4 Design

4.1 Design Context

4.1.1 Broader Context

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

List relevant considerations related to your project in each of the following areas:

Area	Description
Public health, safety, and welfare	Our system will reduce the response time for a service dog to recognizing their owners PTSD episode, meaning the user's will experience less traumatic PTSD episodes resulting in an improved quality of life for our users.
Global, cultural, and social	The development of this device has the potential to change cultural and societal stigmas associated with PTSD by improving possibilities for people suffering from PTSD. The development of this device brings awareness about PTSD without bringing attention to an individual during a PTSD attack due to the design of discreet detection.
Environmental	Much of our product is just an application for user's to download on their phones, meaning production and usage of our product will have limited impact on the environment
Economic	Our product has the possibility to reduce the cost of training a service dog, thus making them more affordable for our customers.

4.1.2 Prior Work/Solutions

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

– If you are following previous work, cite that and discuss the advantages/shortcomings

– Note that while you are not expected to "compete" with other existing products / research groups, you should be able to differentiate your project from what is available. Thus, provide a list of pros and cons of your target solution compared to all other related products/systems.

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

Relevant Prior Work for Dog Device:

Market Products Available:

1. Haptic Vibration Collar for dog training [1]

   Uses vibrations to alert a dog to problematic behavior. These devices are widely used for correcting bad behavior in dogs. This device is a collar that has prongs for sending vibrations directly to the skin on the dog's neck. These prongs allow for better sensation transfer from the haptic collar to the dog [1].

   Pros: Does not need a vest to be attached to the dog

   Cons: Somewhat uncomfortable for the dog depending on proper adjustment

Additional Research on Haptic Devices for dog training:

1. A Vibrotactile Vest for Remote Human-Dog Communication [2]

   Research on developing and implementing a haptic vest for training dogs via vibrational motors and various programmable stimuli associated with certain commands. This literature highlights some design considerations for implementing haptic feedback inside a worn vest. The paper highlights issues when sending vibrations to certain areas on the dog's back that may be less sensitive to haptic feedback and how to adjust for issues like these [2].

Relevant Prior Work for User (Human) Device:

Market Products Available (Disclaimer: These devices do not detect PTSD and is not intended to do so but in relation to our project, we will be using pre existing technology for the human user and compare them on a basis of their functionalities relevant to what we want to do and other devices/products that do them.):

1. Apple Watch

   This device tracks biometric data and gives the user a visual interpretation of it either with numbers or diagrams. Has software and hardware to detect any critical abnormalities and learn from users in normal states. Not made to detect PTSD but can detect states that PTSD triggers. [3]

   Pros: Best fitness companions; has both electrical and optical heart rate sensor; can warn the user of any abnormalities, either high or low beats per minute.

   Cons: Cannot detect if it is PTSD episode

2. Fitbit

   This device tracks user biometric data and gives the user a visual interpretation of it either with numbers or diagrams. It also can detect fight or flight response triggers. While this is

not entirely made to function as a PTSD device, it can track stress levels,heart rate, etc. which all contribute to PTSD. [4]

Pros: Can track biometric data and warn you in the case of critical abnormalities.

Cons: Does not warn service dogs of this biometric data in the case it is critical to a PTSD attack. Not made to track PTSD episodes.

Relevant Prior Work for Detection Algorithms:

Heart Rate and Body Acceleration

One study tested whether smart watches could detect PTSD events using the heart rate data. The researchers found that it could track the event, but with some error during movement or physical activity. However, they deduced that while using heart rate data and body acceleration data together, the accuracy improved and "enable[ed] algorithms to distinguish between heart rate fluctuations due to physical activity and heart rate fluctuations due to mental stress." [5]

Pros: Able to distinguish between physical activity and stress.

Cons: 0.7 AUC (fair to poor accuracy)

Heart Rate Variability

Another study was able to use a watch which tracked both heart rate variability and actigraphic data— sleep parameters and average motor activity over a period of days—to classify and predict PTSD events. In addition the researchers were able to develop a method that " automatically detect[ed] rest and activity periods of the day using the cosinor analysis." [6]

Pros: Able to detect rest and activity. With user input, AUC increased to .77 (fair accuracy), showing that user input can be helpful to improve data and the results

Cons: Without user data, 0.7 AUC (fair to poor accuracy)

4.1.3 Technical Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

1. **The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–**
2. **The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.**

1. Our App is built using Flutter as a framework and an MVC design pattern.

2. Machine Learning elements will require further technical research as well as statistical analysis knowledge.

4.2 Design Exploration

4.2.1 Design Decisions

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc. Describe why these decisions are important to project success.

Key Dog Device Design Decisions:

1. Arduino Nano BLE (Decision Made)

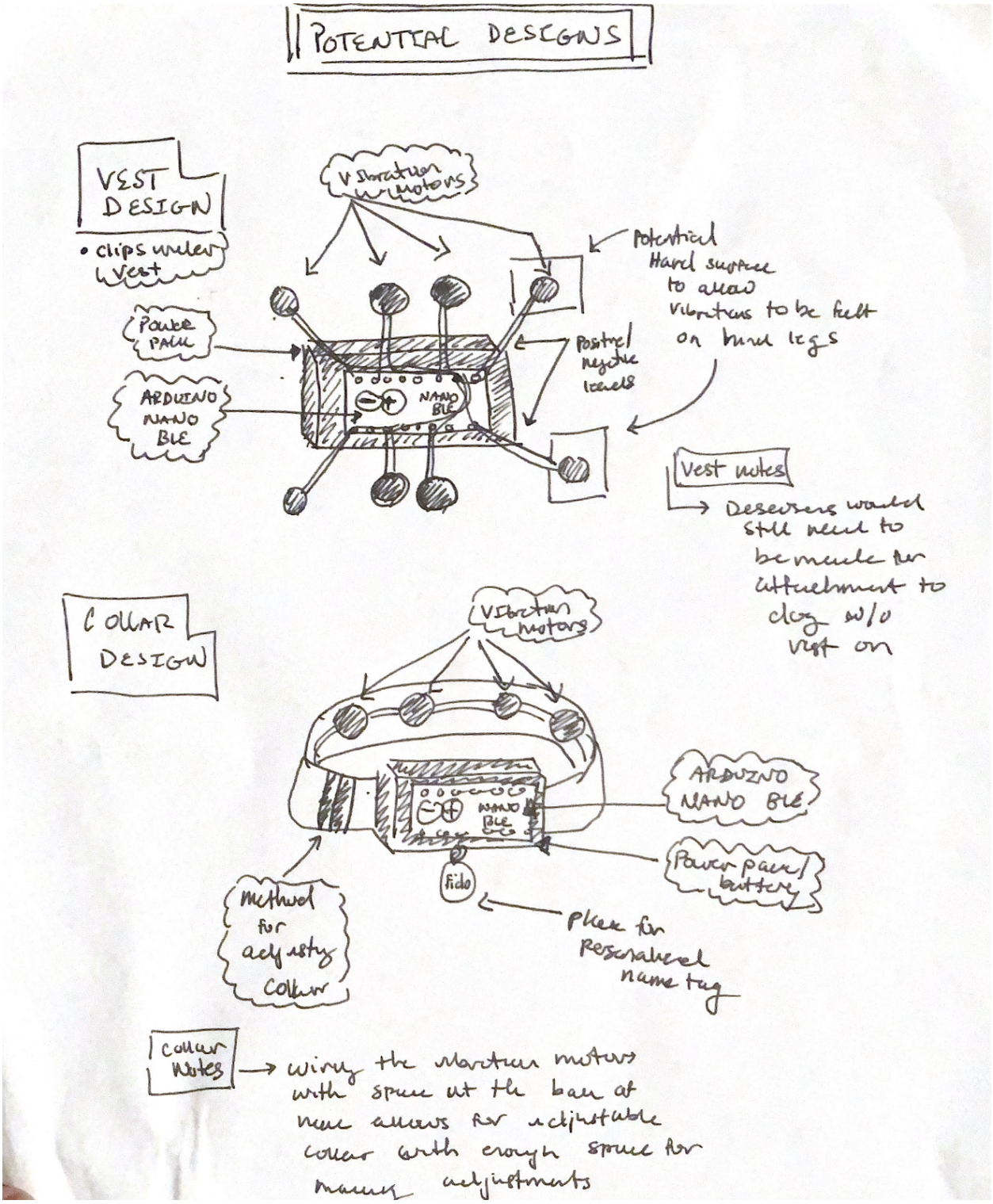
   The Arduino chosen has a built-in Bluetooth module capable of 5.0 Bluetooth connectivity and low power consumption. This is an important design decision because it allows us to maintain small dimensions for the circuitry of the dog's device and implement IEEE standards for Bluetooth connectivity.

2. Vibration Motors (Decision Made)

   The vibration motors as the form of feedback provided to a dog is an important design feature because it allows us to provide a stimulus without hurting or hindering the dog. Configurability of these vibration motors is another important design feature because this allows for adjustments to be made individually depending on the dog's size and weight or his hair. This can be done by varying the supplied voltage to the motor for the optimal level of dog response.

3. Design of Device Attachment (Decision Still In Progress)

   The physical design of the device is important as this will affect whether or not the detection can be used without a vest, whether or not the dog endures abrasions when wearing it for long periods of time, and whether or not the device will be suitable for multiple types of dogs. There are a few different iterations we have already gone through and some of the potential physical designs are sketched below:



4.2.2 Ideation

For at least one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). Describe at least five options that you considered.

During deciding how the dog device should attach to the dog. We wanted it to be effectively connected so it is securely touching the dog for vibrations to be felt, without being uncomfortable. We spoke in a group about the size and shape that would be best suited for this application. We considered a device that would attach to the dog's collar and hang. We discussed the possibility of finding a way to keep the device on the back of the neck of the dog for greater comfort in another idea. Next we began to move away from attaching to the dog's neck for fear of it catching when the dog turns its head. We considered the attachment of the device to the vest of the dog in some fashion. One design idea for this was to have the vibration motor separate from the device and connected by a wire to be slid into the dog's vest. After considering this, we were worried about the integrity of the wire as the dog moved around and the device was removed repeatedly for charging. These considerations brought us to our current final design model. In this model we will fit components within a thin rectangular prism and attach it to the bottom of the vest so that when the vest is attached, it will reside between the vest and the dog making firm contact with the skin. This design allowed for all of the cons of other designs to be eliminated, providing a simpler, and more robust device.

4.2.3 Decision-Making and Trade-Off

Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish to include a weighted decision matrix or other relevant tool. Describe the option you chose and why you chose it.

Decision Matrix

Dog's device

	Touching the dog	Appropriate vibration	Design of Device Attachment	Size and Shape	Microcontroller (Arduino Nano BLE)	Final Weight
Weighted Scale(1-5; 1 being Low Importance 5 being High Importance)	4	3	4	5	5	
Collar Scale(1-10; 1 being Low Importance 10 being High Importance)	6	4	4	8	9	137
Vest Scale(1-10; 1 being Low Importance 10 being High Importance)	8	7	8	8	9	**170**

We decided on using the vest since it has the highest value in the weighted total matrix. Also, in terms of the given categories, it scores highly in comparison to the collar decision. We found the vest to be the most feasible and realistic given explanations of the pros and cons of both above (ideation paragraph).

References:

1. Gantt, E. (2021, September 24). *Is a vibration collar best for my pet?* Wag! Retrieved October 21, 2022, from https://wagwalking.com/wellness/is-a-vibration-collar-best-for-my-pet
2. Y. Golan, B. Serota, A. Shapiro, O. Shriki and I. Nisky, "A Vibrotactile Vest for Remote Human-Dog Communication," *2019 IEEE World Haptics Conference (WHC)*, 2019, pp. 556-561, doi: 10.1109/WHC.2019.8816079
3. https://www.apple.com/apple-watch-series-7/index.html
4. https://www.fitbit.com/global/eu/products/smartwatches/versa3
5. Sadeghi M, McDonald AD, Sasangohar F (2022) Posttraumatic stress disorder hyperarousal event detection using smartwatch physiological and activity data. PLOS ONE 17(5): e0267749. https://doi.org/10.1371/journal.pone.0267749
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