Deliverable E: Design Constraints and Prototype 2

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1 Introduction

The objective of this report is to thoroughly discuss prototype 2 that was developed for the mounted communication pointer project. Section 2 thoroughly goes over the prototype 2 itself and the various tests that were conducted on it to validate target specifications. Section 3 tries to highlight various non-functional design constraints that could be incorporated into prototype 3 and the final prototype. Finally, section 4 covers the feedback that was received from the client after presenting our prototype 2.

To improve the readability of this report, the sections are presented in a chronological order instead of the order suggested in the lab manual.

2 Prototype 2

The second prototype of the mountable laser pointer project dealt with the glasses mounted subsystem. To elaborate, this prototype consisted of fabricating the glasses mount case. The case was a 3D printed model. Then a few tests were performed to measure the product mass of frames and the product size, sturdiness of the casing, the time to mount and detach, as well as the time before discomfort, and the mount compatibility with frames.

Initially, we also wanted to test the hip mounted subsystem in prototype 2. However, not all parts that consist of the final product are not available at the time of writing this report. Rather than delay the submission of the report any longer, we have decided to push the hip mounted subsystem prototype and all its tests to prototype 3.

2.1 Critical Product Assumptions to be Tested

One main critical product assumption that must be tested is the feasibility of the glasses mounted casing. This includes the manufacturability with 3D printing, the weight of the casing, the size of the casing, and the mountability. These criteria have been tested in prototype 2.

Another product assumption that must be tested once the upper casing is finalized is the integration of the clip mount and the casing. The adhesive used must be able to withstand the pressure needed to open and close the clips.

It is currently assumed that the laser has a diameter smaller than 8mm. Once the button, accelerometer, and laser have been purchased, the integration of these three parts with the upper casing may be tested to ensure that the manufacturers' claimed dimensions are accurate. The physical space needed inside the casing for the connections between these parts must also be investigated. In addition, the final weight must also be calculated.

Finally, the water resistance properties of the casing will not be validated at this moment. Not that due to limitations in testing equipment available (and not wanting to destroy any electrical component), actual water resistance tests cannot be performed. Instead, we will assume that our product is not water resistance at all due to there being holes in the casing that cannot be blocked off.

2.2 Current Prototypes

For prototype 2, the first 3D printed prototype for the glasses mounted casing was manufactured. The casing design was modified from the original CAD presented in Deliverable C before printing. The first major change is that the side wall thickness was changed to be 2.5mm. The end wall thicknesses were not changed from the original 5mm to allow for increased support of the laser and wires that will be fed through holes in these surfaces. Using a nozzle size of 0.6mm and at 20% infill, the resulting prototype showed sufficient accuracy and strength for the product. The prototype can be seen in the figures below.

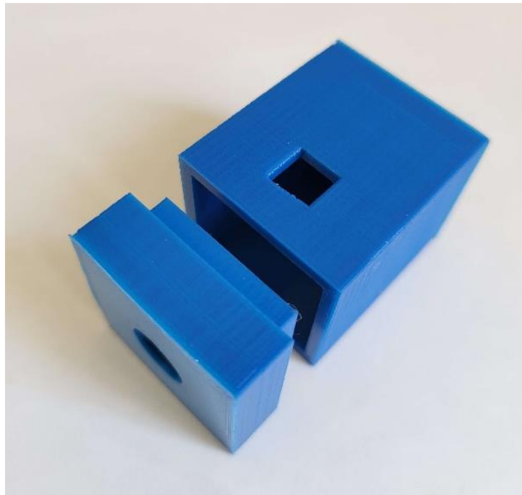

Figure 1 Upper Casing

As can be seen in Figure 1, the upper casing consists of two separately printed parts. As detailed in the Detailed Design Report, these are the lid and the body. The front view (left) and the back view (right) can be seen in Figure 2.

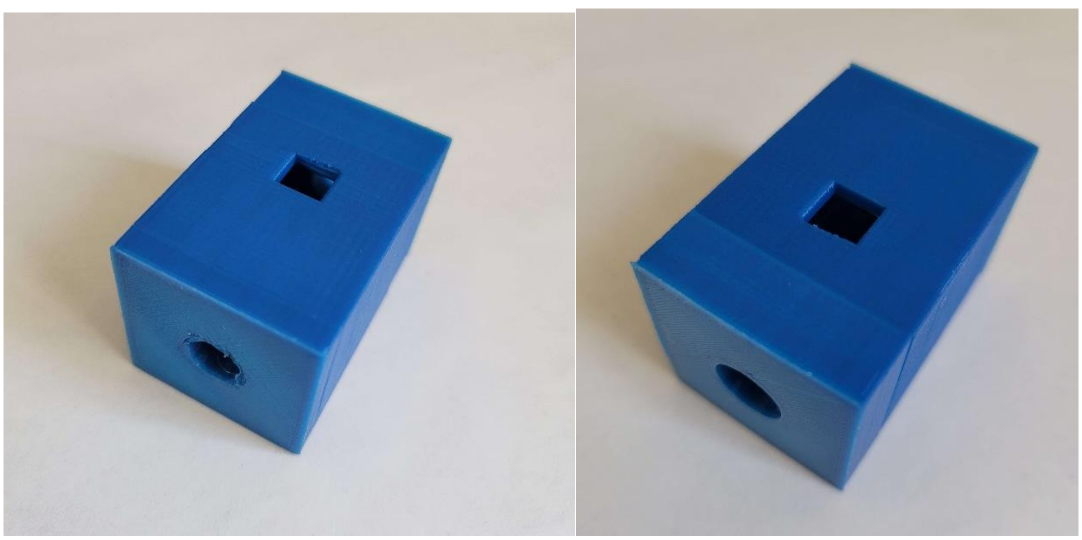

Figure 2 Front and Back view of Upper Casing

The body part of the casing can be seen in Figure 3 below.

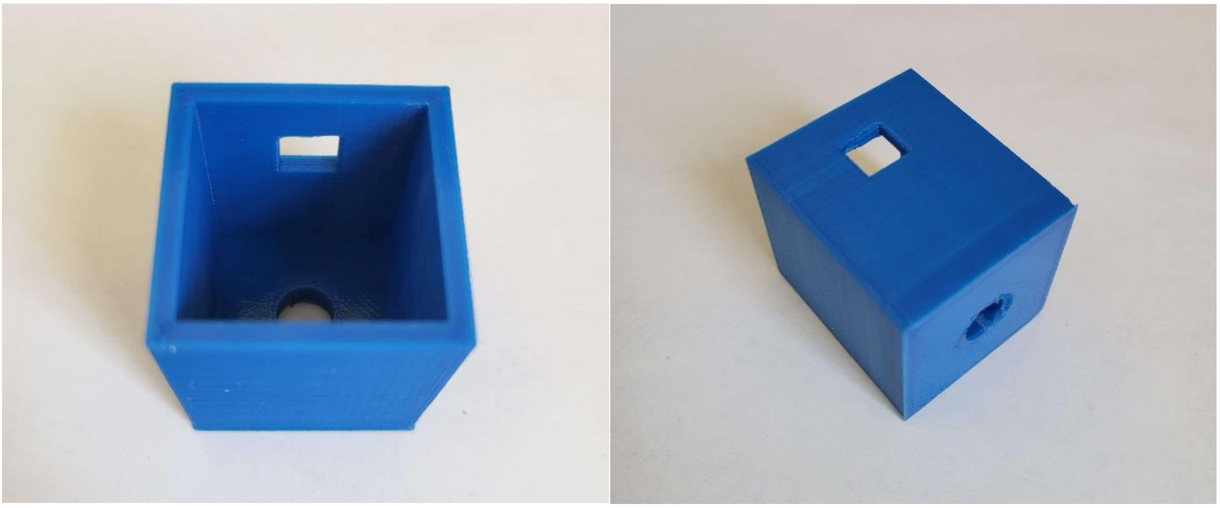

Figure 3 Body of Upper Casing

As can be seen in Figure 4, the lid piece was modified to include an insert that slides into the second piece. The integration of the lid and body piece can be seen in Figure 1 and Figure 2. This design allows for easier placement of the pieces during assembly. A clearance of 0.3mm used in this prototype. The dimensions used for this piece are indicated in Figure 5.

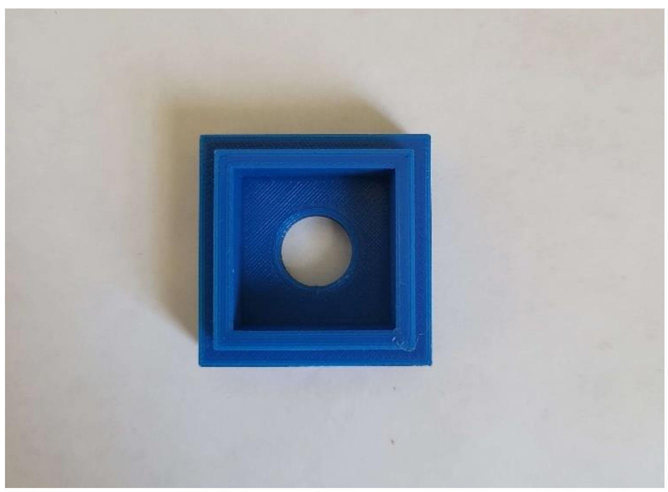

Figure 4 Lid Piece of Upper Casing

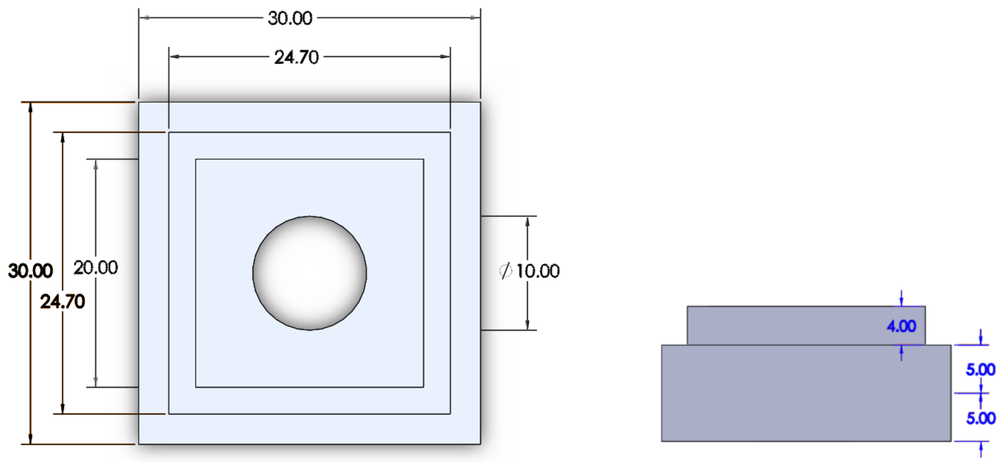

Figure 5 CAD design of lid piece

To ease the testing process without making permanent changes to the upper casing, two clips were attached to the uppercasing body using clear tape as seen in Figure 6. Specifically for this prototype, the upper casing was tested with two 20 x 7 mm clips which was taped to the casing. This was done to allow us to easily move the clips around for a few of the tests should we choose to do so.

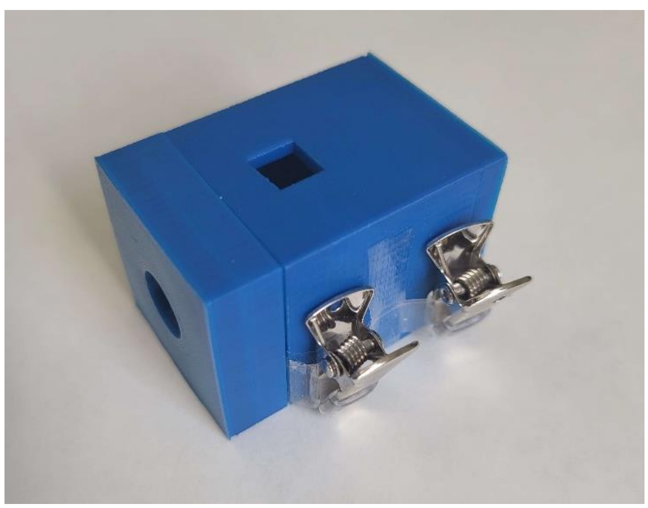

Figure 6 Casing with clips

2.3 Current Tests

Since not all components for the glasses mounted subsystem has arrived at the time of writing, only tests considering the upper casing will be conducted. These tests will try to validate the target specifications with scientific rigor. This section outlines all tests that were conducted on the upper casing.

2.3.1 Feasibility Test

This test will try to test whether the current design of the upper casing will be feasible for the final design. It will test various target specifications such as product mass on frame, time to mount, and other specifications that can be tested using simple tests.

The list of tests that were conducted in this section is as follows:

- Product mass on frames test:
    1) Weigh the assembled upper casing on a weighing machine.
- Time to mount test:
    1) Place a pair of glasses and the assembled upper casing on a flat surface.
    2) Start a timer.
    3) Mount the assembled upper casing on an arm (frame) of the glasses.
    4) Stop the timer and record the time.
    5) Repeat steps 1) to 5) five times.
    6) Average the results.
- Product size test:
    1) Measure the length, width and height of the assembled upper casing using a ruler.
- Time to detach test:
    1) Mount the assembled upper casing on an arm (frame) of a pair of glasses and place the result on a flat surface.
    2) Start a timer.
    3) Detach the mounted upper casing from the arm (frame) of the glasses.
    4) Stop the timer and record the time.
    5) Repeat steps 1) to 5) five times.
    6) Average the results.
- Aesthetically pleasing test:
    1) Ensure that the colour of the assembled upper casing is uniform.

2.3.2 Mount Compatibility Test

To ensure that our design is compatible with various dimensions and sizes of frames, we would have to first obtain various pairs of glasses each with different dimensions. However, since only two of our team members wear glasses, the sample size was very small. As such, the dimension of each pair of glasses was varied using foam to increase the sample size for this test.

With that in mind, the outline for the mount compatibility test is as follows:

1) Mount the assembled upper casing on an arm (frame) of a pair of glasses and place the result on a flat surface.
2) Gently sway the glasses left and right three times and note if the mounted upper casing moved from its original position.
3) Gently sway the glasses up and down three times and note if the mounted upper casing moved from its original position.
4) Accept the dimensions if no visible movement occurred in steps 2) and 3). Reject otherwise.

2.3.3 Time before Discomfort Test

The target specification for time before discomfort is 12 hours. That time is too long for anyone to realistically test in one sitting. As such, this test will be designed in such a way that allows for the results to be extrapolated. This will be done by testing the comfort levels of both having the casing mounted and unmounted for a short amount of time. Using the unmounted tests as a baseline, a regular glasses wearer can gauge how comfortable the glasses are with the casing mounted. Hopefully, they can use this information to extrapolate how much longer/shorter they can have the casing-mounted glasses before it starts to strain them.

The test will also be conducted for various head positions. This will be done to account for the effects of pointing the laser in various directions in our test results.

With that in mind, the outline for time before discomfort test is as follows:
1) Acquire a pair of glasses that you use the most.
2) Put on the glasses and look straight for 5 minutes.
3) Note down how comfortable the glasses were from a scale from 1 to 10, with 10 being the most comfortable.
4) Mount the assembled upper casing on an arm (frame) of a pair of glasses.
5) Put on the casing-mounted glasses and look straight for 5 minutes.
6) Note down how comfortable the casing-mounted glasses were from a scale from 1 to 10, with 10 being the most comfortable.
7) Extrapolate how long the casing-mounted glasses can be kept on before discomfort using information from step 3), step 6) and life experience.
8) Repeat steps 1) to 7) for the following positions: look up, look down, look left, look right.
9) Average the results.

2.4 Test Results

This section contains the results of all tests that were conducted using outlines from section 2.3.

2.4.1 Feasibility Test Results

The following table shows the target specifications that have been tested using the test outline from section 2.3.1.

Table 1: Target Specifications Comparison for Feasibility Test

Metric #	Metric	Target	Results	Unit	Pass/Fail
2	Product mass on frames	20	17 (with clips; without accelerometer, laser, button, wiring mass)	g	Pass
3	Time to mount	30	1	s	Pass
8	Product size: 1. Laser and accelerometer casing	L x w x h 2 x 1 x 1	4.5 x 3 x 3	cm	Fail
16	Time to detach	30	2	s	Pass
17	Aesthetically pleasing	Y	Y (uniform colour)	Y/N	Pass

Since the electrical parts of the product have not yet been assembled and placed within the casing due to possible redesigning of the casing, target specification 2 was only partially tested. The mass of the casing and clip were measured to be 17g. This is below the target specification of 20g.

The time to mount this prototype is approximately 1s when the glasses are not being worn. This result exceeds the target of 30s by a large margin. Similar results were obtained for the time to detach the product.

The product size was measured to be greater than the target size. This is due to the error in estimation of accelerometer size as well as the clearance space that was added to aid in assembly. However, the product size still allows for easy mounting to a pair of glasses, and since the mass is small, does not hinder the wearability of the product.

The aesthetic appeal was observed to be moderate as the casing was of uniform color and symmetric shape.

2.4.2 Mount Compatibility Test Results

The following table shows the target specifications that have been tested using the test outline from section 2.3.2.

Table 2: Target Specifications Comparison for Mount Compatibility Test

Metric #	Metric	Target	Results	Unit	Pass/Fail
9	Mount compatibility with frames (Frame cross section dimensions)	3 x 3 to 5 x 10	6 x 2 to 10 x 3.5	mm	Fail

Using the clips allowed the upper casing to be mounted on a frame of cross section 6 x 2 mm and 10 x 3.5 mm. Although the prototype was secured with adequate grip to both frames, since the frames used were not equal or smaller than and greater than the target range, the compatibility cannot be said to have been completely reached without further testing.

2.4.3 Time before Discomfort Test Results

The following table shows the target specifications that have been tested using the test outline from section 2.3.3.

Table 3: Target Specifications Comparison for Time before Discomfort Test

Metric #	Metric	Target	Results	Unit	Pass/Fail
14	Time before discomfort	12	12+ (without weight of accelerometer, laser, button, wiring)	h	Pass

Since the electrical parts of the product have not yet been assembled and placed within the casing due to possible redesigning of the casing, target specification 14 was only partially tested. The prototype was worn for 10 minutes and did not result in excessive displacement of glasses or discomfort. From the test results, it has been extrapolated that the current prototype without electrical components could be worn for 12h without major discomfort for all positions.

However, when the tester tilted their head downward, the displacement of the glasses increased slightly than when the product was not mounted. However, the glasses did not fall. In addition, the final product will have a wire fed through the back of the casing which may help balance the weight of the product.

2.5 Future Prototype Designs

As a result of the testing done with the current prototype in section 2.4, some changes will need to be made to the glasses-mounted subsystem. As aforementioned, the casing was found wo be within a reasonable size and weight to mount on a pair of glasses. The wall thickness of 2.5mm was also estimated to be sturdy enough for regular use of the product. The product was also able to withstand the pressure needed to open and close spring clips when placed in the intended position. However, creating a smaller prototype would be ideal to decrease the mass and chances of unnecessary instability of the laser. To improve the design, fillets may also be added to all corners to prevent injury. This would eliminate the need of filing the sharp edges of this prototype.

As aforementioned in section 2.2, a clearance of 0.3mm was chosen to ensure the fit of the two pieces. Although this design allows easier assembly of pieces than the original design, after confirming the clearance and friction of the material, a sliding door may allow for a non-permanent lid to the casing. This would allow the inside of the casing to be accessed without breaking open the permanent adhesive. A CAD design with said changes is shown in Figure 7.

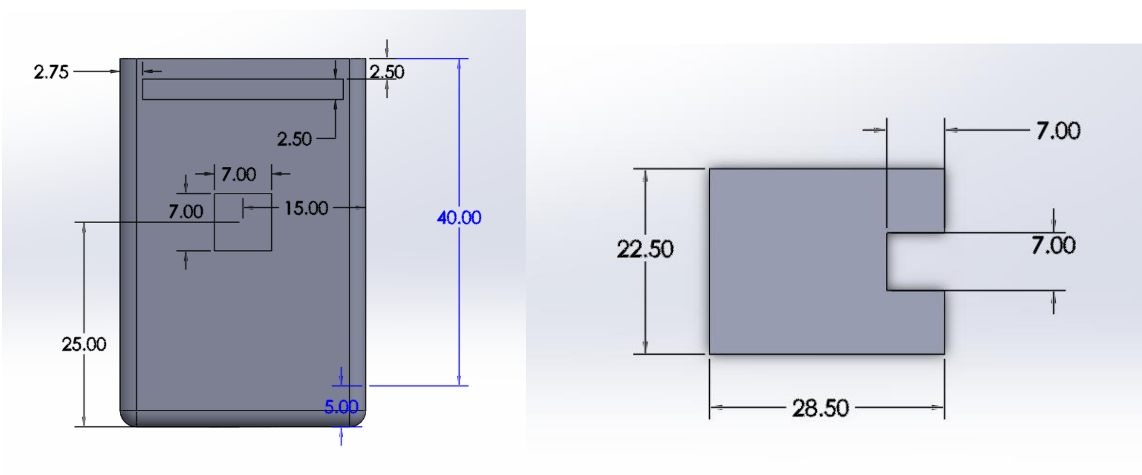

Figure 7 New Upper Casing Design

Although the Arduino casing has not been printed, the design will be slightly changed in accordance with the information gained from the prototype of the upper casing. The walls will be a thickness of 2.5mm and the arms will be 1.5mm thickness to allow more flexibility.

3 Non-Functional Design Constraints

While prototype 2 tests a lot of the functional design constraints, we have yet to consider, implement and test any of the non-functional design constraints. This section will try to remedy said situation based on the results from prototype 2 and client feedback from section 2. Since it is too late to integrate the suggested changes in this section in prototype 2, we will be reserving the changes for prototype 3.

3.1 Usability

One of the most important non-functional design constraints for the development of this prototype and subsequent prototypes is the usability of the product. This is important for both the client and the user of the product. From the client's point of view, a product that is easy to use is important, as our client's focus is on the care of our users, not on understanding and using new technologies. It is important that our product's scope is focused with limited but integral features. As such, usability was considered in the design of the shut off feature and charging feature of the product.

3.1.1 Shut Off Feature

For the shut off feature, only one master switch was required on the device as per the client: an ON/OFF switch. This makes the setup process as easy as flipping a switch. However, this would make the design less emancipatory by taking control way from the primary user. Since the primary user has limited hand mobility, it would be hard for them to use the master switch.

To combat this issue, an auto shut down feature using timer and motion detection will be implemented on top of the master switch. This feature shuts off the laser after 10 minutes when no movement is detected. It ensures that the laser will remain on while in use and turn off on its own once the user has finished using the communication board. This enables our primary user to turn the laser on/off as simply as possible, since no prerequisite knowledge is required on the part of the user.

This change should also help conserve the battery life of the product. Assuming, in the worst case scenario, that the master switch has been left on by the caretaker, which results in the laser being turned on for 10 mins every time the user moves their head. If the user moves their head 90% of the time while keeping the glasses on, they will still conserve a significant amount of battery life.

3.1.2 Charging Feature

For the charging feature, only the battery's capacity was constrained by our client. The actual charging mechanism was left for us to figure out. We decided to use a simple USB power bank that exists independently of the rest of the system to improve the usability of the charging feature. This power bank will be charged with a USB A cable and a phone power adapter. Since the primary user probably uses a smartphone, the charging process will be both intuitive and easy due to preexisting knowledge.

Even if the user does not use USB charging for their phone, odds are they have another device that requires USB connection. Out of all the USB connection types, USB-A is still the most commonly known one [1]. As such, we expect the user to at least have some existing exposure to the concept of USB cables, which will ease the knowledge transfer.

3.2 Size

A second important non-functional constraint is size, and its impact on the mount attached to the glasses. While there is a functional constraint that dictates the maximum size the mount casing, size can also be used as a non-functional design constraint. The physical shape and size of the mount can be manipulated to fulfill various non-functional requirements. For our project, size of the mounted component will affect the aesthetics, and comfort of our end user.

3.2.1 Aesthetics

Studies show that our brains are wired to prefer symmetry over asymmetry . As such, we will be ensuring that the final prototype achieves visual symmetry if possible. This does not restrict our design to primitive blocky shape necessarily. We can restrict the symmetry to either vertical symmetry or horizontal symmetry to help reduce the volume of the mounting casing if need be.

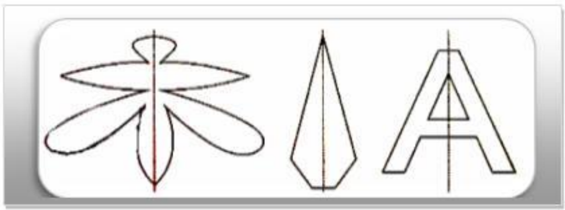

Figure 8: Example of Vertical Symmetry

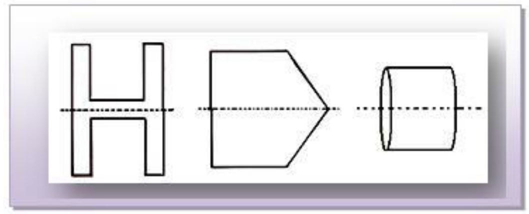

Figure 9: Example of Horizontal Symmetry

If possible, we would like to pick vertical symmetry over horizontal symmetry, as that is what the human brain unconsciously tends to prefer .

3.2.2 Comfort of End User

The user and client would want a mount that is comfortable to use for an extended amount of time. Keeping the mount compact would reduce the weight of the mount material, which should prolong the time it takes before user starts feeling discomfort due to prolong use of our product. Now that we have a better understanding of the size of each component the mount needs to contain from section 2, the mount can be redesigned to make better use of space, thus reducing its size.

The mount needs to contain the laser, accelerometer, and a button. We need to reorganize the layout to minimize space between them while keeping the components as functional as possible. The chosen accelerometers have several axes that could be placed parallel to the head. The button location is flexible so long as it remains accessible. The laser is the only component that has a strict mounting requiring, which is to remain parallel to the frames. Space for wiring should also be accounted for while trying to reduce the size of the mount as small as possible.

Using the dimensions of the parts that will be used in the final prototype, the following table was generated to help calculated the how much air space can be gotten rid of. Note that the button was not considered in this calculation since it will be protruding out of the case.

Table 4: Volume of Mounted Parts

Part	Volume (cm^3)
Mount Casing	40.5
Laser Diode	1.02
Accelerometer	3

From Table 4, we can see that only 10% of the current mount casing is used by components in prototype 2. As such, there is plenty of extra space that can be removed to fulfil this non-functional requirement. Note that some extra space will always exist due to wiring clearance and mounting case wall thickness.

3.3 Updates to Detailed Design

Based on the analysis on the non-functional design requirements, the following changes will be made to the subsystems of the detailed design. These changes will be thoroughly tested in prototype 3.

3.3.1 Laser Software Subsystem

As suggested by section 3.1.1, the laser software subsystem will add a timer to the existing acceleration-based laser switch that was built in prototype 1. The code will only keep the laser on for 10 minutes since it first detects movement. After this time has passed, the laser will automatically turn off. The laser will stay turned off until new movement is detected, at which point the laser will be turned on again.

The threshold for movement detection by the accelerometer and the actual duration of keeping the laser on will have to be tested thoroughly in prototype 3.

3.3.2 Glasses Mounted Subsystem

As suggested by section 3.2.1 and 3.2.2, the glasses mounted casing must be reduced in size while staying symmetric. Ideally the casing stays symmetric both horizontally and vertically. If that is not possible, horizontal symmetry will be preferred.

3.3.3 Hip Mounted Subsystem

As suggested by section 3.1.2, the battery bank should stay independent of the rest of the system. Only the Arduino Uno will be encased withing the hip mounted casing. The battery bank will exist outside of the casing and stay connected to the Arduino Uno with the help of a USB-A wire.

4 Client Feedback

Both the prototypes developed in section 2 and the changes from section 2.5 and section 3.3 were discussed with the client at Client Meeting 3. During this discussion, it was apparent that the client liked the direction that we were taking the product in. He agreed that the current iteration of the glasses mounted casing was on the bigger side and thought that our idea to make it a bit smaller was great.

In addition, two additional pieces of information were revealed during the meeting. It was revealed that the primary user for this product has more limited head movement than anticipated. Since we are relying on a timer based shut off system for the laser instead of a movement based shut off system, this detail will not affect our detailed design at all.

It was also revealed that the primary user for this product uses frameless glasses. This will work in our favor since we have full control over the dimensions of the dummy frame purchased for the final product. Doing so will ensure that the clips and the frame fit perfectly with one another, giving no wiggle room.

As no major modifications were requested by our client, no changes will be made in our detailed design in this section.

5 Conclusion

Since the client feedback from section 4 was positive overall, we can continue proceeding with the project as planned. Our upcoming prototypes will use the finds from section 2 and section 3 to try and improve upon the current detailed design. The time to implement said changes are accounted for in our Gantt chart. As such, we expect to finish our final prototype before Design Day.

6 References

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