Final Report
Auditory and Visual Stimuli System for Fast Eye Movement Analysis

By
Brian Lewis
Anthony Vessicchio
Steve Kapinos
Team No. 3

Client Contact:
Dr. John D. Enderle
Biomedical Engineering Book Series Editor for Morgan & Claypool Publishers
Professor of Biomedical Engineering
University of Connecticut
Bronwell Building, Room 209
260 Glenbrook Road
Storrs, Connecticut 06269-2247
Phone: (860) 486 5521
Fax: (860) 486-2500
Email: jenderle@bme.uconn.edu
Web: http://engr.uconn.edu/~jenderle
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Abstract

The system we are building will allow for our client, Dr. John Enderle, to further his research in diagnosing mild traumatic brain injuries using data from rapid eye movements. Our device will be capable of producing visual and auditory stimuli at several different locations while being able to test eye movements at several different angles. Our device will use standard EOG electrode placement to record rapid eye movements which makes our device a universal fit for all patients. Many of the components of our device have already been purchased by previous senior design teams and the remaining components are off the shelf products which will allow for us to stay under our budget. Although there are several types of concussion tests already on the market, many of the tests presently available involve running lengthy tests and rely on cognitive questionnaires. Dr. John Enderle is the first researcher to attempt to use fast eye movements as the determining factor for concussion diagnosis which will allow for more efficient and precise concussion diagnosis. Using data from fast eye movement testing will also allow for a quantitative diagnosis of concussions which will make future diagnoses more accurate. Over one million people a year are affected by concussions in the United States alone and there is a great need for a more efficient and accurate way to test for concussions. Once the device is complete, Dr. Enderle will be able to present the device to organizations in need of such a device such as the military and contact.
1. Introduction

1.1 Background

Our client, Dr. John Enderle, is a researcher and professor at the University of Connecticut. Over the past thirty years, he has spent his time researching rapid eye movements and their corresponding neuronal activities. His research has led to the belief that there is a way to determine whether or not a person has suffered a mild traumatic brain injury based on their results from a visual/auditory combination eye movement test. His final goal is to build a device that is able to produce a combination of auditory and visual stimuli at several different locations in order to test as many different eye movements as possible. The device will use an EOG signal in order to track the eye movements and to get the most accurate readings possible. By recording the rapid eye movements of the patients in response to the visual and auditory stimuli, the device will be able to determine an accurate diagnosis.

In the United States alone, around one million people suffer at least one concussion every year. In today’s society, many people are at risk for concussions including people who partake in popular contact sports such as football and hockey, as well as active members of the military. If ignored or treated improperly, concussions can lead to very serious long term traumatic brain injuries and even death. Dr. John Enderle, along with previous senior design teams, has come up with a preliminary design for the auditory and visual stimuli system for tracking fast eye movements and has asked that we modify the design in order to implement an accurate way to record the response to the auditory and visual stimuli at several different locations.

1.2 Purpose of the Project

The auditory and visual stimuli system for fast eye movements will be used in order to help our client further pursue his goal of diagnosing patients with mild traumatic brain injury. The design for this system is necessary in order to achieve a way to safely, efficiently, and accurately diagnose a patient with mild brain trauma. The auditory and visual stimuli system will be able to test patients of all heights and weights and will be durable so that it will be able to run several tests. As previously mentioned, the device will be made so that the auditory and visual stimuli sources are activated in a randomized fashion so that the subject does not know the location of the stimuli prior to testing. This will assure that the recorded response of the subject’s eye movements are an accurate portrayal of the subject’s ability to react to the stimuli. Our client will be able to use the results from the auditory/visual stimuli tests done using our device and ultimately use them to accurately diagnose patients with potential mild traumatic brain injury. Once the device is properly modified to include clear auditory stimuli at each visual stimuli location, it will be able to accurately track the subject’s ability to respond to the different types of stimuli and ultimately determine an accurate diagnosis using the data from their eye movements.
1.3 Previous Work Done by Others

As previously discussed, in today’s society many people are at a high risk for concussions. There is a great need in the military and in contact sports such as football and hockey for an accurate and efficient way to test for concussions. Currently, there are several concussion tests available on the market. However, most of them involve a series of long cognitive tests that require in depth baseline tests. There is a great need for a test that is more efficient while still accurate. The most commonly used computerized concussion test today is the ImPACT test. The ImPACT test is able to measure patient symptoms and help assist a doctor in making return-to-play decisions. However, the ImPACT test takes around 20 minutes to complete and is not supposed to be used as a stand-alone tool. Our client hopes that our design will be more efficient and that it will be able to be used as a stand-alone tool to diagnose mild traumatic brain injury.

1.3.1 Products

Dr. Laura J. Balcer of the Departments of Neurology, Ophthalmology, and Epidemiology at the University of Pennsylvania School of Medicine determined in 2010 that the King-Devick test is an accurate and reliable method for diagnosing athletes with head trauma. She is currently trying to implement the test into being used on the sidelines of contact sports for concussion testing. However, Dr. Balcer’s method does not involve the neurological response of the patient’s to auditory stimuli which our client feels is important in proper concussion testing. Dr. Enderle plans to be the first researcher to study eye movements in response to auditory and visual stimuli for the purpose of diagnosing concussions.

1.3.2 Patent Search Results

United States patent number 12/979,419 is held by David W. Hagedorn and James W.G. Thompon and is similar to the device we are building in that it uses an electrode system in order to analyze the brain’s response to auditory and visual stimuli. However, the device in this patent does not involve mechanical structure like our black board containing the visual and auditory stimuli sites. Our device is very unique in that Dr. John Enderle is the first researcher to study the possible diagnosis of mild traumatic brain injury using the data from rapid eye movements in response to auditory and visual stimuli. Due to this, this patent and other products on the market are not similar enough to jeopardize the originality of our design.

1.4 Map of the Rest of the Report

Background information of the client and project has been presented as well as the purpose of the project and previous work that has been done in the field of concussion testing. Section 2 will give details of the project design including the objective of the project and detailed descriptions of each subunit. Section 2 will also provide details of the prototype including a description of the prototype, its operation, and testing of the prototype. Section 3 will provide details of constraints including economic, environmental, sustainability, manufacturability, ethical, health and safety, social, and political. Section 4 will provide a more detailed description of potential safety issues such as electrical, mechanical, biological, chemical, radiation, and thermal hazards. Section 5 will include the impact of engineering solutions in a global, economic, environmental, and societal context. Section 6 will include a description of new material we have learned throughout the process of the project and will also provide a
description of new skills and techniques we acquired. The seventh section will provide an updated budget and timeline for the project. A timeline will be provided using Microsoft Project planning software. Section 8 will provide a description of each team member’s contributions to the project. Section 9 will serve as a conclusion for the report. Sections 10, 11, and 12 will serve as the reference page, the acknowledgement page, and the appendix. The appendix will be split into three sections: updated specifications, purchase requisitions and price quotes, and specific details such as part specifications, datasheets, communication protocol commands, etc.

2. Project Design

2.1 Introduction

The design process for this project took several weeks to complete and was a very tedious and arduous process. The initial design part of the process involved meeting with our client, Dr. John Enderle, and once we knew what he wanted, we were able to create three alternative designs for the project which are shown in subsections 2.1.2-2.1.4. After careful consideration and multiple discussions, we were able to choose the optimal design which is explained in detail in subsection 2.2. The optimal design was chosen for several reasons. Our optimal design will not only fulfill all the needs of our client, but will also make for a safe and effective device. Our optimal design encompasses the best features of each alternative design and combines them to create the best device possible that meets all of the client’s expectations. Our device will be able to safely examine patients of all ages, heights, and genders and provide our client with data in regards to the eye movement response to auditory and visual stimuli for further analysis.

2.1.2 Alternative Design 1

Our first design for an auditory and visual stimuli system for fast eye movement analysis consists of an arched black board consisting of the auditory and visual stimuli. The black board will contain seventy seven LED lights organized in a series of columns and rows. Small speakers will be implemented into the black board at each LED location. Each small speaker will be placed directly behind each LED so that the auditory and visual stimuli are created at the exact same locations. In order to ensure that the sound that is produced is clear and that its location is easily identifiable, speaker screens will be installed at each LED location. This setup is shown in Figure 1 below:
This implementation will allow for the sound produced by the speakers to clearly be heard from the correct location and will also ensure that the sound is produced at the same location that the LED produces the visual stimuli. The speakers will be wired directly behind the speaker screens which will protect the speakers from harm and will also be used to hide the wiring and other electrical components of the system. The speaker screen will also be black to make sure that it blends in with the black board. This is important because it essential that the patient focuses on the LED lights and there cannot be anything else that can potentially distract the patient.

A Microchip microcontroller will be used to control the activation of the LED lights and speakers. The microcontroller will be programmed so that the activation of the LED and speakers appear to be random to the patient. The microcontroller will also be programmed so that the system will have the option of activating just the auditory stimuli, just the visual stimuli, or both. This will allow for the comparison between responses.

The design will also use an EOG signal to record eye movements in response to the auditory and visual stimuli. The EOG signal will be displayed using a LabView program which will create a user friendly display of eye movements so that they can be easily analyzed.

The board will be set up at a height at which the middle of the board is at eye level with the seated patient. This will ensure that the patient is able to see all possible sources of visual stimuli and will be able to react to all sources.

2.1.3 Alternative Design 2

Our second design for an auditory and visual stimuli system for fast eye movement analysis will also consist of an arched black board with seventy seven LED lights arranged in
rows and columns. In this design the back of the black board will consist of an adjustable mount so that the height of the board can easily be adjusted to be at eye level for all patients. The mount will consist of two vertical bars mounted to the wall with adjustable slots that will allow for the board to be easily adjusted for each individual patient. The wall mount will resemble the mount in Figure 2 shown below:

![Figure 2: Adjustable Wall Mount](image)

The arched black board would be modified so that it has pegs that will fit securely into the slots in the wall mount. The wall mount would also be modified to allow for more wiring. More holes would be cut into the wall mount so that the mount will not interfere with the LED or speaker wiring. The wall mount also creates more space between the board and the wall which will make back of the board more accessible in case minor maintenance or adjustments are needed.

In this design, the LED light will be circular and surrounding each speaker. In this design, the speaker will be in the same plane as the board so that the sound is not disrupted at all when it is produced. The speaker/LED setup is shown in Figure 3 below:
With this setup, the sound would not be behind anything which will make for a more clear and detectable sound. Having the LEDs directly around the speakers will also make the visual stimuli and auditory stimuli as close as possible. Using these speakers surrounded with LEDs is also beneficial because the LEDs and speakers are prebuilt together so that makes the wiring in the back of the board less complicated which will make maintenance easier and reduce the chances of wiring coming loose.

The LEDs and speakers will be controlled using an Arduino microcontroller. Arduino microcontrollers are easily programmed to activate the LEDs and speakers in any manner that is needed. The Arduino microcontroller can be programmed using a simplified version of C++ language which will allow us to be able to program the microcontroller using previous knowledge. The microcontroller will be programmed to activate the LEDs and speakers in a manner that appears random to the patient being tested.

An EOG will be used to record eye movements and the signal will be inputted into a LabView program which will display the signal in a user friendly manner that allows for the data to be analyzed.

2.1.4 Alternative Design 3

Our third design for an auditory and visual stimuli system for fast eye movement analysis involves an arched black board with seventy seven LEDs and speakers. The LEDs will be arranged in columns and rows and will be equally spaced out from each other across the board. In this design the speakers will be placed behind the LEDs and a circular hole will be cut out around each LED. To fill the hole, foam headphone ear bud replacements will be cut in order to fit the shape of the hole. This will make for an ideal sound to be produced and will also protect the speakers. Foam headphone ear bud replacements are shown in Figure 4 below:
These ear bud replacements will have a hole cut in the center in order for the LED to be placed in the middle of each. The ear bud replacements will be black in order to match the color of the board so that they blend in to prevent from distracting the patient from reacting to any stimulus other than the LEDs.

This design will use an Arduino microcontroller to control the activation of the LEDs and speakers. In this design the Arduino board will be wired to multiple shift registers in order to increase the amount of inputs the Arduino board can have. The speakers and LEDs will be wired to the shift registers so that they can all be individually controlled by the Arduino. The Arduino will be programmed to activate the LEDs and speakers in a manner that appears random to the patient being tested. The Arduino will also be programmed to give the options of activating the LEDs, the speakers, or both simultaneously.

An EOG will be used to record eye movements in response to the auditory and visual stimuli sources. The EOG signal will be inputted into a LabView program which will display the eye movement data in a user friendly manner that will allow for data analysis.

The board will be set up so that the middle of the board is at eye level with the patient being examined. This will allow the patient to be able to react to all sources of stimuli.

Our optimal design was chosen because it provided the most efficient and functional device. Our optimal design is cheap enough that it allows us to stay under our budget and will provide us with a device that is not only effective, but safe as well.
2.2 Optimal Design

2.2.1 Objective

In the United States alone, around one million people suffer at least one concussion every year. In today’s society, many people are at risk for concussions including people who partake in popular contact sports such as football and hockey, as well as active members of the military. If ignored or treated improperly, concussions can lead to very serious long term traumatic brain injuries and even death.

The client, Dr. John Enderle has been researching rapid eye movements and their respective neuronal activities for the past thirty years. His research has led to the belief that there is a way to determine whether or not a person has suffered mild traumatic brain injury based on their results from a visual/auditory stimuli combination eye movement test. Dr. Enderle believes that he will be able to accurately diagnose concussions based on a patient’s eye movements in response to these stimuli. Our goal is to create a device that is able to record a subject’s rapid eye movements in response to a combination of visual and auditory stimuli that is activated simultaneously at various locations in the subject’s range of vision. The device must also be able to display the recorded eye movements in a user friendly way which allows for further data analysis and comparisons.

The main component of our device will be an arched black board that will be mounted on a wall at a height that is at the subject’s eye level. The black board will have seventy seven Piezo buzzers with LED lights built in arranged evenly in a series of rows and columns. The LED lights on the Piezo buzzers are red. We chose red LED lights for many reasons. Due to the LED lights being red, they stand out very clearly because of the contrast with the black board. The LED lights are also small and don’t require a large amount of power to be activated. The Piezo buzzers with LED lights were also chosen because of our need for auditory stimuli. The Piezo buzzers are small and relatively inexpensive only costing $2.25 per unit. Due to the amount of Piezo buzzers needed, it is important that they are inexpensive so that we remain under budget. The Piezo buzzers function in a way that the speaker and LED can be activated simultaneously. The Piezo buzzers do not require a lot of power to be activated which is also critical to our design.

The activation of the Piezo buzzers and lights will be controlled by an Arduino brand microcontroller. An Arduino Mega 2560 will be used because it has 54 digital input/output pins and due to the large number of LEDs and speakers, it is very beneficial to have as many digital input/output pins as possible.

Due to the large amount of auditory and visual stimuli sources that need to be controlled by the Arduino, we will be using multiplexors in order to give the Arduino the ability to control the activation of the large number of sources. The multiplexors we will be using are the 74HC595s. Multiplexors are essential in our design because they reduce wire count reducing the risk of wires coming loose and because they allow each pin of the Arduino to be able to handle more inputs. Multiplexors are also beneficial because they take some load off of the Arduino because they can store data.
Our device will use an electrooculography (EOG) electrode setup to record the rapid eye movements. The electrodes will be placed using standard EOG electrode placement. The EOG signal will be inputted into a LabView program which will display the recorded eye movements in a user friendly manner that will allow for data analysis.

![Figure 5: Standard Electrode Placement for EOG](image)

The Arduino will be programmed so that the LEDs and speakers are activated in a manner that appears random to the subject being tested. Figure 2 shows a flow chart of the series of events that occur in the auditory and visual stimuli system.

### 2.2.2 Subunits

Our auditory and visual stimuli system can be broken down into several subunits which will be explained in detail below.

#### 2.2.1 Arched Black Board

The main component of our auditory and visual stimuli system for rapid eye movement analysis is a customized arched black board which contains seventy seven Piezo buzzers with LED lights built in. The black board is arched so that the subject is able to respond to stimuli in more than just one plane. The arch of the board allows for eye movements to be tested at as
many angles as possible and allows for the examination of the subject’s response to stimuli in three dimensions.

2.2.2 Piezo Buzzers with LED Lights

The Piezo buzzers with LEDs will be arranged in a series of columns and rows that are evenly spaced out. The LEDs will be red LED lights which make it very easy for the subject to locate them on the board due to the contrast between the red lights and the black board behind them. This is essential to the success of our device because the subject needs to be able to react to the visual stimuli as easily as possible and the contrasting colors will make it easy for the subject to focus on the LEDs. The Piezo LEDs are also beneficial to use as the visual stimuli source because they do not require a large amount of power to be activated. The Piezo buzzers with lights are also cheap and dependable making them ideal for our system. LED lights have an estimated operational life of 100,000 hours making them far superior to alternative types of lights such as an incandescent bulb which has an operational life of approximately 5,000 hours. This long operational life is beneficial to our design because it will lead to our device requiring less maintenance and will allow the device to be able to test many more patients before the need for replacement lights.

Another benefit of using LED lights is that they are easily programmable through an Arduino microcontroller. Our group has some experience in programming LEDs through microcontrollers and this was another factor in our decision to use LEDs. The background we
have in programming LEDs gives us an advantage in building this device and will allow us to more easily build a successful device.

In order to generate auditory stimuli for the purpose of testing the patient’s eye movement response to auditory stimuli, we will implement the seventy seven small and inexpensive Piezo buzzers. Due to the large amount of Piezo buzzers needed for our device, it is very important that the buzzers are relatively cheap so that we will stay under budget. Small speakers are ideal because they do not require a lot of power in order to be activated.

These buzzers are ideal for our device because they are only $2.25 each and can be activated using an Arduino microcontroller. These buzzers are also advantageous for our device because they come with wiring which saves us from having to purchase extra wire for each speaker. They are also beneficial because they come pre-connected to the LEDs which will make it easier for us to implement them into the device. Although these buzzers are small and inexpensive, they are able to create a clear sound when powered by an Arduino which is vital to the success of our device because the subject needs to be able to clearly hear the sound when undergoing examination. If the sound is not clear, the subject’s reaction to the auditory stimuli will not be to their greatest ability and therefore the recorded eye movements will not be sufficient in diagnosing possible mild traumatic brain injury.

The seventy seven Piezo buzzers with LEDs will be implemented at the same locations as the seventy seven LEDs that were previously on the board. The Piezo buzzers will be mounted to the board in a way in which the plane of the speaker is flush with the black board. The Piezo buzzers are advantageous because they allow us to implement the auditory and visual stimuli sources at the same locations. This is necessary because in order to test the eye movement response to auditory and visual stimuli, the two types of stimuli need to be coming from the same location in order to make the test accurate. The device will record the angle of eye movement as part of the examination and if the speakers and LEDs are not at the same locations, the recorded eye movements will be inaccurate because the two stimuli sources will not be at the exact same angle.

In order for the Piezo buzzers to be implemented into the board, we will need to modify the arched black board. We will cut a circular hole around each location so that the buzzers will be flush with the surface of the board.

This cut made will allow us to implement the buzzers into the device and will allow for the device to generate auditory and visual stimuli from the same locations. This cut will be duplicated around all seventy seven Piezo buzzers. The cut will be circular to match the shape of the Piezo buzzer. The cut will be made so that no part of the buzzer is covered by the board. This is beneficial to our design because that will make it so that as little of the speaker is covered as possible. This cut design will aid in the production of a clear sound by each speaker because the speaker will not be covered. This cut will also make it so that the patient can easily identify the
location of the auditory stimuli when each speaker is activated. If this cut was not made, the
speakers would be covered by the black board and the subject would have a very difficult time
trying to identifying the location of the sound and their eye movement response would not be
ideal.

2.2.3 Protective Foam Layer for Speakers

In order for the speakers to function at the most optimal level, they will need to be
protected. Dust and other particles can reach speakers if they are unprotected and this will cause
the speakers to perform at a subpar level. As previously mentioned, the speakers must be able to
produce a clear sound so that the subject can respond to the auditory stimuli to their full ability.
If the sound is deterred in any way, the subject’s eye movement in response to the auditory
stimuli will not be sufficient for an accurate diagnosis.

Due to the cut being made around each Piezo buzzer, the speakers will need a layer of
protection over them to keep them from being exposed. We have decided to cover the hole in
front of each speaker with a layer of thin black foam that is traditionally used to cover ear buds.

Figure 7: Think Black Foam Ear Bud Covers

This layer of thin black foam is beneficial in several ways. The first benefit of using this
layer of thin black foam is that it serves as a layer of protection. This black foam has been used
in the past in covering ear buds and has proven to serve as a sufficient protective layer for
speakers. Another benefit of using this foam is that it is very thin and sound is able to move
through it without being obstructed. This is a very desirable quality in the protective layer
because it allows the speakers to still produce a clear sound that will allow the subject to easily
identify the location of the auditory stimuli during testing.
The black foam layer is also needed so that the hole that is cut is covered up and the wires and circuit parts are not visible to the subject being tested. If the wires and circuit parts were visible to the subject being tested, the subject would be distracted from focusing on the LED lights and their eye movement response to the visual stimuli may not be an accurate representation of their response to the LED lights.

The black foam layer also is an advantageous way to cover the holes that are cut because they are black will not serve as a distraction to the patient. The black board will be completely covered by the black foam and holes will be cut into the foam at each LED location so that the LEDs will still be completely visible. The fact that the foam is black is also beneficial because the black contrasts with the color of the red LEDs and allows for the LEDs to stand out as much as possible. This is vital to the success of our device because the subject needs to be able to clearly see all of the visual stimuli sources so that their eye movement response is produced to their fullest ability and without distraction.

![Figure 8: Black Foam Cover over Holes Cut Around Each LED](image)

### 2.2.4 Arduino Mega 2560 Microcontroller

Per request of our client, our device must be to activate the LEDs and speakers at the same location simultaneously. The device must also be able to activate each Piezo buzzer and LED in a manner in which their activation appears random to the subject being tested. This randomized activation is vital to the device’s success because the subject cannot know the order of which sources of stimuli will be activated. If the patient were to know the order of stimuli...
activation before testing, the test would be flawed and their eye movement measurements would not be a true measurement of their ability to respond to the stimuli. We chose to use an Arduino Mega 2560 Microcontroller to control the activation of the Piezo buzzers and LEDs. The Arduino Mega 2560 has 54 digital input/output pins which is more than any other Arduino model. The large number of digital input/output pins is beneficial to our device because we need to be able to control seventy seven LEDs and seventy seven speakers. The Arduino is also beneficial because it can be connected directly to a computer through a USB cord so that we can directly program the Arduino from the computer.

Figure 9: Arduino Mega 2560

Another benefit of using an Arduino is that the Arduino can be programmed using C programming language. Our group has some background in using C programming language which is beneficial because it will allow us to use prior knowledge to program the Arduino which will make it easier than having to learn a new programming language.
2.2.5 74HC595 Multiplexor

Due to the large amount of speakers and LEDs needed in our device, we will need to increase the capabilities of each input/output pin on the Arduino. In order to do this, we need to use multiplexors which allow each pin of the Arduino to be able to control more Piezo buzzers than they would be able to without the multiplexors. We chose to use 74HC595 multiplexors because they only need 2-5 volts to run and are compatible with Arduino microcontrollers. Using these multiplexors will further the capability of the Arduino microcontroller by enhancing the amount of Piezo buzzers that the Arduino can control and it also takes some of the load off the Arduino by storing some memory itself.

![74HC595 Multiplexor](image)

**Figure 10: 74HC494 Multiplexor**

Each 74HC494 multiplexor will be wired to the Arduino Mega microcontroller via the input/output pins. Each multiplexor will increase the capabilities of each Arduino pin by allowing for more Piezo buzzers to be connected to the Arduino. These multiplexors are crucial to the success of our design because we need to be able to control the activation of all seventy seven Piezo buzzers with LEDs and the Arduino Mega 2560 alone would not be able to control all of them.

2.2.6 Electrooculography (EOG) Electrode System

In order to examine the rapid eye movements of the subject under examination, we need an accurate way to record eye movements in response to the auditory and visual stimuli. An
EOG electrode system is an accurate and well proven way to record rapid eye movements. In our system, two electrodes will be placed on the sides of each eye and one will be placed right above the nose in the center of the forehead. The electrode placement was shown previously in Figure 1. The EOG signal will be inputted into a computer in order to display the recorded eye movements in a way that can be analyzed.

The EOG system will be used to record the eye movement velocity and eye position during the examination. The position and velocity of the eye movements in response to the auditory and visual stimuli will be displayed on the computer through a LabView program which will display the recorded eye movements in a user friendly manner so that the data can be used for further analysis.

In order to test the accuracy of the EOG system, we will hook up the EOG electrode system to different members of our group and run trials. We will test eye movements in every direction and at every angle to assure that the test setup is sufficient in recording all possible eye movements.

2.2.7 LabView Program

In order to analyze the recorded eye movements, the eye movement velocity and position needs to be displayed in a user friendly manner. Our LabView program will input the signal from the EOG signal and will display the eye movement velocity and position in numerical and graphical form so that the data can be used for further analysis.

3. Realistic Constraints

Our device will follow all engineering protocols and standards and the design will be safe and provide our client with a device that meets his needs and fulfills all requirements. Our device will be innovative and unique and will provide our client with the first device of its kind.

3.1 Health and Safety

Since our device will be testing patients with possible mild traumatic head trauma, it is very important that our device does not compromise the health or safety of the patient being tested. Our device can not pose any potential threat to cause more damage to the patient’s head. Our device requires no headgear and the only possible threat are device can cause physically to the patient’s head is during the application of the EOG electrodes. Our device will come with instructions for the operator to be very gentle when applying the electrodes to the patient’s head. The electrodes should cause no pain or discomfort to the patient’s head during testing as long as the operator applies them correctly.
Another potential safety risk of our device is that our device is run with flashing lights and sounds. The flashing lights and sounds may cause discomfort to the patient. The flashing lights may induce seizures to patients who suffer from seizure disorders such as epilepsy, so it is necessary to limit the use of the device so that people with such disorders cannot be examined using the device. In order to prevent any seizures during the usage of our device, the LED lights will not flash at a rapid pace that would cause potential discomfort to the patient. The lights will also be set so that the brightness does not overwhelm or cause discomfort to the patient. Our device will be made to use while the patient is seated which increases the safety of the device because in case the patient gets dizzy or light headed, they have a lesser chance of passing out or fainting if they are seated.

Another possible safety and health hazard of our device is creating loud noises that may cause discomfort to the patient. Our device needs to be able to create sounds that are clearly audible to the patient, however the noises cannot be so loud that they cause discomfort to the patient. In order to prevent our device from needing to produce loud noises, the device will be used in a quiet room with minimal background noise.

### 3.2 Manufacturability

A manufacturing constraint of this project is the time it will take to manufacture the device. Because our device has so many speakers and LED lights, a lot of wiring is required and because there is not a lot of space between each set of speakers and lights, a lot of intricate wiring will be needed. Then wiring that will be required to connect each LED and speaker to the shift registers and Arduino will be very detailed and may cause problems when building the device. Also, the cut that needs to be made around each LED needs to be very precise. This may take some time in assuring that each cut is perfect and efficient for our design.

### 3.3 Ethical

During the production of this device, ethical procedures will be followed. All procedures will follow engineering standards and no unethical testing will be done during production. All testing will be pre-approved and all research will be done with the upmost honesty.

### 3.4 Environmental

The device will be used indoors and will be powered using a computer so there are no real environmental concerns during production of our device.

### 3.5 Sustainability
Over time, as the device is used it is possible that LED lights and speakers may no longer work properly after several uses. Maintenance may have to be done over time on the device including rewiring, replacing LEDs, replacing speakers, and replacing shift registers. No other concerns regarding sustainability should be taken into consideration.

3.6 Social/Political

In general, athletes are not accepting of the idea of a prolonged absence from their sport. Although, the device will be beneficial to the health of athletes, many athletes would rather risk further injury as opposed to not participating in their sport for a prolonged period of time. Many athletes would be opposed to the idea of the device and this is a very important social constraint that must be considered. It will be beneficial to offer an education program in order to enlighten these about the risks and long term effects of mistreating concussions.

4. Safety Issues

Because the patients our device will be dealing with have potential mild traumatic brain trauma, one main safety issue is the prevention of causing any more damage to the head of the patient. Our device uses no headgear and the only contact our device makes with the patient’s head is through the EOG electrodes. Because the EOG electrodes are lightweight and typically cause little to no discomfort to patients, our device should be sufficient in causing no further damage to the patient’s head. Another issue involving the fact the patient may have mild traumatic brain injury is that there is a strong possibility that the patient may be dizzy, light headed, and may possibly have other symptoms associated with brain injuries. Due to these possible symptoms, our device will be designed so that the testing will be done while the patient is seated. This will prevent the patient from being injured if they faint or pass out during testing.

In order to prevent from the user from being endangered by electric shock, all electrical parts of the design including wires, circuit parts, and the shift registers will be covered completely by a combination of the black board and the black foam protective layer. The Arduino microcontroller which controls the activation of the speakers and LED lights will be encased in a shield. A shield is a plastic housing which encloses all of the Arduino’s electrical components preventing the user and patient from making any contact with them. The shield is also beneficial because it allows Arduino to still be able to connect to the computer via USB cable and also allows access to the digital input/output pins.

There are no real threats to the environment caused by our device. All components of the device are able to run off of the computer that they are connected to. The LEDs and speakers do not require any other power source to be activated which prevents the need for a power source that can negatively affect the environment.
5. Impact of Engineering Solutions

Our client, Dr. John Enderle will use our device to collect data on the rapid eye movements of patients and use the data to be able to accurately diagnose mild traumatic brain injury. Dr. Enderle has spent the last thirty years focusing his research on rapid eye movements and their corresponding neuronal activities. He is now in the stage of his research where he believes it is possible to accurately diagnose mild traumatic brain injury if he can gather data of the eye movement response to auditory and visual stimuli of a patient. Our device will be able to produce auditory and visual stimuli at various locations and angles and will be able to display the patient’s response in a manner in which the client can use the data to further his research.

Using our device, our client will be able to become the first researcher in the field to study the rapid eye movement response to auditory and visual stimuli simultaneously. Using the data gathered from our device, our client can become the first researcher to make the quantitative link between the rapid eye movement response of a patient and the diagnosis of mild traumatic brain injury. Most concussion tests on the market today involve cognitive and memory based tests. These tests provide no quantitative data to support the diagnosis of mild traumatic brain injury.

There are over one million people a year who suffer from concussions in the United States alone. If a person with a concussion is diagnosed accurately and quickly, there is a very strong chance that they will recover fully and have no long term symptoms. However, if a person is not diagnosed or diagnosed improperly, they will likely suffer from long term problems such as severe headaches, fatigue, dizziness, confusion, memory problems, sleep disorders, and sensory problems such as vision and hearing disorders. Many athletes and members of the military do not want to sit out from their sport or duty for a prolonged period of time. Due to most of the concussion tests on the market today having no quantitative data to support their diagnoses, many athletes and members of the military are able to cheat the tests so that they do not have to sit out of any competition or service. These people can easily cheat these concussion tests by giving false responses to questions. Our device will eliminate the possibility of people cheating concussion tests because the device will provide quantitative data to accurately diagnose concussions. There is a huge need in today’s world for a device that is able to do this and if our device is successful, it could become the new standard for diagnosing mild traumatic brain injury.

6. Life-Long Learning

Throughout the process of completing our design we have acquired a vast amount of important knowledge that we will be able to not only use throughout our lives as engineers,
but we have learned valuable life lessons that we will be able to use in our everyday lives in the future.

Throughout our research that we have done when coming up with the design for our device, we have accumulated a vast amount of knowledge regarding mild traumatic brain injuries, different types of treatment for such injuries, the effects of such injuries, and prevention of these injuries. The information we have gathered over the course of our research will be very useful for the future due to the incredible need in today’s world for knowledge of concussion diagnosis, treatment, and prevention.

Due to our device using an Arduino microcontroller, we will learn how to be able to program these microcontrollers which will be valuable in the future. Another benefit of using an Arduino microcontroller is that it is programmed using C programming language which is used in various ways in the engineering community. Using shift registers will also give us valuable knowledge because they are also used in many applications in engineering. Circuit design in general is a very tedious process and the ability to create a successful circuit will lead to us acquiring useful life skills such as proper circuit building technique, troubleshooting, and patience.

In order to create a successful device, we will need to plan properly, budget our time and money, use resources tDiso their full potential, and properly document our plans, acknowledgements, and device modifications. These skills are very valuable in life and this project provides us a great learning experience in which we will be able to apply these skills in the workplace in the future. This project will also teach us to use Microsoft Project which is a valuable skill that can be used in future projects. This project will also provide us with valuable teamwork skills that will be necessary in industry, the process of designing and building our project replicates the engineering process in industry and the skills we gain during the process will be very valuable to our lives in the future.

7. Budget and Timeline

7.1 Budget

<table>
<thead>
<tr>
<th>Distributor</th>
<th>Manufacturer</th>
<th>Model #</th>
<th>Component</th>
<th>Price</th>
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<tbody>
<tr>
<td>AliExpress</td>
<td>Bingo</td>
<td>BJ-3</td>
<td>Piezo Buzzer/LED</td>
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<td></td>
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</table>

Table 1: Updated Budget as of November 26, 2012
### 7.2 Timeline

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piezo Buzzer/LED-Breaking apart</td>
<td>2 days</td>
<td>Fri 11/30/12</td>
<td>Sat 12/1/12</td>
</tr>
<tr>
<td>Try to activate LED and buzzer separately</td>
<td>7 days</td>
<td>Sun 12/2/12</td>
<td>Mon 12/10/12</td>
</tr>
<tr>
<td>Code Arduino to activate Piezo Buzzer/LED</td>
<td>3 days</td>
<td>Sat 12/1/12</td>
<td>Tues 12/4/12</td>
</tr>
<tr>
<td>Code Arduino to activate matrix</td>
<td>3 days</td>
<td>Wed 12/5/12</td>
<td>Sat 12/8/12</td>
</tr>
<tr>
<td>Order the rest of Piezo buzzer/LEDs</td>
<td>1 Day</td>
<td>Mon 12/10/12</td>
<td>Mon 12/10/12</td>
</tr>
<tr>
<td>Order multiplexor</td>
<td>1 Day</td>
<td>Mon 12/10/12</td>
<td>Mon 12/10/12</td>
</tr>
<tr>
<td>Order Arduino Shield</td>
<td>1 Day</td>
<td>Mon 12/10/12</td>
<td>Mon 12/10/12</td>
</tr>
<tr>
<td>Implement speakers into board</td>
<td>10 days</td>
<td>Tue 1/22/13</td>
<td>Fri 2/1/13</td>
</tr>
<tr>
<td>Further Arduino Coding with shield and multiplexor</td>
<td>10 days</td>
<td>Fri 2/1/13</td>
<td>Mon 2/11/13</td>
</tr>
<tr>
<td>Implement EOG system</td>
<td>2 days</td>
<td>Tues 2/12/13</td>
<td>Thu 2/14/13</td>
</tr>
<tr>
<td>Design LabView Program</td>
<td>5 days</td>
<td>Fri 2/15/13</td>
<td>Thu 2/21/13</td>
</tr>
<tr>
<td>Implement LabView Program</td>
<td>2 days</td>
<td>Fri 2/22/12</td>
<td>Mon 2/25/13</td>
</tr>
<tr>
<td>Run sample tests</td>
<td>5 days</td>
<td>Fri 3/1/13</td>
<td>Wed 3/6/13</td>
</tr>
<tr>
<td>Analyze Data</td>
<td>4 days</td>
<td>Thu 3/7/13</td>
<td>Mon 3/11/13</td>
</tr>
</tbody>
</table>

**Table 2**: Project timeline for completion of project including hours required and team members completing each task.
8. Team Members Contributions to the Project

8.1 Anthony Vessicchio

Anthony has focused most of his semester on the auditory and visual stimuli system for fast eye movement analysis. He has written all of the reports for the project and has generated the portion of each weekly Powerpoint presentation regarding the auditory and visual stimuli system. Anthony was heavily involved in the design process of the project including the development of the three alternative designs as well as the optimal design. Anthony has ordered parts including the Arduino Mega 2560, Longcat H3D binaural spatializer software, and the Piezo buzzer/LEDs. Anthony has worked with Dr. Enderle and Xiu Zhai to install the Longcat software. He has also attended weekly meeting with Dr. Enderle and Zhai every week throughout the semester in order to relate the project to their studies.

Anthony has focused a lot of his time on researching microcontrollers and the programming involved with each. Once the group decided to use the Arduino microcontroller, Anthony spent time researching the coding and programming language used for Arduino microcontrollers. He has reviewed several Arduino programming tutorials and has become familiar with the Arduino microcontroller. Anthony’s microcontroller research has included the ability to activate an LED, the ability to control an LED matrix, and using the Arduino with a multiplexor. Anthony has recently spent time working with the Piezo buzzer/LEDs. He has attempted to activate each component of the Piezo buzzer/LED separately and has continued his research in doing so. Anthony has also researched the potential Arduino coding involving the activation and control of speakers.

8.2 Steven Kapinos

Steven has focused most of his time this semester on researching Arduino microcontroller coding and programming. Steven has also reviewed several Arduino tutorials and sample codes in order to further his understanding of the Arduino microcontroller functions. Steven has also worked to develop the final design of the project and has done research on several of the project components in order to understand their potential functionality in the device.

Steven has also focused time on preliminary testing for the project such as lighting an LED using a protoboard, lighting an LED using the Arduino, and attempting to activate the Piezo buzzer/LED.

8.3 Brian Lewis

Brian has also focused a lot of his time this semester on researching Arduino microcontroller coding and programming. Brian has done research involving the activation of LEDs and LED matrices using an Arduino microcontroller and has also reviewed several Arduino tutorials in order to become familiar with the Arduino microcontroller. Brian has also done research regarding different components of the project and helped to create the optimal
design for the project. Brian has also attended a few meetings with Dr. Enderle and Xiu Zhai in order to relate our device with their research.

Brian has also worked on different tests for the design of our device including the activation of an LED using an Arduino and the attempt to activate the Piezo buzzer/LED using an Arduino. He also met with Xiu and Dr. Enderle helping to install the Longcat software.

9. Conclusion

Our project is a visual and auditory stimuli system for fast eye movement analysis. Once completed, our device will be able to use and EOG electrode system to record the eye movement response to auditory and visual stimuli. We will be using seventy-seven Piezo buzzer/LEDs as auditory and visual stimuli sources and they will be implemented into an 11x7 matrix on an arched black board. The auditory and visual stimuli sources will be activated in a random fashion to ensure for an accurate test. Eye movement and velocity will be recorded during the test and the results will be displayed in a user-friendly manner using a LabView program.

Our client, Dr. John Enderle, is a professor at the University of Connecticut and has focused his research on rapid eye movements and their neuronal activities. Dr. Enderle has asked us to design this device so that he has an accurate way to record eye movements in response to auditory and visual stimuli. He will use the data collected from our device in order to further his research regarding the diagnosis of mild traumatic brain injuries using eye movement data. Mild traumatic brain injuries are very common in today’s society especially in contact sports and the military. If a person suffers a concussion and is not diagnosed accurately or in a timely manner, it could lead to severe long term consequences and even death. Current concussion tests do not produce qualitative results and Dr. Enderle plans to be the first to have an accurate test that does so. This will have an enormous impact on the medical society.

10. References


11. Acknowledgments

Our team would like to thank the following people for their contributions to this design project:

- Dr. John Enderle: for sponsoring the project and design advice
- Joseph Calderan: for being our Team’s TA and design advice
- Jennifer Desrosiers: for helping us order parts
- Xiu Zhai: for meeting with us weekly to discuss the progress of our project
- Tom Canavan: for microcontroller advice and information

12. Appendix

12.1 Updated Specifications

**Physical:**

- Speakers and LEDs: Piezo Buzzers/LEDs BJ-3
- Eye Movement tracker: EOG electrode system

**Mechanical:**

- EOG electrode system: <1 ounce

**Electrical:**

- Piezo buzzer/LED BJ-3 12V/24V DC
- Arduino Mega 2560 USB port on computer

**Software:**

- Longcat H3D Binaural Spatializer
- LabView Version 10

12.2 Purchase Requisitions
**Figure 11:** Purchase Order Requisition for Arduino Mega 2560
### Figure 12: Purchase Order Requisition for Longcat Software

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<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
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<tbody>
<tr>
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<td>3D Printer</td>
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<td></td>
<td>100.00</td>
<td>100.00</td>
</tr>
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</table>

**Comments:**

Order Date: 9/28/12  
Initals: AA  
COMMENTS: POSTED  
Received: 9/28/12
**Figure 13:** Purchase Order Requisition for Piezo Buzzer/LED
12.3 Part Specifications

**Piezo Buzzer/LEDs BJ-3**
- Operating voltage: AC: 110V  
  DC: 12V/24V
- Rated Current: 100/40/500mA
- Sound Pressure: 110/100/105dB

**Longcat Software**
- Windows XP, Vista, or Seven
- Mac OS X 10.6 or 10.7
- Compatible hosts:
  - VST2.4 compatible
  - AU compatible
  - RTAS
  - AAX-Native