WORCESTER POLYTECHNIC INSTITUTE

ECE 2799 - Habit Helper

Team 14

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1. Introduction

Our product is intended to aid its user in developing healthy habits in the areas of posture and physical activity. The product will accomplish this when the customer attaches the wearable device to his/her body. The location and attachment method will allow the device to move with the wearer's body and obtain relevant measurements with a movement sensor. These measurements will then be used to provide feedback to the customer. Feedback includes a slight vibration as a reminder to sit up straight and a smartphone application interface that will display data recorded over time as a way to track improvement. In this report, the numerous ideas that have been discussed during our brainstorm meeting on the design and implementation of the device are evaluated. These ideas are scrutinized with criteria generated from market research results including cost, functionality, comfort, etc. Additionally, the product is evaluated in comparison to its competitors in order to determine if the product is suitably marketable. The conclusion is the culmination of the best aspects of each idea into one cohesive whole which will be built upon for the duration of the project.

2. Design Options

After brainstorming for possible ways to design the product, we had to consider our ideas and attempt to select the most effective options. First, we narrowed our ideas down to a few options for each module of the design. The options for each module are listed in Section 3 of this report. Next, in order to evaluate the design options, we used criteria which were based on customer and product requirements. In addition, we took into account the ease of implementation for various designs since we must complete the full prototype within a very short time. The following categories were used to evaluate our options:

- Cost
- Functionality
- Size
- Comfort
- Ease of use
- Battery Life

- Aesthetics
- Ease of Implementation

During the value analysis process, a high score overall suggests that the design being evaluated will satisfy the both the customer requirements and our own resource constraints.

Next, we assigned weights to each of these categories. We assigned weights based on each category's importance as suggested by our market research. For example, comfort was requested by a notable number of potential customers, so that has a particularly high weight. Each weight is on a scale of importance from 0 to 100.

- Cost—80
- Functionality—95
- Size—90
- Comfort—100
- Ease of use—65
- Battery Life—70
- Aesthetics—40
- Ease of Implementation—30

We used a separate set of criteria to analyze the microcontroller, bluetooth module, and battery options since there were so many specific technical criteria for each. The details for these criteria are found in Section 3 of this report.

3. Specific Module Design Options

This section will describe the various design options which we found through our brainstorming. Each subsection will describe the requirements and options for a single module of our design, and describe the value analysis process for that module. We divided these modules based on the block diagram shown in figure 1. The value analysis scores in each module are directly based on the listed advantages and disadvantages of each option.

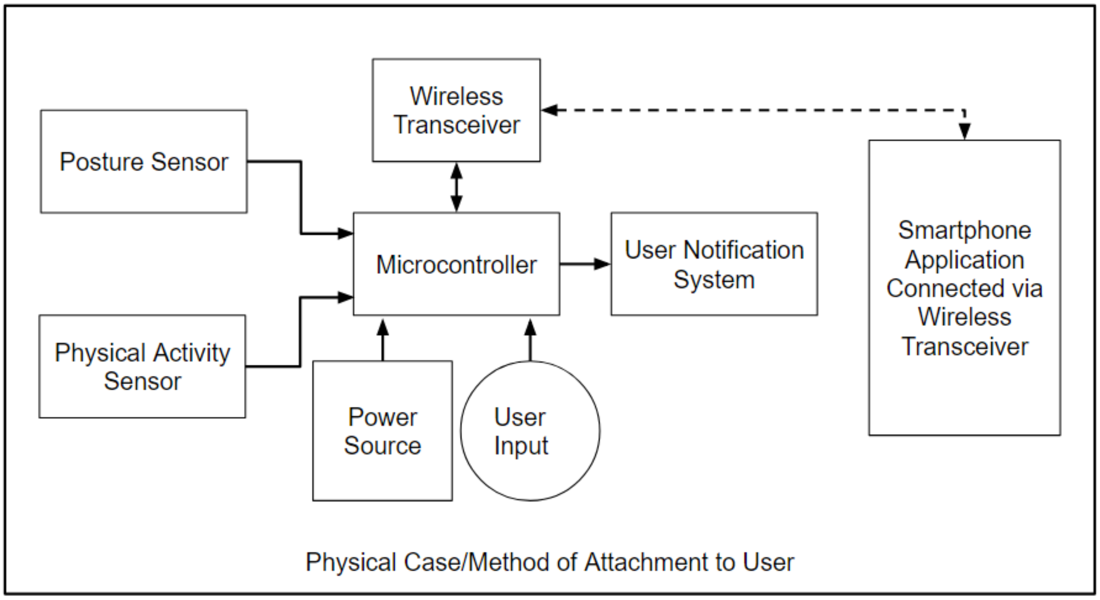

Figure 1: Block Diagram of the Product

3.1 Physical Case

This subsection will cover the requirements, options, advantages and disadvantages as well as value analysis for the physical case of the device. The physical case is the part of the device which the user will actually see during use. It also includes the method of attachment to the user's body. Each design option is differentiated by its shape, size, method of attachment, and location on the body.

3.1.1 Requirements

Based on the product requirements, the physical case must meet the following requirements:

- Compact
- Comfortable design
- Durable
- Easy to use
- Aesthetically pleasing design

3.1.2 Design Options

The design options which remained after narrowing down our ideas for the case of the device are listed below, along with the possible advantages and disadvantages of each:

- Oval shaped case placed on the upper back/spine with an adhesive pad
    - small
    - discreet under clothes
    - may be difficult to put on
    - replacing adhesive pads could be an issue
    - may not stick on the skin
- Oval shaped case placed on the upper back/spine with a harness
    - discreet under most clothing
    - would most likely stay on
    - sizing could be an issue
    - may be uncomfortable under arms
- Crescent shaped flexible case placed around the neck from behind, with high friction silicone on the back to keep in place
    - easy to put on
    - gives the option to implement a heart rate monitor in future versions
    - may not stay in place due to the lack of adhesive
    - would not be completely hidden under clothes
- Long thin case attached around the neck at the top (as described above) and around the back at the bottom with a belt
    - would stay in place
    - gives the option to implement a heart rate monitor in future versions
    - a hassle to put on
    - bulky
- Long thin case attached around the neck at the top and around the back at the bottom with suspenders
    - would stay in place
    - gives the option to implement a heart rate monitor in future versions

    - a hassle to put on
    - bulky
- Oval shaped case placed on the chest with an adhesive pad
    - small
    - easy to put on because of placement on the chest
    - gives the option to implement a heart rate monitor in future versions
    - may not be covered by clothes
    - replacing adhesive pads could be an issue
    - may not stick on the skin

3.1.3 Value Analysis

Below are the criteria used for the value analysis process as well as the scoring scales for each. Please note that in this case, durability is taken into account with ease of use, as the durability in question refers primarily to the need for replacement parts.

- Functionality (how many functions it is able to accomplish): 1 least, 10 most
- Size: 1 big, 10 small
- Comfort: 1 uncomfortable, 10 comfortable
- Ease of use: 1 hard, 10 easy
- Aesthetics: 1 not at all appealing, 10 very appealing
- Ease of Implementation: 1 hard, 10 easy

Figure 2 demonstrates the value analysis process used to determine the best option for this module. All scores assigned were based directly on market research and research on existing designs.

	Cost	Functionality	Size	Comfort	Ease of use	Battery Life	Aesthetics	Ease of Implementation	Weighted Total
Weight	80	95	90	100	65	70	40	30	
Upper back/spine with adhesive (oval shaped)	x	5	10	6	4	x	10	8	2875

Upper back/spine with harness	x	5	5	5	7	x	6	5	2270
Around neck with high friction silicone on back to keep in place	x	10	7	9	10	x	9	4	3610
Neck and back with belt	x	5	3	3	5	x	4	3	1620
Neck and back with suspenders	x	5	4	4	5	x	3	3	1770
Chest with adhesive	x	10	10	6	6	x	8	8	3400

Figure 2: Value Analysis of the Device Case Options

3.2 Sensors

This subsection will cover the requirements, options, advantages and disadvantages as well as value analysis for the sensors of the device. These sensors will take all of the necessary measurements for the core functionalities of the device, including posture measurement and physical activity measurement. The design options include 3 different types of sensors. Some selections (for example, the flex sensor for posture) would require that we use multiple types of sensors to implement all of the core functionalities, while other sensors could accomplish the measurements for both posture and physical activity.

3.2.1 Requirements

Based on the product requirements, the sensors in our device must meet requirements in the following categories:

- Cost
- Functionality
- Size
- Ease of Implementation

3.2.2 Design Options

The design options for the device sensors are listed below, along with the possible advantages and disadvantages of each:

- Accelerometer
    - small
    - can be functional in a variety of locations
    - low cost
- Flex Sensor
    - long
    - cannot fit in a compact design
    - can only be placed on the spine
    - low cost
- IMU
    - small
    - high functionality (can track both posture and physical activity/motion)
    - mid cost

3.2.3 Value Analysis

Below are the criteria used for the value analysis process as well as the scoring scales for each:

- Cost: 1 highest cost, 10 lowest cost
- Functionality: 1 least, 10 most
- Size: 1 big, 10 small
- Ease of Implementation: 1 hard, 10 easy

Figure 3 demonstrates the value analysis process used to determine the best option for this module. All scores assigned were based directly on market research and research on existing designs.

	Cost	Functionality	Size	Comfort	Ease of use	Battery Life	Aesthetics	Ease of Implementation	Weighted Total
Weight	80	95	90	100	65	70	40	30	
Accelerometer	5	5	7	x	x	x	x	5	1655
Flex sensor	5	1	1	x	x	x	x	5	735
IMU (Adafruit BNO055 Absolute-Orientation Sensor)	2	10	6	x	x	x	x	5	1800

Figure 3: Value Analysis of Sensor Options

3.3 User Input

This subsection will cover the requirements, options, advantages and disadvantages, and value analysis for the user input of the device. This is the method that the user will use to turn the device on and off.

3.3.1 Requirements

Based on the product requirements, the user input system in our device must meet requirements in the following categories:

- Cost
- Functionality
- Ease of Implementation

3.3.2 Design Options

The design options for the user input system are listed below, along with the possible advantages and disadvantages of each:

- Button
  - low cost
  - easy to implement

- Switch
    - low cost
    - easy to implement
    - The user will have a simple way to know if the device is on or off
- On/Off via App
    - zero cost
    - difficult to code/implement
    - device would have to be “on” to some extent at all times

3.3.3 Value Analysis

Below are the criteria used for the value analysis process as well as the scoring scales for each:

- Cost: 1 highest cost, 10 lowest cost
- Functionality: 1 least functional, 10 most functional
- Ease of Implementation: 1 hard, 10 easy

Figure 4 demonstrates the value analysis process used to determine the best option for this module. All scores assigned were based directly on market research and research on existing designs.

	Cost	Functionality	Size	Comfort	Ease of use	Battery Life	Aesthetics	Ease of Implementation	Weighted Total
Weight	80	95	90	100	65	70	40	30	
Button	7	5	x	x	x	x	x	10	1335
Switch	7	10	x	x	x	x	x	10	1810
On/Off from app	10	7	x	x	x	x	x	1	1495

Figure 4: Value Analysis of User Input Options

3.4 User Notification System

This subsection will cover the requirements, options, advantages and disadvantages as well as value analysis for the user notification system of the device. This is the method that will be used to alert the user when he/she has been slouching. It may also be used to deliver other notifications such as exercise reminders or alarms.

3.4.1 Requirements

Based on the product requirements, the notification system in our device must meet requirements in the following categories:

- Cost
- Comfort
- Ease of Use
- Ease of Implementation

3.4.2 Design Options

The design options for the user notification system are listed below, along with the possible advantages and disadvantages of each:

- Vibration
  - low cost
  - notification is instant and easy to act on
  - easy to implement in the device
  - discrete (only the user will feel/hear the notification)
- Audible Sound
  - low cost
  - easy to install
  - instant notification
  - disruptive and will probably annoy customers
  - may make users hesitant to wear it in public spaces
- Phone Notification

- zero cost
- more comfortable (as a vibration or sound could be alarming)
- notification is delayed as people must look at their phones to receive the message
- much more difficult to implement

3.4.3 Value Analysis

Below are the criteria used for the value analysis process as well as the scoring scales for each:

- Cost: 1 highest cost, 10 lowest cost
- Comfort: 1 uncomfortable, 10 comfortable
- Ease of use: 1 hard, 10 easy
- Ease of Implementation: 1 hard, 10 easy

Figure 5 demonstrates the value analysis process used to determine the best option for this module. All scores assigned were based directly on market research and research on existing designs.

All 1-10	Cost	Functionality	Size	Comfort	Ease of use	Battery Life	Aesthetics	Ease of Implementation	Weighted Total
Weight	80	95	90	100	65	70	40	30	
Vibration	6	x	x	7	10	x	x	8	2070
Audible sound	7	x	x	1	8	x	x	8	1420
Phone notification	10	x	x	10	5	x	x	4	2245

Figure 5: Value Analysis of User Notification Options

3.5 Wireless Transceiver

This subsection will cover the requirements, options, and value analysis for the wireless transceiver of the device. We chose to use Bluetooth because it suits our application very well since it can make connectivity between devices more reliable than other wireless alternatives and it is compatible with many phone devices, including older versions. It is a standardized protocol which is sending and receiving data via a 2.4GHz wireless link, it is secure and it is ideal for short-range, low-power, low-cost applications. We decided to choose Bluetooth SPP (Serial Port Profile) over BLE, because the former is designed for continuous two-way data transfer with high application throughput (up to 2.1 Mbps). Consequently, it is ideal for sending bursts of data between two devices. Certainly, there is a trade-off between SPP and BLE regarding data throughput and power consumption, but during prototyping we would like to make sure that performance is guaranteed for short distances by having a continuous broadband link (multiple data will be received/transmitted) and that there is not excessive power consumed (e.g. Wi-Fi has relatively higher power consumption). We plan on using an Arduino microcontroller as explained in section 3.6, therefore we searched specifically for compatible Arduino Bluetooth Modules.

Name	**Bluetooth Classic**	**Bluetooth 4.0 Low Energy (BLE)**	**ZigBee**	**WiFi**
IEEE Standard	802.15.1	802.15.1	802.15.4	802.11 (a, b, g, n)
Frequency (GHz)	2.4	2.4	0.868, 0.915, 2.4	2.4 and 5
Maximum raw bit rate (Mbps)	1-3	1	0.250	11 (b), 54 (g), 600 (n)
Typical data throughput (Mbps)	0.7-2.1	0.27	0.2	7 (b), 25 (g), 150 (n)
Maximum (Outdoor) Range (Meters)	10 (class 2), 100 (class 1)	50	10-100	100-250
Relative Power Consumption	Medium	Very low	Very low	High
Example Battery Life	Days	Months to years	Months to years	Hours
Network Size	7	Undefined	64,000+	255

Figure 6: Comparison of different protocols and profiles (Sparkfun Bluetooth Basics)

3.5.1 Requirements

Based on the product requirements, the wireless transceiver in our device must meet requirements in the following categories:

- Cost
- Functionality
- Size

- Ease of Implementation

3.5.2 Design Options

The design options for the wireless transceiver are listed below:

- HC-05
- HC-06

3.5.3 Value Analysis

Below are the criteria used for the value analysis process as well as the scoring scales for each.

- Bluetooth Profile
- Cost
- Range
- Functionality
- Sensitivity
- Operating Voltage Range
- Operating Current
- Size

The weights and score scales for each of the criteria are detailed in figure 7. These weights were chosen based on the importance of each criteria for our specific application. Each weight is on a scale from 1-5. It should be noted that since there is no direct way to determine the weights of criteria not covered in market research, they are somewhat subjectively based on what we view as important to the design. Figure 7 demonstrates the value analysis process used to determine the best option for this module.

		HC-05			HC-06		
	Weight (1-5)	Parameter Value	Value (1-5)	Weighted Value	Parameter Value	Value (1-5)	Weighted Value

Bluetooth Profile	5	Serial Port Profile (SPP)	5	25	Serial Port Profile	5	25
Cost	5	$6.99 (banggood.com)	5	25	$8.99 (Amazon.com)	4	20
Range	4	9 meters (30ft)	3	12	9 meters (30ft)	3	12
Functionality	2	Master or Slave	5	10	Slave	1	2
Sensitivity	4	-80dBm	3	12	-80dBm	3	12
Operating Voltage Range	5	4V to 6V (Typically +5V)	4	20	3.3V to 6V	5	25
Operating Current	5	30mA	5	25	40mA	3	15
Size	5	27mm×13mm×2mm	3	15	27mm×13mm×2mm	3	15
			Total=	144		Total=	126

Figure 7: Value Analysis of Wireless Transceiver Options

3.6 Microcontroller

This subsection will cover the requirements, options and value analysis for the microcontroller of the device. Our goals regarding the microcontroller were that we wanted our final selection to not only be very small in size, but to also have satisfactory memory and processing power for our project. Although microcontrollers with bluetooth capabilities exist, we decided to implement the bluetooth functionality separately because bluetooth microcontrollers were either bigger in size, more expensive compared to some other microcontroller/bluetooth module combinations we found, or did not have enough resources for us to be convinced at this stage that they could be used as a central microcontroller in our project.

3.6.1 Requirements

Based on the product requirements, the microcontroller in our device must meet requirements in the following categories:

- Cost
- Functionality
- Size
- Ease of Implementation

3.6.2 Design Options

The design options for the user input system are listed below. The advantages and disadvantages of each are detailed in the value analysis chart.

- Arduino Nano
- Arduino Pro Mini
- Arduino Micro

We narrowed the choices down to several types of Arduino microcontrollers because Arduino is a reputable brand for small but relatively powerful microcontrollers. In addition, there is an exceptional amount of open source software and documentation available and they will be easier to implement because we already have some familiarity with their use.

3.6.3 Value Analysis

Below are the categories of criteria used for the value analysis process:

- Processor
- Size
- Interface
- Power Consumption
- Memory
- I/O
- Practicality

The weights and score scales for each of the criteria are detailed in figure 8. These weights were chosen based on the importance of each criteria for our specific application. Each weight is on a scale from 1-5. It should be noted that since there is no direct way to determine the weights of criteria not covered in market research, they are somewhat subjectively based on what we view as important to the design. Figure 8 demonstrates the value analysis process used to determine the best option for this module.

		Arduino Nano			Arduino Pro Mini			Arduino Micro		
Parameter	Weight (1-5)	Parameter Value	Value (1-5)	Weighted Value	Parameter Value	Value (1-5)	Weighted Value	Parameter Value	Value (1-5)	Weighted Value
Processor										
1) Processor Type	5	ATmega328	4.5	22.5	ATmega328	4.5	22.5	ATmega32U4	5	25
2) Frequency (Clock Speed)	3	16MHz	3	9	16MHz	3	9	16MHz	3	9
Size										
1) Dimensions	5	1.70 in. x 0.73 in. (43.18 mm x 18.54 mm)	4	20	0.7 in × 1.3 in (17.8 mm × 33.0 mm)	5	25	0.7 in × 1.9 in (17.8 mm × 48.3 mm)	3	15
Interface										
1) Host Interface	4	USB	5	20	Six pin serial header (need external circuit to program it - header has additional cost)	3	12	USB	5	20
Power Consumption										
1) Operating Voltage	3	5V	3	9	5V	3	9	5V	3	9
2) Input Voltage	5	7V - 12V (recommended)	3	15	5V to 12V	3	15	7-12V	3	15
3) Current Draw (for Frequency in the range of 1MHz to 20MHz and Voltage = 5V)	5	0.62mA/MHz	4	20	0.62mA/MHz	4	20	0.88mA/MHz	3	15
4) Voltage limits on input/output pins	2	-0.5V to Vcc+0.5V (Vcc = 5V)	3	6	-0.5V to Vcc+0.5V (Vcc = 5V)	3	6	-0.5V to Vcc+0.5V (Vcc = 5V)	3	6
5) DC Current per I/O Pin	4	40mA	5	20	40mA	5	20	20 mA	4	16
Memory										
1) Flash	5	32kB	3	15	32kB	3	15	32kB	3	15
2) EEPROM	5	1kB	3	15	1kB	3	15	1kB	3	15
3) SRAM	5	2kB	3	15	2kB	3	15	2.5kB	4	20

I/O										
1) Digital I/O Pins	4	14	5	20	14	5	20	20	3	12
2) Digital I/O Pins with PWM	4	6	5	20	6	5	20	7	4	16
3) Analog input Pins	4	8	4	16	6	5	20	12	3	12
Practicality										
1) Cost (the higher the value, the lower the price - lowest price found from Digi-Key and Mouser is displayed)	5	$4.25 (But we already have one)	5	25	$9.95 (Digi-Key)	3	15	$19.80 (Mouser)	1	5
2) Opensource?	4	Yes	5	20	Yes	5	20	Yes	5	20
3) Cost of Software	2	FREE	5	10	FREE	5	10	FREE	5	10
4) Ease of Implementation	1		5	5		3	3		4	4
			Total =	302.5		Total=	291.5		Total=	259

Figure 8: Value Analysis of Microcontroller Options

3.7 Power Source

This subsection will cover the requirements, options, advantages and disadvantages as well as value analysis for the power source of the device.

3.7.1 Requirements

Our microcontroller (Arduino Nano) requires an input voltage of 7V to 12V and then uses its regulator to lower it to its operating voltage (5V). The maximum total current we can draw from an Arduino Nano when it is powered via an external power supply is 500mA. The IMU will be powered through the Nano's 5V pin and will require maximum 12.3mA. The Bluetooth transceiver (HC-05) will also be powered through the 5V pin and will require about 30mA. Finally, our vibrating motor (vibrating mini motor disc from Adafruit) will be powered through one of the Nano's digital pins that will provide it with 40 mA (current draw it requires when it is working under 2V) in order to work whenever it is needed. However, on average, the current draw of our system is estimated to be around 60mA (approximately 20mA for the Arduino Nano while running, around 10mA for the IMU and about 30mA for our Bluetooth transceiver). The current draw of the vibrating motor is not included in this estimation, since it will be off for most of the time. Moreover, we would like to note that we will measure current draw more accurately using a Digital Multimeter when we receive our modules. On the other hand, our goal for battery life is to last about 5 days, with 16 hours of battery life allocated to each day. Therefore, our goal for total battery life is about 80 hours. Consequently, from the equation below, we will be able to determine how much capacity is required from the battery. The reason behind multiplying the division of battery capacity with current draw with 0.80 is so we can receive a more realistic number of the battery life provided to our project and not base our solution off ideal battery life.

$$\frac{Battery\ Capacity\ (Amphours)}{Current\ Draw\ (Amps)} \cdot 0.8\ =\ Battery\ Life\ (Hours)$$

The resulting battery capacity we get from this equation based on our requirements is 6000mAh.

Based on our market and technical research, we need to consider the following factors when choosing a battery.

- Cost
- Size
- Battery life
- Ease of use
- Ease of implementation

3.7.2 Design Options

Since we have an idea of what capacity we need, the main decisions we need to make with respect to the battery(s) are size, shape, type, and rechargeable/non-rechargeable.

Some possible types are listed below:

- Coin Cell (Lithium)
- AA, AAA, C, D (NiMH or NiCd - rechargeable)
- Silver Flat Pack (Lithium Polymer - rechargeable)
- AA, AAA, C, and D (Alkaline or Zinc-carbon)

3.7.3 Value Analysis

We considered the following criteria in our value analysis for the battery.

- Cost: 1 highest cost, 10 lowest cost
- Size: 1 big, 10 small
- Ease of use: 1 hard, 10 easy
- Battery Life: 1 short, 10 long
- Ease of Implementation: 1 hard, 10 easy

Our value analysis process is shown in figure 9.

		Two Li-ion Rechargeable Batteries (6000 mAh 3.7V) connected in series (Amazon)			Four C AccuPower NiMH Batteries (6000 mAh) connected in series (megabatteries.com)			Two UltraFire TR-26650 Li-ion Batteries connected in series (lightmalls.com)		
	Weight(1-100)	Parameter Value	Value(1-10)	Weighted Value	Parameter Value	Value(1-10)	Weighted Value	Parameter Value	Value(1-10)	Weighted Value
Voltage	10	7.4V	10	100	4.8V	7	70	7.2V	10	100
Capacity	10	6000mAh	10	100	6000mAh	10	100	6000mAh	10	100
Size	9	Height: 65mm, Diameter: 18mm	8	72		5	45	Height: 65.3mm, Diameter: 26mm	7	63
Shape	4	Cylindrical	9	36	Cylindrical	9	36	Cylindrical	9	36

Cost	9	10 pack for $17.99	8	72	$37	5	45	$11.98	9	81
Rechargeable?	10	Yes	10	100	Yes	10	100	Yes	10	100
Battery Life of our Circuit with this Battery	9	About 80 hours	10	90	About 80 hours	10	90	About 80 hours	10	90
			Total=	570		Total=	486		Total=	570

Figure 9: Value Analysis of Power Source Options

4. Preferred Design Approach

Based on the value analysis for our specific module design options, we plan on using the following components in our design:

- Case: Crescent shaped flexible case placed around the neck from behind
- Sensors (Posture and physical activity): Adafruit BNO055 Absolute-Orientation Sensor (IMU)
- User input (on/off): Switch
- User notification system: Vibrating mini motor disc
- Microcontroller: Arduino Nano Microcontroller
- Wireless Transceiver: HC-05 Wireless Bluetooth Serial Transceiver Module
- Power source: Two 3.7V 4800mAh rechargeable lithium battery cells connected in series (80 hour battery life-5 days at 16 hours per day)

We have chosen to use the Adafruit BNO055 Absolute-Orientation Sensor as an IMU in our prototype because it meets all of our requirements and we already have access to one. For the actual product, a different IMU could be used which might be a more optimal design choice. All of these modules will be located inside the crescent shaped case shown in figure 10.

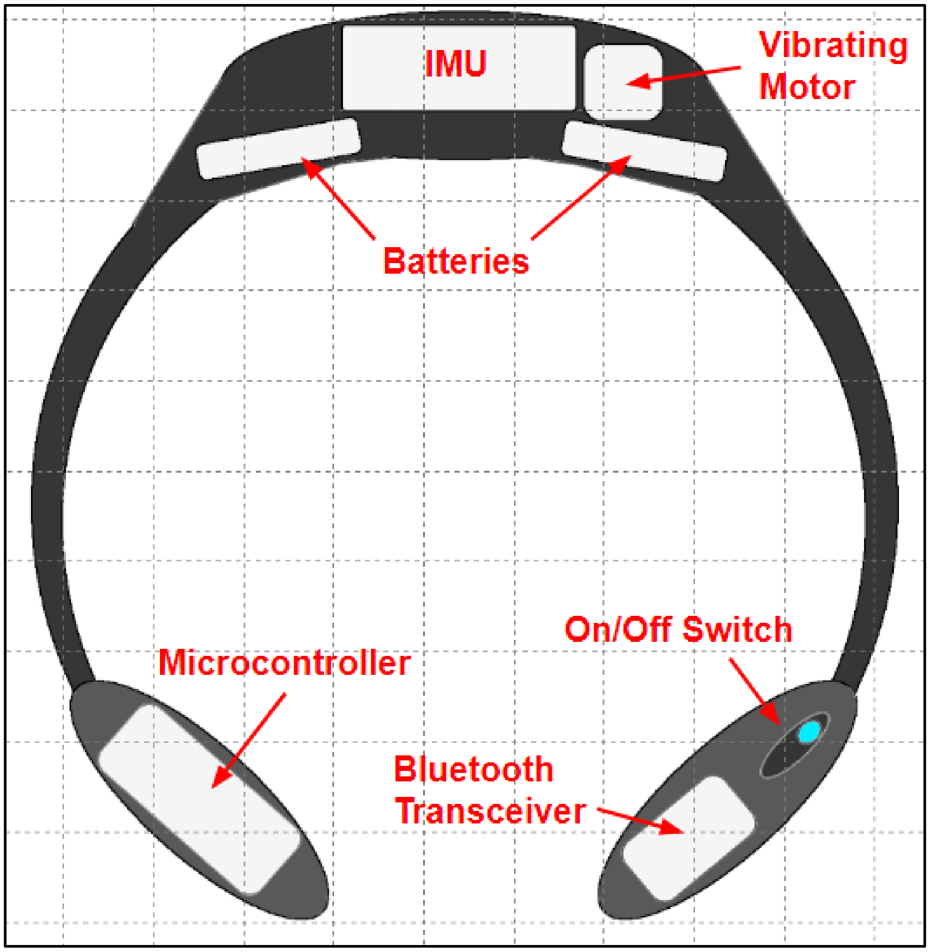

Figure 10: Proposed Design

The device's functionality is analytically explained in the flowchart below (figure 11).

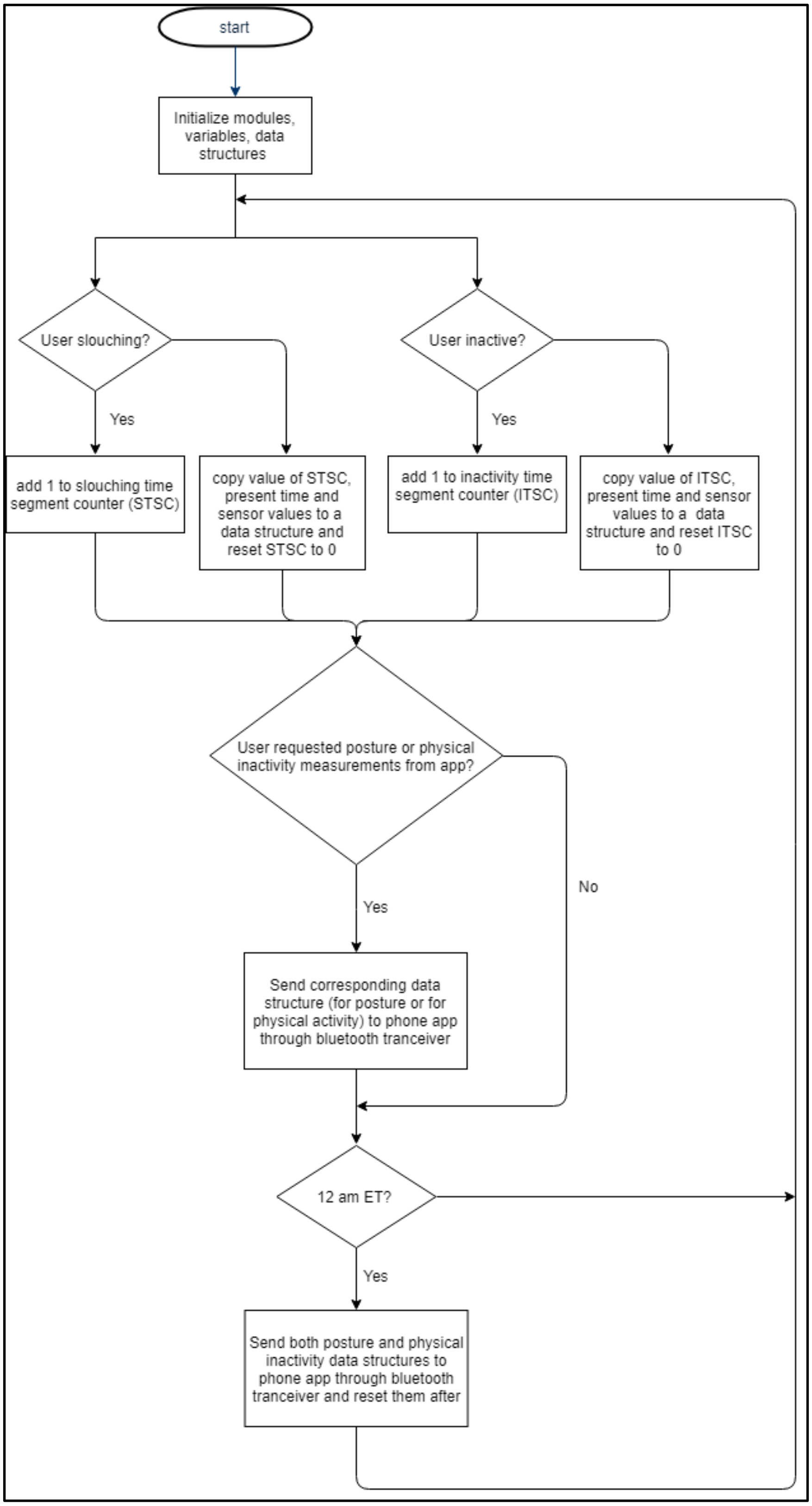

Figure 11: Device Flowchart

With reference to the implementation of the app, we will create a Bluetooth Terminal by establishing a link between the user's phone and the HC-05 module connected to our device. Through this terminal, the user will be able to "ask" the device about the amount of time they have been slouching and/or have been physically inactive any time of a given day. At the end of each day, the device will transmit the corresponding day's results which will also be displayed in graphs for visual feedback. The results, and thereby the graphs, will show the minutes a user has spent in a good vs. a bad posture and will also convey the minutes of the user's physical inactivity. Figure 12 below is a flowchart displaying our app's functionality.

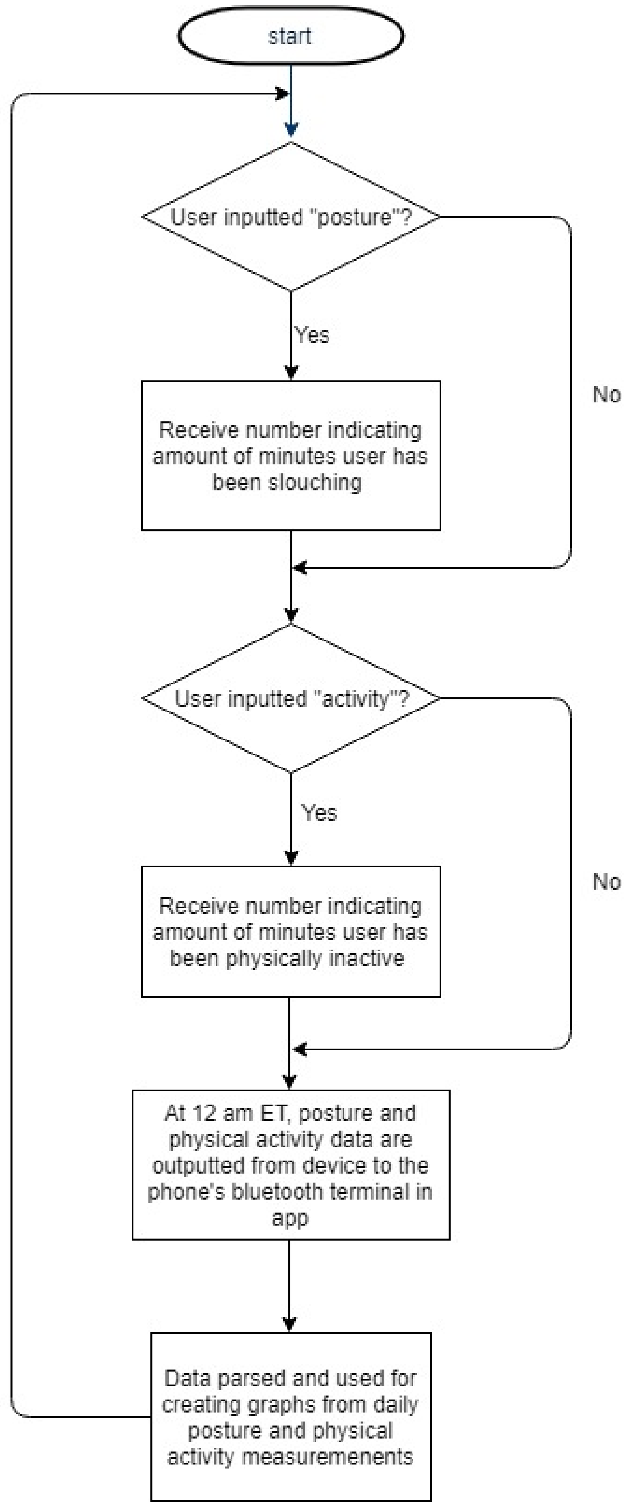

Figure 12: Phone Application Flowchart

All of the choices for our design approach were made based on our value analysis. However, there are many potential flaws with our value analysis process. First, there are most likely aspects of each module which we failed to consider. Second, there is a level of subjectiveness in both the weight and scoring process for each value criteria. Although we based these numbers on research, there is not always an exact one to one value, so some interpretation needs to be made. Third, an inherent flaw of value analysis is that it only considers the options you have already found. There is always the possibility that a superior option exists which has not been considered. Because of this, we view the value analysis outcomes more as educated guesses than facts, and are always open to new information.

5. Competitive Value Analysis

5.1 Introducing Our Competitors...

The companies who are also selling products attempting to correct posture and/or increase physical activity span the range of very established and reputable products to some that are not yet available to purchase. The list of products found to be in competition with our device are listed below:

- UpRight Go- This device sticks to the top of the spine and vibrates when the user slouches. A smartphone app connects to the device and archives the user's progress and contains other controls and features.
- Lumo Lift- Like the UpRight Go this device is meant to be worn; however, instead of the device sticking to the user's skin, the Lift is magnetized and it comes with a tasteful magnetic square that is placed on the front of the shirt or on a bra strap to keep the device in place. The Lift is placed on the chest area and like UpRight Go it measures posture and vibrates when it senses the user slouching. A smartphone app connects to the device and archives the user's progress along with other features.
- Zikto Walk- This device is a bracelet worn on the wrist that detects bad posture when walking. It vibrates when is senses that the user is not walking with the correct form. The bracelet connects to an app and archives the user's progress.

- Prana- The Prana sensor clips to the wearer’s waistband and measures breathing, which can also give posture information. The sensor connects to an app that has a variety of features including breathing exercises and games.
- FitBit Flex- The Flex is a bracelet that uses a pedometer to track physical activity.

These products were chosen as competitors because the product specifications and advertising seemed to target people in the same or a similar market to ours. While our product is not the same as any one of these, the features are similar enough that our customers might be interested in these competing products for the same problem.

5.2 Competitor Value with Respect to Customer Criteria

In order to accurately compare our product idea with the existing competition we evaluated each one using our customer criteria. This section uses the same criteria and scoring system as the value analysis performed on our own design options, except ease of implementation is not considered. Additionally, battery life is scored using the number of days that the battery lasts.

- FitBit Flex:
    - Cost: $99.95
    - Size: The bracelet relatively thick making it extremely noticeable.
    - Functionality: Tracks physical activity very well, but does not do any posture tracking.
    - Comfort: Fairly comfortable as is has a sturdy, adjustable band that will keep it from falling off or sliding around. However, he band could get caught on things and can irritate the skin when wet.
    - Ease of Use: It has a user friendly interface on the bracelet itself and has a well refined computerized interface on the user’s phone. The band is also completely waterproof so the user can wear it in the shower and can track physical activity when swimming.
    - Battery Life: Up to 5 days and is rechargeable.
    - Aesthetics: Comes in different colors to make up for the fact that the product is always in plain view. Sleek and uses quality materials.

- UpRight Go:
    - Cost: $59 (plus replacement adhesive pads)
    - Size: Product is small and can be hidden under clothes if placed properly.
    - Functionality: UpRIght Go is a accurate posture measuring device… when it stays on. There are many reviews from customers who complain that the device either did not stick to their bodies or it would not stay on. Due to the nature of this device if it did not adhere to the correct location on the body it was more or less useless.
    - Comfort: Due to the method of adhesion this product must be ripped off the body at least once per day which is very uncomfortable and even painful. Additionally, it is very awkward to place this product in the optimal location on the user's back.
    - Ease of Use: This product has a very straight forward user interface that includes turning the product on, placing it in the right location, and that's pretty much it. The app allows you to see your progress and change the device from "tracking" mode (which only tracks your posture and does not use the vibrator to notify the user when they are slouching) to "habit forming" mode (which does use the vibrator)
    - Battery Life: 8 - 12 hours
    - Aesthetics: The device is sleek and a nice shiny white color. However, the device would look strange if not covered using a completely closed back shirt.
- Lumo Lift:
    - Cost: $249.95
    - Functionality: This device is the most functional among the competitors. The vibration function can be turned on and off simply by double tapping the magnetic square.
    - Size: This device is separated into two parts. The sensor and the majority of the electrical components are housed in the largest piece housed beneath the clothes. This piece is quite thin and can easily be hidden with clothing. The second piece, the magnetic square, is quite small and is worn on the front of the shirt or on a bra strap. There is a downside aspect here as the product cannot be totally hidden for men and women who would prefer not to clip anything to their bra.

- Comfort: The Lift is placed on the front of the body, so there is no awkward reaching to get just the right spot on the back like the UpRight Go. Additionally, the device connects to the body via a magnet, so there is no painful sticker removal and no need to buy replacement adhesive pads. There might be some discomfort with the device possibly bumping against the chest of the user when they move as the device is not directly connected to the body. Lumo suggest wearing tight clothes when using this device, but it is naive to think that customers will only wear tight clothes from now on to accommodate the device.
- Ease of Use: There are more features associated with this device making the user interface more complex than the other products discussed, however; it is more convenient once the customer knows how to operate the device and the app that goes with it.
- Battery Life: Up to 5 days and is rechargeable.
- Aesthetics: It is evident that the aesthetics for this device were considered carefully. The magnetic square meant to be worn on the front of the customer's top comes in ten different colors and can be mixed and matched to accommodate the customer's stylistic needs. Additionally, even though the second piece of the device is housed beneath the clothes it comes in three colors and is in sleek, visually appealing metallic colors.

- Zikto Fitness and Activity Tracker:
  - Cost: $81.24
  - Functionality: The Zikto Fitness and Activity Tracker tracks balance and walking posture when the customer exercises. From customer reviews it appears this device has a lot of bugs, for example, many users frustrated because the bracelet buzzes when performing common actions (such as looking at phone).
  - Size: Rather bulky and not discreet to wear.
  - Comfort: Fairly comfortable to wear, has an adjustable strap.
  - Ease of Use: Customers indicate that there are a lot of space for improvement in this product which includes creating a more durable product (the wristband has a tendency to snap). The smartphone app also needs improvement as many customers have called it useless.

    - Battery Life: Up to three days, not rechargeable.
    - Aesthetics: The bracelet is rather ugly. It comes in two colors, but it is bulky and not visually appealing at all.
- Prana:
    - Cost: Unknown. This product is not for sale yet and their patent is currently pending.
    - Functionality: Primarily tracks breathing, but it also includes posture tracking and step tracking.
    - Size: Super small and discrete. The only piece that can be seen on the front of the clothes is the back of the clip that holds it to the waistband of the wearer's pants.
    - Comfort: This device does not touch the skin very much and it is designed to be placed on the waistband of the pants which are generally tightest piece of clothing that a person wears. However, this is not always the case as people could wear pants that are too large. This would skew the data as this product relies on measuring breathing patterns on the lower back.
    - Ease of Use: Easy set up, the customer needs only to place the sensor and communicate with it using a smartphone app.
    - Battery Life: Up to 7 days with wireless charging capabilities.
    - Aesthetics: The sensor has no special visually pleasing features because it is mostly hidden within the waistband of the wearer's pants.

5.3 Value Analysis

The value analysis performed to compare our product with successful existing products is shown in figure 13 below.

	Cost	Functionality	Size	Comfort	Ease of use	Battery Life	Aesthetics	Weighted Total
Weight	80	95	90	100	65	70	40	

Our Product	8.5	7.5	5	9	10	5	7	4022.5
FitBit Flex	7	1	6	6	9	5	7	3010
Upright Go	10	7	7	4	4	0.5	10	3190
Lumo Lift	1	10	8	7	9	5	9	3745
Zikto Fitness and Activity Tracker	8	3	6	6	5	3	5	2800
Prana	1	8	10	9	8	7	6	3890

Figure 13: Competitive Value Analysis

5.4 Conclusions

Our conclusions here are rather speculative; however, they were based on the requirements obtained from market research. There could be some discrepancies in grading our competitors because what we and our survey group want might not be what the market as a whole is looking for. As a result, what we perceive as a major asset or downfall might be disputed by others. On the other hand, we thoroughly researched these competitors and read both what the company says the device should be able to do, along with customer reviews detailing what the product actually does. We listened to the customer reviews intently to see what aspects about the product that people liked and disliked in order to improve our own design. Overall, the value analysis above may have a few errors, but the outcome still gives a sufficiently accurate reading on our product's potential for success.

6. Conclusion

Our final design choice has both advantages and disadvantages. Some of these are listed below.

Advantages:

- Reasonable cost
- Battery life of approximately 5 days (at 16 hours per day)
- Easy to put on
- Simple user interface
- Tracks both posture and physical activity
- Offers behavioral statistics
- Vibration is quiet and discreet
- User can easily tell if the device is on or off due to the use of a physical on/off switch
- Bluetooth should make it fairly simple for the user to connect the device to their smartphone

Disadvantages:

- May not be completely hidden under clothing (depending on the clothing), so if the user does not find the device aesthetically pleasing that could be an issue
- Needs testing to ensure that it will stay in place during use
- Bluetooth only works in a short range, so the user will need to have the device nearby in order to access the day's statistics
- The user will be able to turn the device on and off manually; this could interrupt the normal function of the device, particularly with regards to syncing with the phone app

With respect to customer criteria, our product seems to have the most value in comparison to our competitors. Despite the disadvantages associated with our product, we meet (and in many cases exceed) what customers asked for. For example, our product tracks both physical activity and posture for people who have a sedentary career and experience pain from slouching and/or too little exercise. Additionally, our product is very comfortable as it does not adhere to the customer's body or clothes with adhesive pads or magnets. Overall, the customer criteria has been met with the product's design.

The value analysis results are valid to the best of our abilities. They are completely based on customer requirements collected doing market research and researching competitors. The scores and weights are based upon what our prospective customers and the team thought was most important. Additionally, we took into account with the “Ease of Implementation” section which ideas the team could implement with the most accuracy and finish with the most polished and functional product. There are, of course, places in the value analysis where errors might have occured because of team bias or customer requirements that do not reflect the entire market. In the future, we will discover these inconsistencies but at this point, the value assigned to each product or idea is accurate to the best of our knowledge.

From our value analysis, our product should be very competitive in the market we have chosen. Taking into account what we know to be the customers’ requirements we discovered that our product has the highest score of all of the competing products we researched. We did have an advantage in this area as our product was still only an idea and could be inspired and built upon the competitor products we found. As a result, we were able to identify the downfalls of our competitors through customer reviews and comparison to our customer requirements. Consequently, we were able to ensure that our product did not make the same mistakes. Therefore, our product should be very competitive in the market as it has built off all the pre-existing devices.

There are some aspects of the product which we may need to reconsider as the project progresses. One of the major risks with the proposed design is the method of attachment. Until we are able to test a prototype, we cannot say with 100% certainty that it will stay in place during use. We may need to change the design if it does not function as planned. A possible solution is to include adhesive silicone on the back, but we would like to avoid it, if possible. Another risk is the IMU sensor itself. We cannot know until we test it that the measurements will be sufficiently accurate and consistent for our application. Finally, depending on the time and resources available, we may need to alter the design and functionality of the phone application. There may not be time to design and program the exact functionality we are hoping for. In this case, the core functionality will be maintained and some of the less crucial features can be excluded from the prototype.

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