participants. Through this data further information can be gathered about participants' stress levels by analyzing the changes in heart rate and EDA data over time and whether a decrease or increase is observed.

In-Depth Structural System:

While the structural system has a good start, a lot more needs to be done if this design were still to be used in the future. The analysis and calculations only cover one side of the building. In order to have a better idea on where to place the columns and girders, every single column would have to be calculated. After each column is found, it's possible to test new column placements as well as determine the cost for the system. The same can be done for the girders as well as any beams that need to be included.

PEACE Room Design:

One of the design goals that was not met was designing a better PEACE Room. A goal was to take feedback from the questionnaires and make suggestions to improve the design. These

designs would then be implemented into the architectural design plans. Some suggestions that developed were damping the lights since most participants thought they were too bright, opening the space so it doesn't feel as cramped, and adding new sounds to test. Another idea was to redo the walls and motors. The use of wall panels attached to motors would be developed to make installation easier and the motors chosen wouldn't be as loud. These ideas would have been expanded upon if time permitted.

<u>Advertisement</u>

Most of the participants gathered were either friends or classmates. Some were recommended by the advisors but for the most part, no participants volunteered for the experiment. Posters were placed around the school at one point but they didn't attract any attention. The poster can be found in the appendix. Further expansion of the advertisements could be made but it might not be enough. If possible, giving participants an incentive to go may be necessary. A raffle could be held where if a student volunteers for an experiment, their name will be put into a raffle and the winner will win a gift card. If a greater number of participants are needed, the advertisements need to be improved.

<u>VR Data:</u>

Many changes and fixes need to be made in order to keep the VR testing alive. According to last year's MQP team, the VR game was apparently deleted and all they had left was the executable. This means that the game cannot be edited other than changing the color order using a text file. However the color changer is inconsistent. After trying to change the order to white, blue and red, it would keep skipping colors and not doing what it was supposed to do. Many participants claimed that the VR headset was uncomfortable when combined with the EEG headset. The EEG headset would also struggle to consistently connect to the computer. The VR tracking cameras would sometimes disconnect when the participant was in the middle of the game.

All of these issues were not solved and it made VR testing almost impossible. If the use of VR is still needed for this test, people who have experience with game design and VR need to come onto the project in order to solve these issues. If that doesn't happen, the VR testing should be abandoned.

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Appendix:

Appendix A: Load Calculations:

Columns

$(1.2(66.4) + 1.6(120) + 0.5(45)) \times 10.25 \times \frac{1}{100} = 303.77$ kips

W14 x 48 $\phi_c P_n = 331$, $r_x/r_y = 3.06$, $A_g = 14.1$, $r_y = 1.91$
W12 x 45 $\phi_c P_n = 316$, $r_x/r_y = 2.64$, $A_g = 13.1$, $r_y = 1.95$
W10 x 45 $\phi_c P_n = 333$, $r_x/r_y = 2.15$, $A_g = 13.3$, $r_y = 2.01$

W14 $\rightarrow \dfrac{15 ft \times 12'''}{1.91} = 94.24$

W12 $\rightarrow \dfrac{15 \times 12'''}{1.95} = 92.31$

W10 $\rightarrow \dfrac{15 \times 12'''}{2.01} = 89.55$

Inelastic $\quad 4.71 \sqrt{\dfrac{E}{F_y}} = 113.4$

W10 W12 W14   113.4

$F_e = \dfrac{\pi^2 E}{\left(\frac{L}{r}\right)^2}$

W10
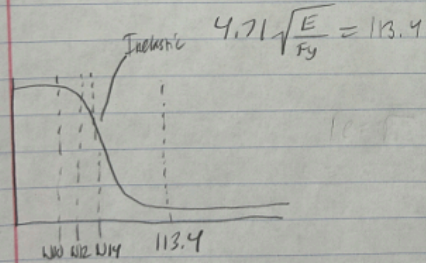
$F_e = \dfrac{\pi^2 (29000)}{89.55^2} = 35.69$ ksi

$F_{cr} = \left[0.658^{(50/35.69)} \right] 50 = 27.817$ ksi

$\phi P_n = 0.9 (27.82)(13.3) = 333.005 > 333 \; \times$

W12

$$F_e = \frac{\pi^2 (29000)}{92.31^2} = 33.59 \text{ ksi}$$

$$F_{cr} = \left[0.658^{(50/33.59)}\right] 50 = 26.82 \text{ ksi}$$

$$\emptyset P_n = 0.9 (26.82)(13.1) = 316.21 > 316 \times$$

W14

$$F_e = \frac{\pi^2 (29000)}{94.24^2} = 32.23 \text{ ksi}$$

$$F_{cr} = \left[0.658^{(50/32.23)}\right] 50 = 26.12 \text{ ksi}$$

$$\emptyset P_n = 0.9 (26.12)(14.1) = 331.4 > 331 \times$$

W14×53 $\phi_c P_n = 369$, $r_x/r_y = 3.07$, $A_s = 15.6$, $r_y = 1.92$
W12×50 $\phi_c P_n = 355$, $r_x/r_y = 2.64$, $A_g = 14.6$, $r_y = 1.96$
W10×49 $\phi_c P_n = 449$, $r_x/r_y = 1.71$, $A_g = 14.4$, $r_y = 2.54$

W14 → $\dfrac{15'×12''/'}{1.92} = 93.75$

W12 → $\dfrac{15'×12''/'}{1.96} = 91.84$

W10 → $\dfrac{15'×12''/'}{2.54} = 70.87$

W10

$F_e = \pi^2(29000)/70.87^2 = 56.99$ ksi
$F_{cr} = [0.658^{(50/56.99)}]50 = 34.63$ ksi
$\phi P_n = 0.9(34.63)(14.4) = 448.8 < 449$ ✓

W12

$F_e = \pi^2(29000)/91.84^2 = 33.93$
$F_{cr} = [0.658^{(50/33.93)}]50 = 26.98$
$\phi P_n = 0.9(26.98)(14.6) = 354.51 < 355$ ✓

W14

$F_e = \pi^2(29000)/93.75^2 = 32.56$
$F_{cr} = [0.658^{(50/32.56)}]50 = 26.29$
$\phi P_n = 0.9(26.29)(15.6) = 369.11 > 369$ ✗

72

$$W_u = (1.2(664) + 1.6(1210)) \times \frac{1}{1000} = 2.73 \, W/ft$$

$$M_u = \frac{(2.73)(10.5)^2}{8} = 37.62$$

3-2 W10×12 Wt = 12 psf M_u = 46.9 kip·ft

$$W_u = (1.2(664+12) + 1.6(1210)) \times \frac{1}{1000} = 2.75 \, k/ft$$

$$M_u = \frac{(2.75)(10.5)^2}{8} = 37.89 < 46.9 \checkmark$$

3-3 W10×12 $I_x = 53.8 \, in^4$

$$\frac{1}{360}(12 \times 10.5) = 0.35$$

$$\Delta_{LL} = \frac{5(1210/12)(12 \times 10.5)^4}{(384)(29 \times 10^6)(53.8)} = 0.21 < 0.35 \checkmark$$

$$\frac{1}{240}(12 \times 10.5) = 0.525$$

$$\Delta_{DL} = \frac{5((1210 + 664 + 12)/12)(12 \times 10.5)^4}{(384)(29 \times 10^6)(53.8)} = 0.33 < 0.525 \checkmark$$

The Gilder is W10×12

Appendix B: Experiment Poster:

Appendix C: Design Drawings:
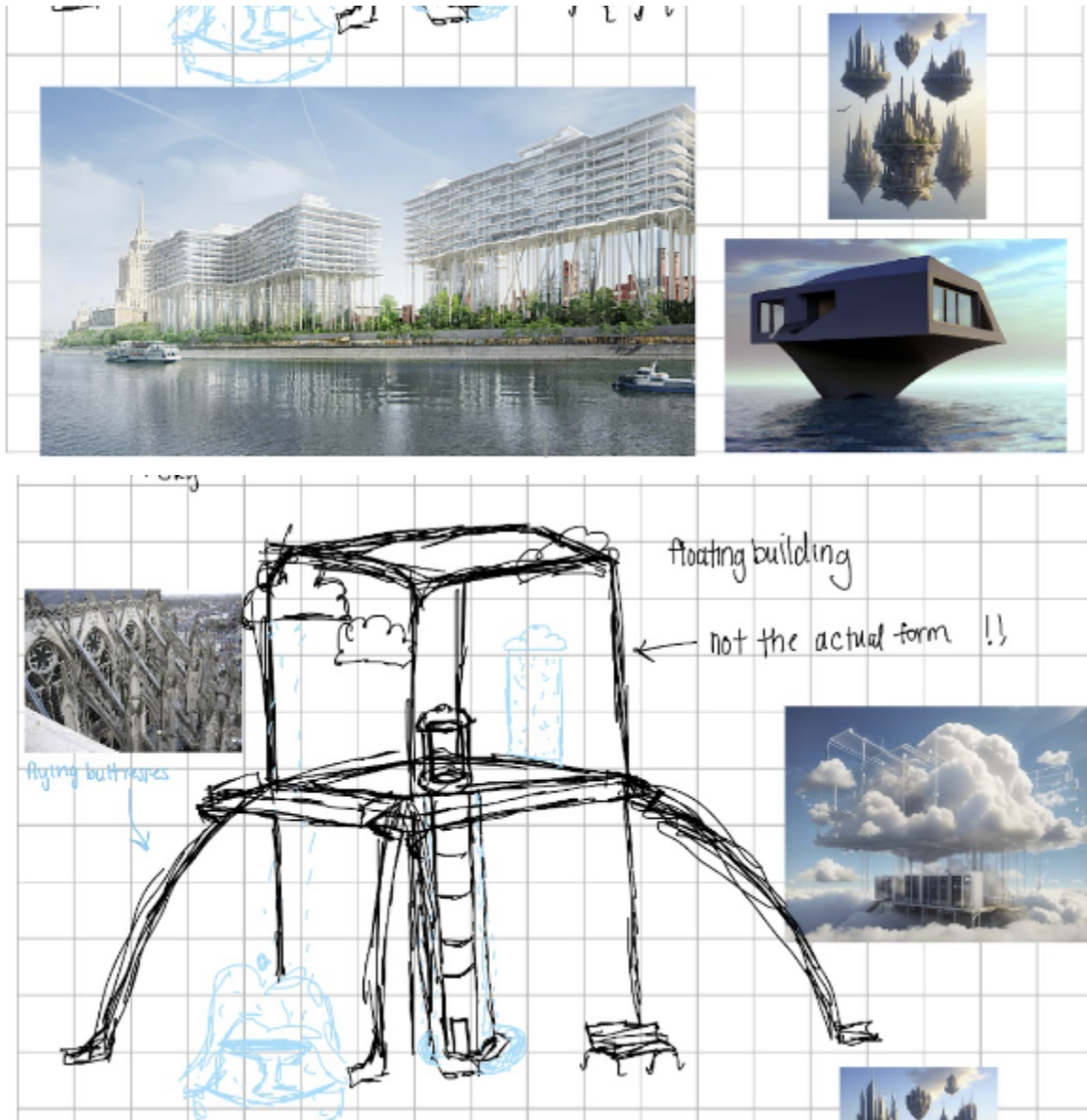
Top image shows inspirations from quick google searches. Bottom image shows the first iteration of the floating building's structure.
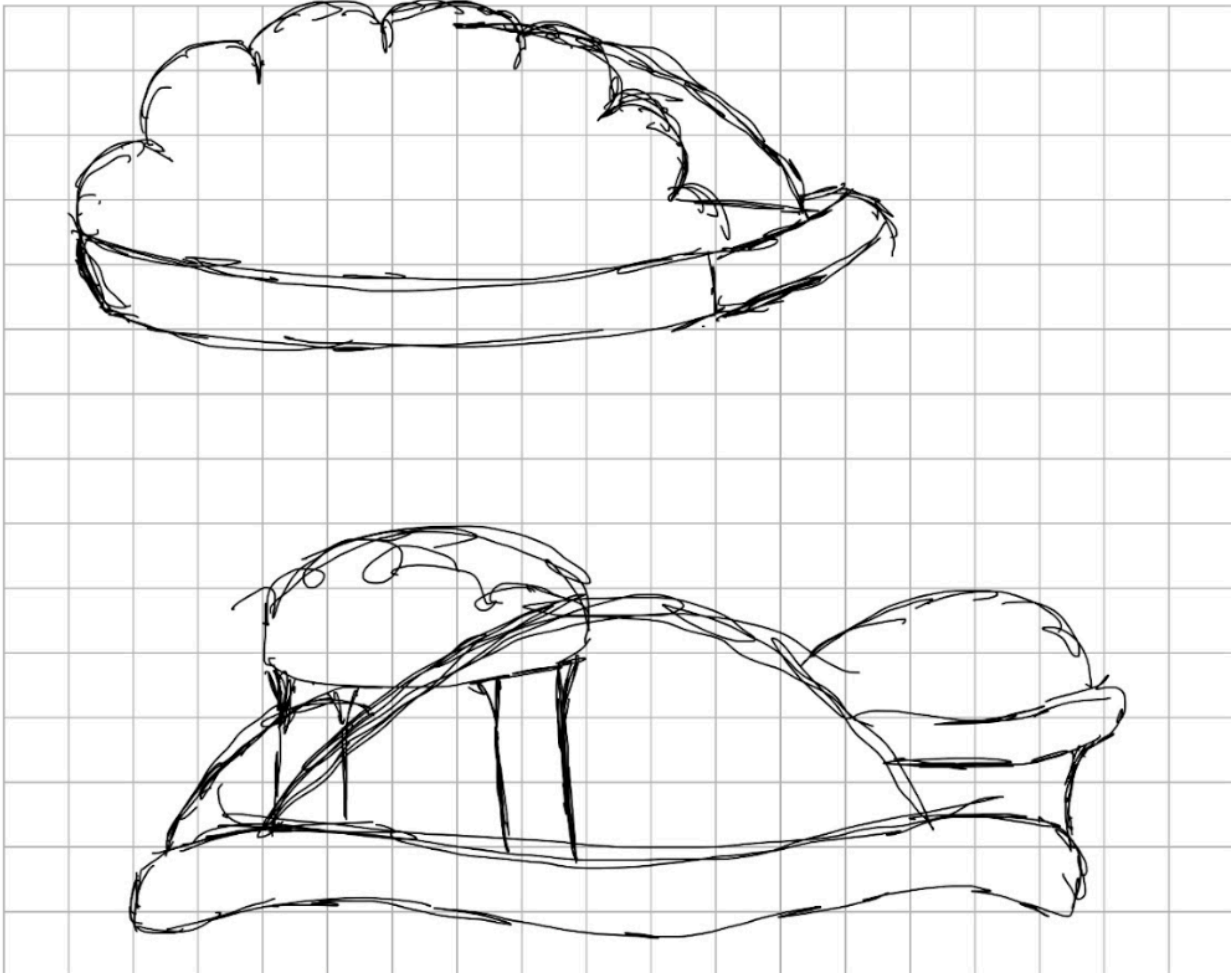
Cloud form iterations. Clouds come in many different sizes and shapes but which kind of form would be able to stand on its own and function as a proper building like the typical box form. How can a mixed-use program be implemented into this spherical form?

Gothic Arch w/ light?
motifs

cloud shap
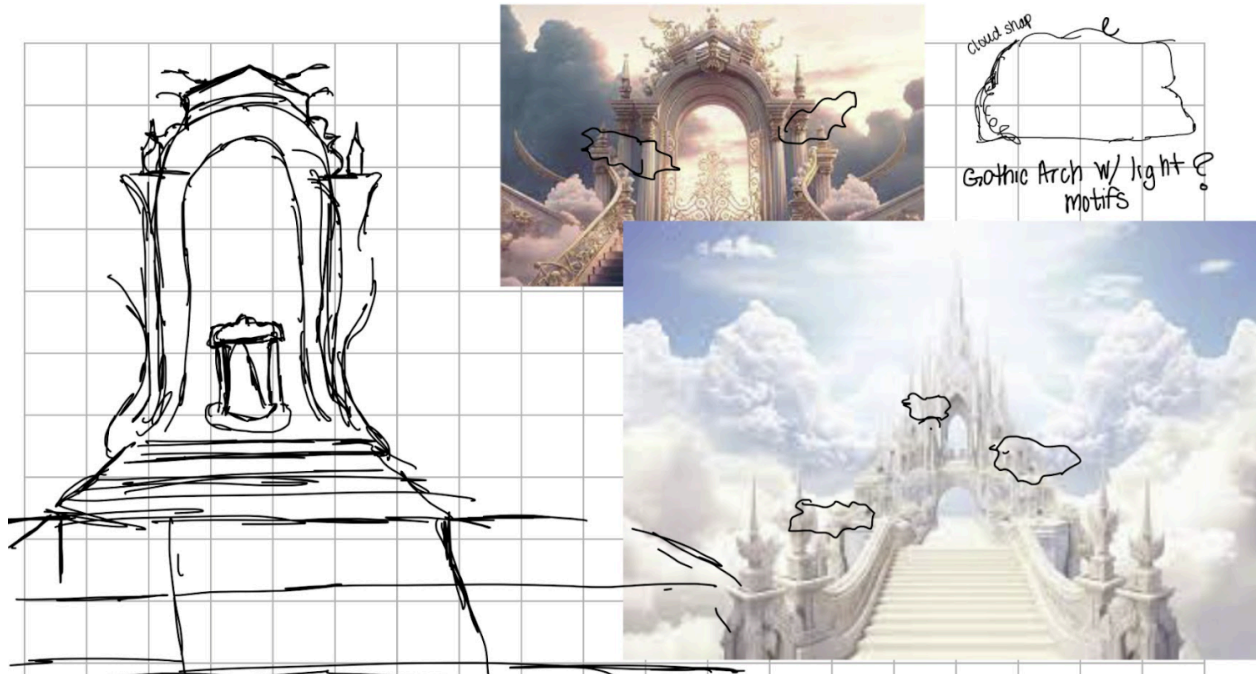
The gothic architecture inspirations that align with the Western Catholic imagery of Heaven of a cathedral or castle. But the flaw of this form is that it show the imbalance of Heaven's Cloud working equally on both sides where it's fully aligning with Heaven in the religious sense.
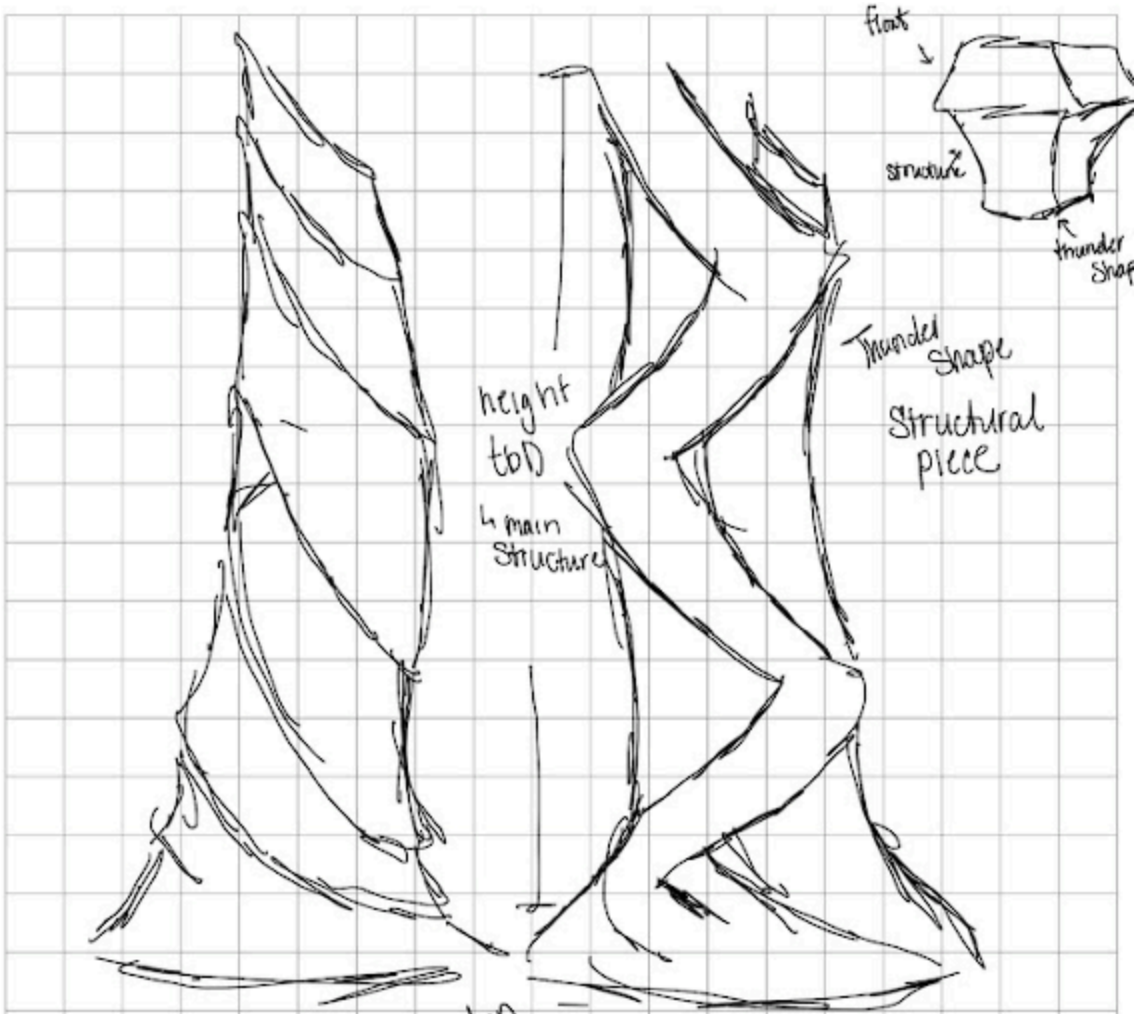
One drawing iteration that eventually led to the final form of the project. The purpose of this drawing was to visualize how the lightning shape can be incorporated into the building.

Appendix D Python Code for the PEACE GUI:

```python
import sys
import numpy as np
import os  # Add this import for accessing file paths
from PyQt5.QtWidgets import QApplication, QMainWindow, QWidget,
QVBoxLayout, QPushButton, QStackedWidget, QSlider, QLabel, QHBoxLayout
from PyQt5.QtMultimedia import QMediaContent, QMediaPlayer
from PyQt5.QtCore import QUrl  # Add this import for QUrl
from PyQt5.QtGui import QColor, QPalette
from PyQt5.QtCore import Qt # Text
from PyQt5.QtGui import QPixmap  # Import QPixmap for handling images
```

```python
import serial
import time
import numpy as np
import cv2
from pylsl import StreamInlet, resolve_stream
import pandas as pd
import threading
import datetime
import subprocess
import boto3
import os


'''
Wall 1 motor 1- top of left wall
Wall 1 motor 2- middle of left wall
Wall 1 motor 3- bottom of left wall
Wall 1 motor 4 - left part of celing
Wall 2 motor 1 - top of close wall
Wall 2 motor 2 - middle of close wall
Wall 2 motor 3 - bottom of close wall
Wall 3 motor 4 - right part of the celing
Roof motor 2 & 4 dont work
'''


# Replace the serial port names with the appropriate ones for your
Arduino.
# The first two arduino gets to the roof control
# The roof motors are number 4
serial_ports = ['COM3' ,'COM4' ,'COM5' ,'COM6']
# number of motors
motor_num = 16
# sleep period
sleep_prd = 1
# park period
park_prd = 14
# Motor modes
STOP     = 0
FORWARD  = 1
```

```python
BACKWARD = 2

# ----- Create a list of serial objects
serial_objects = [serial.Serial(port, 9600) for port in serial_ports]

#Walls al the way in, 0 is in 15 is out
prv_setup = [[0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0]]
cur_stat = prv_setup

class MotorControlGUI(QMainWindow):
    #matches motors with walls, 1 through 4 each corresponding with a wall
    motor_serial = np.array([1, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 4, 4, 4,
4])
    #Assigns each motor a position on the wall.
    motor_pin    = np.array([1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3,
4])

    def __init__(self):
        super().__init__()
        self.park_motors()#Resets motors to be all the way in
        self.setWindowTitle("Motor Control GUI")
        self.setGeometry(100, 100, 400, 300)

        self.central_widget = QStackedWidget()
        self.setCentralWidget(self.central_widget)

        #the different predetermined setups
        self.setup_A = np.array([[0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0],
[0, 0, 0, 0]])#All the way in
        self.setup_B = np.array([[15, 15, 15, 15], [15, 15, 15, 15], [15,
15, 15, 15], [15, 15, 15, 15]])#All the way out
        self.setup_C = np.array([[7, 7, 7, 7], [7, 7, 7, 7], [7, 7, 7, 7],
[7, 7, 7, 7]])#Halfway
        self.setup_D = np.array([[5, 5, 7, 15], [15, 0, 13, 4], [4, 0, 15,
3], [15, 6, 0, 10]])
        self.setup_H = np.array([[0, 0, 12, 7], [13, 2, 5, 5], [0, 2, 11,
7], [8, 8, 8, 7]])

        # Inside your MotorControlGUI class constructor
        palette = self.palette()
```

```python
        palette.setColor(self.backgroundRole(), QColor("#F2E0C9"))  # Set
background color
        self.setPalette(palette)



        self.page_1 = QWidget()
        layout_1 = QVBoxLayout()

        # Add title page for the GUI
        title_label = QLabel("PEACE\nPersonal Emotional Augmented
Controlled Environment")
        title_label.setStyleSheet("color: #393640; font-size: 17px;
font-weight: bold;")
        title_label.setAlignment(Qt.AlignCenter)  # Center-align the text


        # Add Image
        image_label = QLabel()
        pixmap =
QPixmap(r"C:\Users\Ethan\Documents\2023SummerWork\PEACE_GUI\PEACE.png")
        image_height_inches = 2.5  # Desired height in inches
        image_height_pixels = int(image_height_inches *
pixmap.logicalDpiY())  # Convert inches to pixels
        pixmap = pixmap.scaledToHeight(image_height_pixels,
Qt.SmoothTransformation)  # Scale pixmap to desired height
        image_label.setPixmap(pixmap)
        image_label.setAlignment(Qt.AlignCenter)

        layout_1.addWidget(title_label)
        layout_1.addWidget(image_label)  #

        #buttons for each of the walls
        wall_button_1 = QPushButton("Wall 1")
        wall_button_1.clicked.connect(lambda: self.show_wall_page(1))
        wall_button_2 = QPushButton("Wall 2")
        wall_button_2.clicked.connect(lambda: self.show_wall_page(2))
        wall_button_3 = QPushButton("Wall 3")
        wall_button_3.clicked.connect(lambda: self.show_wall_page(3))
        wall_button_4 = QPushButton("Wall 4")
        wall_button_4.clicked.connect(lambda: self.show_wall_page(4))
        layout_1.addWidget(wall_button_1)
```

```python
layout_1.addWidget(wall_button_2)
layout_1.addWidget(wall_button_3)
layout_1.addWidget(wall_button_4)
self.page_1.setLayout(layout_1)
self.central_widget.addWidget(self.page_1)


self.page_1.setLayout(layout_1)
self.central_widget.addWidget(self.page_1)

# Add a button to navigate to the Roof page
roof_button = QPushButton("Roof")
roof_button.clicked.connect(self.show_roof_page)
layout_1.addWidget(roof_button)

#Participant Button - opens panas and consent form
participant_button = QPushButton("Participant Page")
participant_button.clicked.connect(self.participant_loop)
layout_1.addWidget(participant_button)

#Data Button
data_button = QPushButton("Data Page")
data_button.clicked.connect(self.show_data)
layout_1.addWidget(data_button)

self.page_1.setLayout(layout_1)
self.central_widget.addWidget(self.page_1)


#Create the Roof Page
self.roof_page = self.create_roof_page()
self.central_widget.addWidget(self.roof_page)

#Creates buttons for the presets
setup_button_A = QPushButton("Apply Setup A (Walls In)")
setup_button_B = QPushButton("Apply Setup B (Walls out)")
setup_button_C = QPushButton("Apply Setup C (Halfway)")
setup_button_D = QPushButton("Apply Setup D")
setup_button_H = QPushButton("Apply Setup H")
```

```python
        setup_button_A.clicked.connect(lambda:
self.apply_setup(self.setup_A))
        setup_button_B.clicked.connect(lambda:
self.apply_setup(self.setup_B))
        setup_button_C.clicked.connect(lambda:
self.apply_setup(self.setup_C))
        setup_button_D.clicked.connect(lambda:
self.apply_setup(self.setup_D))
        setup_button_H.clicked.connect(lambda:
self.apply_setup(self.setup_H))

        layout_1.addWidget(setup_button_A)
        layout_1.addWidget(setup_button_B)
        layout_1.addWidget(setup_button_C)
        layout_1.addWidget(setup_button_D)
        layout_1.addWidget(setup_button_H)


        # Initialize the media player
        self.media_player = QMediaPlayer()

        #creates the page for the sounds
        self.music_page = QWidget()
        layout_music = QVBoxLayout()

        #Music Button
        music_button = QPushButton("Music Page")
        music_button.clicked.connect(self.show_music_page)
        layout_1.addWidget(music_button)

        #Reset Button
        reset_button = QPushButton("Reset")
        reset_button.clicked.connect(lambda: self.reset_sliders())
        layout_1.addWidget(reset_button)

        #Send Motor Button
        send_button = QPushButton("Send Motor Values")
        send_button.clicked.connect(self.send_motor_control)
        layout_1.addWidget(send_button)
```

```python
        #creates wall pages for each wall
        self.wall_pages = []
        for wall_num in range(1, 5):
            wall_page = self.create_wall_page(wall_num)
            self.wall_pages.append(wall_page)
            self.central_widget.addWidget(wall_page)

        self.motor_values = [[0, 0, 0, 0] for _ in range(4)]  # Initial
values for each wall's motors
        self.global_motor_values = np.array(self.motor_values)  # Global
numpy array



        #Music Page
        ocean_button = QPushButton("Ocean")
        ocean_button.clicked.connect(lambda:
self.play_music(r"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\Music\ocean rolling waves.mp3"))
        rain_button = QPushButton("Rain")
        rain_button.clicked.connect(lambda: self.play_music(r"C:\Users\MQP
BuiltEnv Team\Downloads\2023SummerWork\Music\light rain.mp3"))
        birds_button = QPushButton("Birds")
        birds_button.clicked.connect(lambda:
self.play_music(r"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\Music\morning birds chirp.mp3"))
        waterfall_button = QPushButton("Waterfall")
        waterfall_button.clicked.connect(lambda:
self.play_music(r"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\Music\waterfall.mp3"))
        river_button = QPushButton("River")
        river_button.clicked.connect(lambda:
self.play_music(r"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\Music\running river.mp3"))

        layout_music.addWidget(ocean_button)
        layout_music.addWidget(rain_button)
        layout_music.addWidget(birds_button)
        layout_music.addWidget(waterfall_button)
        layout_music.addWidget(river_button)
```

```python
        stop_button = QPushButton("Stop Music")
        stop_button.clicked.connect(self.stop_music)
        layout_music.addWidget(stop_button)

        back_button_music = QPushButton("Back")
        back_button_music.clicked.connect(self.show_home_page)
        layout_music.addWidget(back_button_music)

        # Add the new button here
        """buttons = [wall_button_1, wall_button_2, wall_button_3,
wall_button_4,
        setup_button_A, setup_button_B, setup_button_C, setup_button_D,
setup_button_H,
        music_button, reset_button, exit_button, soft_noise_button,
rain_button, wind_button,
        back_button_music, send_button]  # Add the new button here
        button_palette = QPalette()

        button_stylesheet = "background-color: #BFA995; color: #393640;"
        for button in buttons:
            button.setStyleSheet(button_stylesheet)

        # Inside your MotorControlGUI class constructor, after creating
buttons
        text_palette = QPalette()
        text_palette.setColor(QPalette.ButtonText, QColor("#393640"))  #
Set text color
        for button in buttons:
            button.setPalette(text_palette)"""

        #Data Page
        self.dataPage = QWidget()
        dataLayout = QVBoxLayout()

        data_camera_button = QPushButton("Record Camera")
        data_camera_button.clicked.connect(self.record_Camera_Loop)
        dataLayout.addWidget(data_camera_button)

        data_EEG_button = QPushButton("Record EEG")
```

```python
        data_EEG_button.clicked.connect(self.record_EEG_Loop)
        dataLayout.addWidget(data_EEG_button)

        data_watch_button = QPushButton("Download Watch Data")
        data_watch_button.clicked.connect(self.download_csv_from_s3)
        dataLayout.addWidget(data_watch_button)

        data_back_button = QPushButton("Back")
        data_back_button.clicked.connect(self.show_home_page)
        dataLayout.addWidget(data_back_button)

        self.dataPage.setLayout(dataLayout)
        self.central_widget.addWidget(self.dataPage)


        self.music_page.setLayout(layout_music)
        self.central_widget.addWidget(self.music_page)  # Add the music
page to the stacked widget
        #self.central_widget.setCurrentWidget(self.music_page)  # Set
initial current widget to music page

    def download_csv_from_s3(self): # add argument that will allow
        #temp.txt is where the id for the participant is stored
        with open(r"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\temp.txt", 'r') as f:#temp.txt is where the
id for the participant is stored
            ID = f.read()

        # Replace these values with your actual credentials and file
details
        access_key = 'AKIAWWZYTIF5UYUDU44W'
        secret_key = 'UNDhqvPU8az+PrrQxZS7v6CsTmZ6ZS7YRyaEXPFR'
        bucket_name = 'empatica-us-east-1-prod-data'
        prefix = 'v2/809/'  # Replace with the object (file) key in the
bucket
        local_directory = rf"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\Users\{ID}" # Local directory where files
will be saved

        # Establish a connection to the S3 service
```

```python
        s3 = boto3.client('s3', aws_access_key_id=access_key,
aws_secret_access_key=secret_key)

        try:
            # List all objects in the specified prefix
            objects = s3.list_objects_v2(Bucket=bucket_name,
Prefix=prefix)

            # Download each CSV file in the prefix
            for obj in objects.get('Contents', []):
                key = obj['Key']
                #print(str(ID))
                newID = ID[7:-2] + ID[-1:]
                #print(newID)
                if ('1-1-' + newID) in key:
                    if key.endswith('.csv'):
                        file_name = os.path.join(local_directory,
os.path.basename(key))
                        s3.download_file(bucket_name, key, file_name)
                        #print("key: " + str(key))
                        #print("Bucket name: " + str(bucket_name))
                        #print("file name: " + str(file_name))
                        print(f"Downloaded: {file_name}")

            print("All CSV files downloaded successfully.")
        except Exception as e:
            print(f"Error downloading CSV files: {e}")


    #SHows the data page
    def show_data(self):
        self.central_widget.setCurrentWidget(self.dataPage)

    #thread to record camera to avoid errors
    def record_Camera_Loop(self):
        cameraThread = threading.Thread(target=self.record_camera)
        cameraThread.start()

    def record_camera(self):
```

```python
        with open(r"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\temp.txt", 'r') as f:#temp.txt is where the
id for the participant is stored
            ID = f.read()

        #initialize video capture and where to save it
        vid = cv2.VideoCapture(1)
        fourcc = cv2.VideoWriter_fourcc(*'XVID')
        out = cv2.VideoWriter(rf"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\Users\{ID}\camera.avi",fourcc, 20.0,
(640,480))



        while(True):
            # Capture the video frame
            # by frame
            ret, frame = vid.read()
             # Add timestamp to the frame
            timestamp = datetime.datetime.now().strftime("%Y-%m-%d
%H:%M:%S")
            #print(timestamp + "timestamp \n")
            cv2.putText(frame, timestamp, (10, 30),
cv2.FONT_HERSHEY_SIMPLEX, 1, (0, 0, 0), 2, cv2.LINE_AA)
            #frame = cv2.flip(frame,0)
            out.write(frame)
            # Display the resulting frame
            cv2.imshow('frame', frame)
            # the 'q' button is set as the
            # quitting button you may use any
            # desired button of your choice
            if cv2.waitKey(1) & 0xFF == ord('q'):
                break

        # After the loop release the cap object
        vid.release()
        out.release()
        # Destroy all the windows
        cv2.destroyAllWindows()


    #thread to avoid errors
```

```python
    def record_EEG_Loop(self):
        EEGthread = threading.Thread(target=self.record_EEG)
        EEGthread.start()


    def record_EEG(self):
        start_time = time.time#start time to record for allotted time

        with open(r"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\temp.txt", 'r') as f:#get participant ID
            ID = f.read()

        # Define the MAC-address of the acquisition device used in
OpenSignals
        mac_address = "00:07:80:4B:18:75"
        # Resolve stream
        print("Looking for an available OpenSignals stream from the
specified device...")
        os_stream = resolve_stream("type", mac_address)

        # Create an inlet to receive signal samples from the stream
        inlet = StreamInlet(os_stream[0])
        samples = []
        timestamps = []
        print("EEG Stream found")
        while True:
            # Receive samples
            sample, timestamp = inlet.pull_sample()

            samples.append(sample)
            timestamps.append(datetime.datetime.now().strftime("%Y-%m-%d
%H:%M:%S"))#append the time that the data was recorded to match with
camera
            #print(time.time)
            elapsed_time = time.time() - start_time
            if elapsed_time >= 900: #Set the length of the data aquisition
and record for that long
                break

        dict = {'samples': samples, 'timestamp': timestamps}
        df = pd.DataFrame(dict)#save EEG data and time to a csv
```

```python
        df.to_csv(rf"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\Users\{ID}\EEG_Stream.csv", index=False)
        print("All Done")


    def participant_loop(self):#loop to avoid errors
        partThread = threading.Thread(target=self.show_participant)
        partThread.start()


    def show_participant(self):#runs participant stuff
        subprocess.run(["python", r"C:\Users\MQP BuiltEnv
Team\Downloads\2023SummerWork\ID.py"])


    def create_wall_page(self, wall_num):#creates the pages for the walls
        page = QWidget()
        layout = QVBoxLayout()
        for motor_num in range(1, 5):
            motor_label = QLabel(f"Wall {wall_num} Motor {motor_num}")
            slider = QSlider()
            slider.setOrientation(1)
            slider.setRange(0, 15)
            slider.valueChanged.connect(lambda value, wall=wall_num,
motor=motor_num: self.on_slider_change(value, wall, motor))
            layout.addWidget(motor_label)
            layout.addWidget(slider)
        back_button = QPushButton("Back")
        back_button.clicked.connect(self.show_home_page)
        layout.addWidget(back_button)
        page.setLayout(layout)
        return page


    def show_wall_page(self, wall_num):
        self.central_widget.setCurrentWidget(self.wall_pages[wall_num -
1])


    def create_roof_page(self):#creates the page for the roof
        page = QWidget()
        layout = QVBoxLayout()

        # Create sliders for the roof motors
        roof_motor_label = QLabel("Roof Motors")
```

```python
            layout.addWidget(roof_motor_label)

        for wall_num in range(1, 5):
            motor_label = QLabel(f"Roof Motor {wall_num}")
            slider = QSlider()
            slider.setOrientation(0)
            slider.setRange(0, 15)
            # Connect slider value changes to update
global_motor_values[:, 4]
            slider.valueChanged.connect(lambda value, wall=wall_num:
self.on_slider_change(value,  wall, 4))
            layout.addWidget(motor_label)
            layout.addWidget(slider)

        back_button = QPushButton("Back")
        back_button.clicked.connect(self.show_home_page)
        layout.addWidget(back_button)

        page.setLayout(layout)
        return page

    def show_roof_page(self):
        self.central_widget.setCurrentWidget(self.roof_page)

    def open_ports(self):
        # ----- Create a list of serial objects
        serial_objects = [serial.Serial(port, 9600) for port in
serial_ports]

    # ----- Send the park position command to the motors resetting motors
    def park_motors(self):
        # Set backward
        for j in range(0,park_prd):
            for i in range(0, motor_num):
                self.send_motor_command(self.motor_serial[i],
self.motor_pin[i], BACKWARD)
            #prv_setup = [[0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0,
0, 0]]

            print("Parking motors.")
            time.sleep(sleep_prd)
```

```python
    def exit_application(self):
        self.park_motors()
        for serial_object in serial_objects:
            serial_object.close()
        QApplication.instance().quit()  # Close the application


    def show_music_page(self):
        self.central_widget.setCurrentWidget(self.music_page)


    def play_music(self, file_path):

self.media_player.setMedia(QMediaContent(QUrl.fromLocalFile(file_path)))
        self.media_player.play()


    def stop_music(self):
        self.media_player.stop()


    def show_home_page(self):
        self.central_widget.setCurrentWidget(self.page_1)


    #change walls when slider adjusted
    def on_slider_change(self, value, wall_num, motor_num):
        global cur_stat
        self.motor_values[wall_num - 1][motor_num - 1] = value
        self.global_motor_values = np.array(self.motor_values)  # Update
global numpy array
        cur_stat = self.global_motor_values
        #print(f"Wall {wall_num} Motor {motor_num} value: {value}")
        #print(self.global_motor_values)


    def reset_sliders(self):
        for wall_num in range (1,5):
            for motor_num in range(1, 5):
                slider = self.wall_pages[wall_num -
1].layout().itemAt(motor_num * 2 - 1).widget()
                slider.setValue(0)  # Reset the slider value to 0
                self.on_slider_change(0, wall_num, motor_num)
        self.park_motors()
```

```python
    def apply_setup(self, setup):
        global cur_stat
        cur_stat = setup
        for wall_num in range (1,5):
            for motor_num in range(1, 5):
                slider = self.wall_pages[wall_num -
1].layout().itemAt(motor_num * 2 - 1).widget()
                value = setup[wall_num-1][motor_num-1]
                slider.setValue(value)
                self.on_slider_change(value, wall_num, motor_num)


    #sends commands to the arduino
    def send_motor_command(self, serial_number, pin_number, motor_mode):
        # Ensure motor_number is within the valid range (1 to 3).
        motor_number = pin_number
        # Ensure motor_mode is within the valid range (0 to 2).
        motor_mode = motor_mode
        # Combine the motor_number and motor_mode into a single string
message.
        message = f"{pin_number},{motor_mode}\n"
        # Send the message as bytes to the appropriate Arduino.
        serial_object = serial_objects[serial_number - 1]
        serial_object.write(bytes(message, 'utf-8'))
        #print(f"Sent command: {message.strip()}")


    #does the math to determine movement of the motors
    def send_motor_control(self):
        global cur_stat
        global prv_setup
        print(cur_stat)
        print(prv_setup)
        cur = cur_stat
        prv = prv_setup
        # find time difference
        diff_array = cur - prv
        diff_array = diff_array.flatten()
        print(diff_array)
        # set visit array
        move_check = np.zeros(motor_num)
```

```python
        # go over the loop
        # PEACE Control here
        while sum(abs(diff_array) > 0):#Checks if the walls need to move
forward or backward and moves accordingly until done
            for i in range(0, motor_num):
                if diff_array[i] > 0:
                    if move_check[i]==0:

self.send_motor_command(self.motor_serial[i], self.motor_pin[i], FORWARD)
                        move_check[i] = 1
                    diff_array[i] -= 1
                if diff_array[i] < 0:
                    if move_check[i]==0:

self.send_motor_command(self.motor_serial[i], self.motor_pin[i], BACKWARD)
                        move_check[i] = 1
                    diff_array[i] += 1
            # sleep period
            time.sleep(sleep_prd)

        for i in range(0, motor_num):
            self.send_motor_command(self.motor_serial[i],
self.motor_pin[i], STOP)
        # set the state
        prv_setup = cur_stat
        print("Sending motor command:")
        print(self.global_motor_values.flatten())

if __name__ == "__main__":
    app = QApplication(sys.argv)
    gui = MotorControlGUI()
    gui.show()
    sys.exit(app.exec_())
```