Communication Aid for Nathan

By Team D.U.G.
Final Report

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Abstract

Individuals with service dogs are frequently interrupted by members of the public who want to get their “dog fix” from the working dog. At best, this experience is an annoyance; at worst, the service dog can be so distracted that they are unable to focus on their handler, potentially jeopardizing the safety of the service dog’s human partner. Moreover, people often approach and interact with the service dog without asking or acknowledging their handler, which is disrespectful to the individual. To understand the magnitude of this issue, our team worked with Abby and her service dog Nathan to understand how this situation arises, what she currently does to handle it, and what her ideal solution would look like. From our conversations with Abby, we came up with multiple designs and evaluated them against her criteria, as well as more general design considerations, including robustness, ease of use, and flexibility of component placement. Our final design is a Bluetooth speaker that can be attached to any of Abby's mobility devices, along with a remote control that Abby can wear or hold to trigger pre-recorded audio messages.

Background

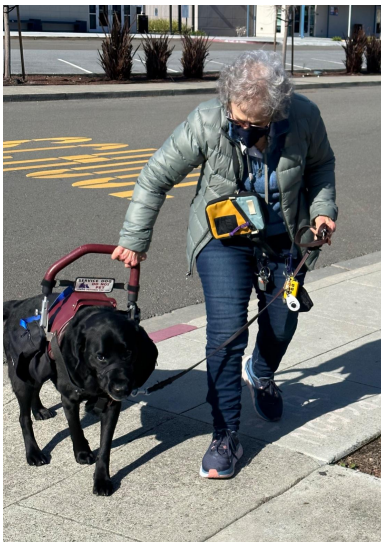


Figure 1: Abby and Nathan

Abby is a student, artist, designer, and a clinical social worker. She is an individual with multiple disabilities: a mobility challenge and a visual impairment. She has a service dog named Nathan, who she has been working with for about 8 years.

Abby has been an invaluable advisor, and while our project is built specifically for her, it could also be useful more broadly for anyone who goes out in public with a service dog. Our background research says that people trying to pet working dogs is a very common and frustrating issue.

Because our device "speaks" on behalf of the dog or the handler, it could be specifically helpful for service dog owners who have problems communicating with others due to differences in speech or discomfort in social situations.

Problem

There are over 500,000 service dogs working in the U.S. today. [1] Service dogs can be invaluable for individuals who are deaf or hard of hearing, who experience seizures, who have diabetes or severe allergies, who are on the autism spectrum, or who have impaired motor function and/or use a mobility device. [2] While individuals who are blind or have low vision often go out in public with guide dogs, Abby informed us that guide dogs tend to *not* have this issue, due to the more obvious perception of a working dog and, often, a white cane.

In our specific case, Abby and Nathan are constantly interrupted by people who want to pet Nathan. These distractions put Abby in jeopardy, since Nathan may be unable to do his job. These interactions also disrupt Abby's day-to-day life, which can be very annoying for her. While she appreciates the opportunity to educate people about service dog etiquette, she doesn't always have the time or inclination to have these interactions.

Aim

Our proposed solution, after discussion with Abby, is to give Nathan a “voice” to explain to members of the public that he is working and ask them not to pet him. Abby wants to maintain control of the “voice” by manually activating it and choosing the content of the audio message. In addition, we want to support Abby’s work of educating the public about service dog etiquette without putting the responsibility and burden solely on Abby by also incorporating a longer educational audio message.

Design Criteria

To help better understand the problem, our team interviewed Abby who explained how this situation arises in her daily life and how she currently deals with it. Abby highlighted the frequency of these disruptive occurrences, particularly in noisy and crowded environments or while she was occupied with other tasks. When Nathan is distracted while on the job by other people, the responsibility falls on Abby to inform them to not engage with him and this interrupts her and Nathan's activities. Abby sometimes appreciates the opportunity to educate people, particularly children, about the etiquette surrounding service dogs, but only when she has the time.

From this interview, we established our main design criteria to guide our brainstorming and initial ideation of our design:

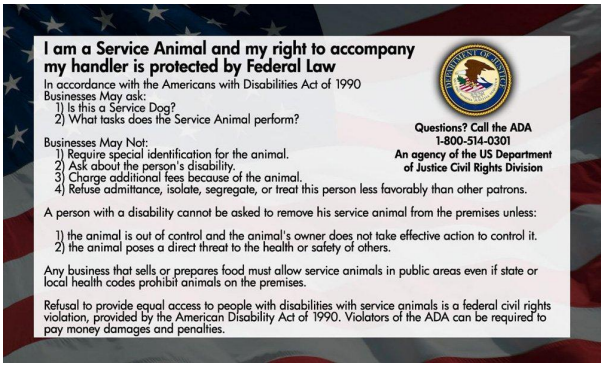
- Loud enough to be heard in crowded environments
- Variety of content and tone in audio messages
- Easy to access and activate
- Lightweight, portable, ergonomic with flexible placement
- Ability to educate
- Nothing attached to Nathan’s Canine Companions harness
- Doesn’t distract Nathan

Understanding the Problem

Currently, the only existing solution for this problem is signage. These signs are mostly seen as placards or badges worn on the service dogs' harness or vest stating "Service Dog: Do Not Pet" or other similar messaging, as shown in Figure 2. Signage has limited effectiveness eliminating the problem. It may be hard to see and read, particularly for children, and it is also easy to ignore or overlook. [3]

Figure 2: Examples of signage on service dogs

The desire to educate the public about service dog etiquette is partially solved by handing out informational cards. An example of these information cards is shown in Figure 3. This is common for explaining the legal role and rights of service dogs specified by the ADA, but some have adapted the technique to etiquette as well. These cards do not avoid the interruption, but they can reduce the burden on the individual to patiently articulate and explain in a time of frustration.



I am a Service Animal and my right to accompany my handler is protected by Federal Law

In accordance with the Americans with Disabilities Act of 1990
Businesses May ask:
1) Is this a Service Dog?
2) What tasks does the Service Animal perform?

Businesses May Not:
1) Require special identification for the animal.
2) Ask about the person's disability.
3) Charge additional fees because of the animal.
4) Refuse admittance, isolate, segregate, or treat this person less favorably than other patrons.

A person with a disability cannot be asked to remove his service animal from the premises unless:

1) the animal is out of control and the animal's owner does not take effective action to control it.
2) the animal poses a direct threat to the health or safety of others.

Any business that sells or prepares food must allow service animals in public areas even if state or local health codes prohibit animals on the premises.

Refusal to provide equal access to people with disabilities with service animals is a federal civil rights violation, provided by the American Disability Act of 1990. Violators of the ADA can be required to pay money damages and penalties.

Questions? Call the ADA
1-800-514-0301
An agency of the US Department of Justice Civil Rights Division

Figure 3: Service animal information card [4]

Overall, there are not many solutions that exist to address this problem, which makes it even more frustrating.

Design Ideation

During the early phases of brainstorming, we considered a tethered connection between a remote controller and speaker embedded through Nathan's leash. This early ideation around a hard tethered connection was quickly ruled out due to concerns about robustness, reliability and durability. We also considered embedding the electronic components of the device into the shell of Nathan's harness, but moved away because of robustness and complexity. Sketches for both these ideas are in Figure 4. We then switched gears to focus on a wireless approach.

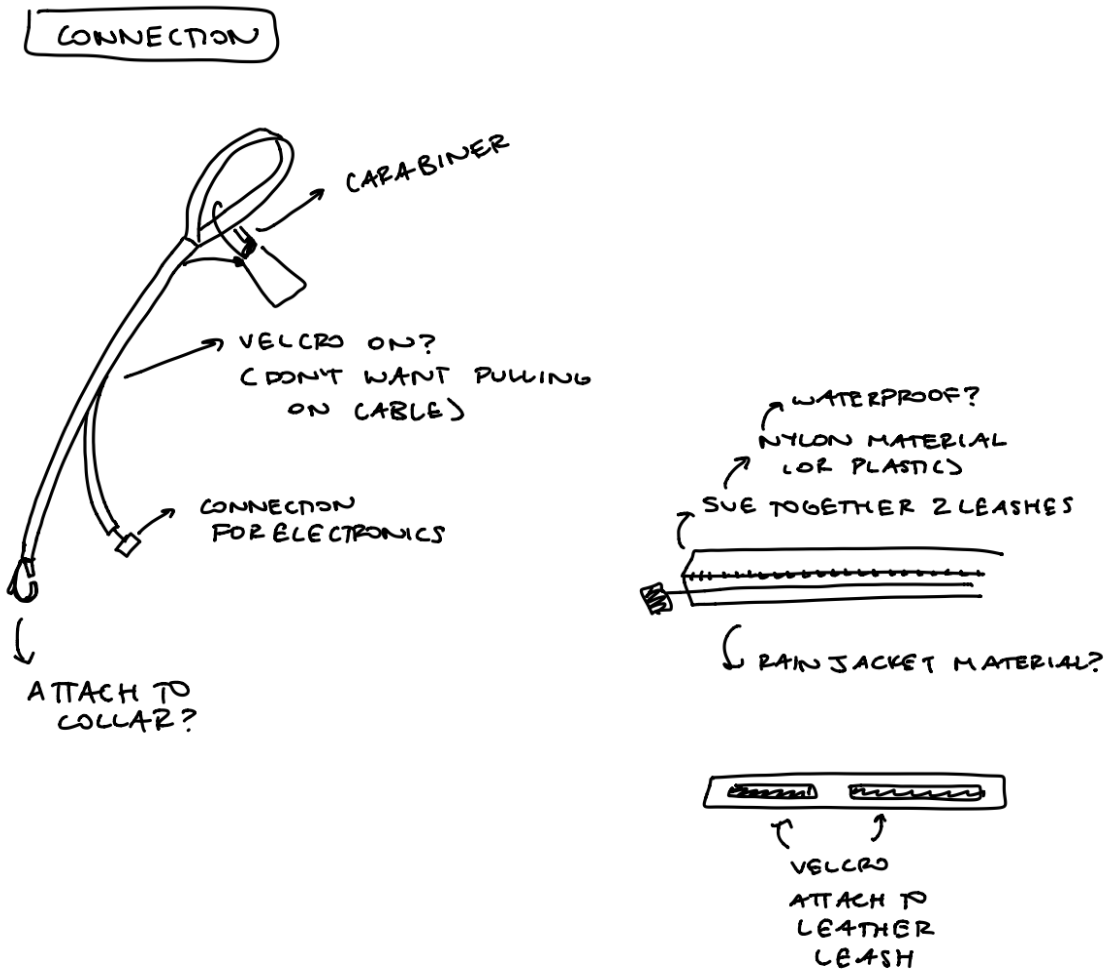


Figure 4a: Sketches of ideation for tethered connection

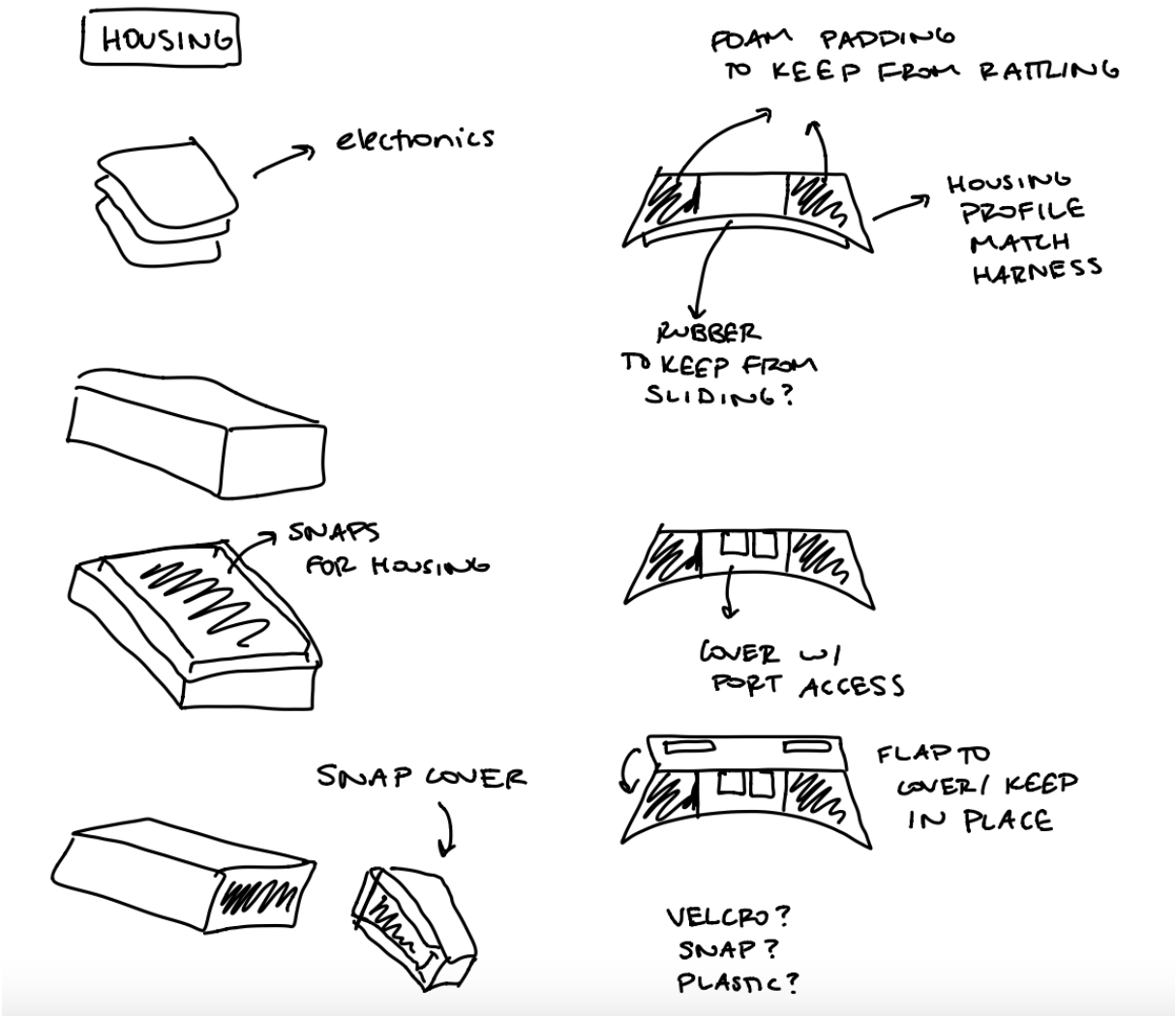


Figure 4b: Embedding electronics in Nathan's harness

Our first design option was connecting two Arduinos via Bluetooth (one being the controller and the other a speaker) and building a custom speaker, but we ultimately decided against it because of the complexity of this system as well as Arduino's limited capabilities to store and transmit wireless audio. We found a Raspberry Pi Zero 2 W to be a better option because it provided an easier interface for connecting with a commercially available Bluetooth speaker and storing the audio messages. As part of this wireless approach, we considered different methods of attachment for the wireless speaker. One option was to attach the speaker directly onto Nathan's harness, but this would need to be approved by the Canine Companions for Life association, so we moved away from this idea due to course time constraints. We realized we needed an

attachment option that would allow Abby to use this device with her mobility scooter and her different wheelchairs, so we moved towards a carabiner attachment approach. Abby uses a variety of carabiners to attach bags and other containers to her mobility devices, her person, and Nathan, so adding an additional device would have negligible inconvenience: the remote could be attached to her lanyard, and the speaker easily attached and detached from her wheelchair, scooter, or backpack.

Design Process

Once we selected and purchased the electronic components, we began the prototyping phase. We began rapid prototyping the form factor of the remote to fit the electronics inside the device and fit comfortably in Abby's hand. Figure 5 shows the initial foam prototype for this hand controller. Figure 6 shows the second iteration of the foam models that were used for user testing with Abby to get a sense of what would be most comfortable for her to use. Additionally, we began exploring the layout options for the buttons on the remote as well as the different options for types of buttons. We created a preliminary CAD model of the remote to get a sense of overall aesthetics, which is shown in Figure 7.

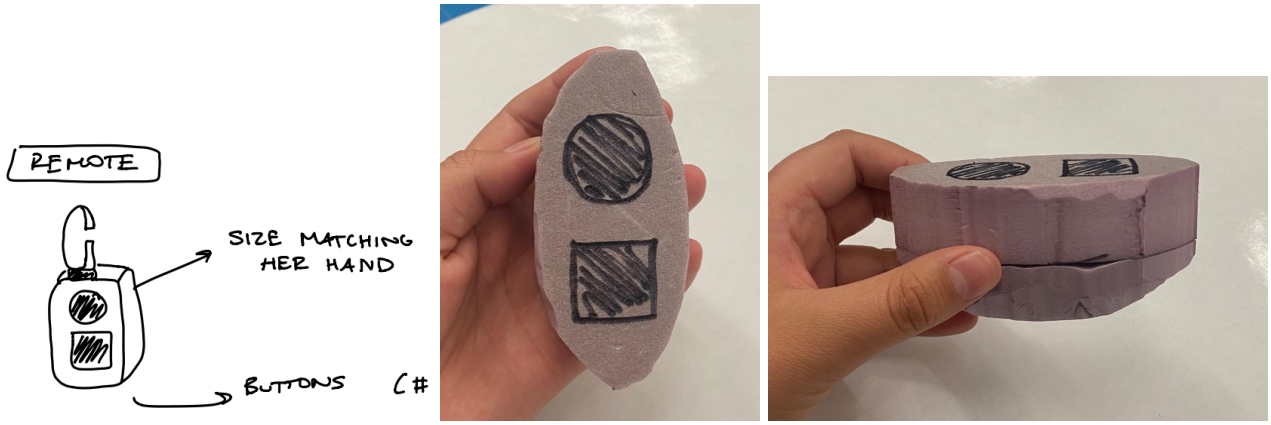


Figure 5: Early sketch of remote (left) and rapid prototype of remote form factor (center, right)

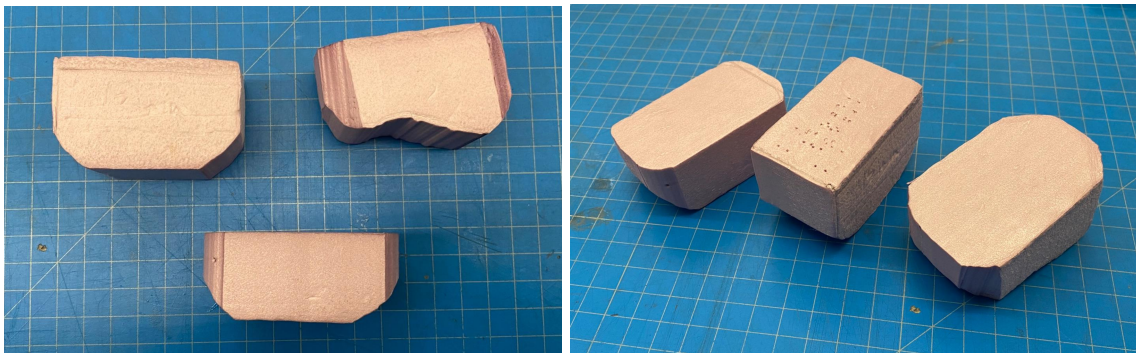


Figure 6: Rapid prototypes of remote form factor

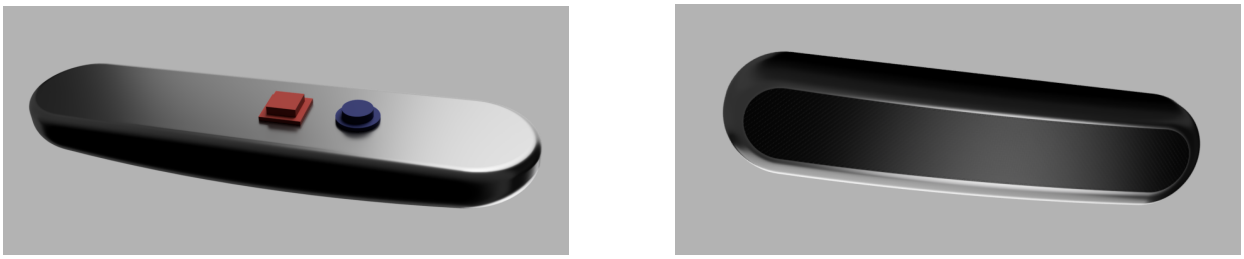


Figure 7: Preliminary CAD model of the remote

Once Abby selected her favorite foam prototype, we updated our CAD model to match these dimensions and began 3D printing. Figure 8 shows one of our first 3D printed prototypes, which gave us valuable insights into the internal spacing needs of the electronics and buttons. Based on this prototype, we iterated on this design to better fit the electronics and allow for an easier attachment of the carabiner, which is highlighted in Figure 9. We also used this prototype in our final user testing with Abby, prior to her leaving town. During this testing with Abby, she expressed how much she liked the overall design and ease of use of our device. She mentioned wanting a squishy and more comfortable grip for the remote, if possible. We also examined different carabiners that Abby already uses to determine what type would be the best for her to use with our speaker and remote. Additionally, we were able to perform and record a field test of the device.

Figure 8: First 3D-printed prototype of remote

Figure 9: Second 3D-printed prototype of remote

We began prototyping our electronic components and through extensive testing, we were able to connect the Raspberry Pi to the speaker automatically over Bluetooth and have it play audio. Afterwards, we designed a simple circuit on a breadboard to connect the buttons to the Raspberry Pi's GPIO pins, allowing the Raspberry Pi to read the state of the buttons. All of the GPIO pins are represented as files within the Raspberry Pi, so to read their state, we instantiate the files corresponding to the GPIO pins we are using and check for changes to their value in a Bash script. The script includes "debouncing" so that a single button press doesn't get mistaken for multiple. Lastly, we transferred the breadboard circuit onto a perfboard and soldered all the electronics together, including the Raspberry Pi, battery and buttons.

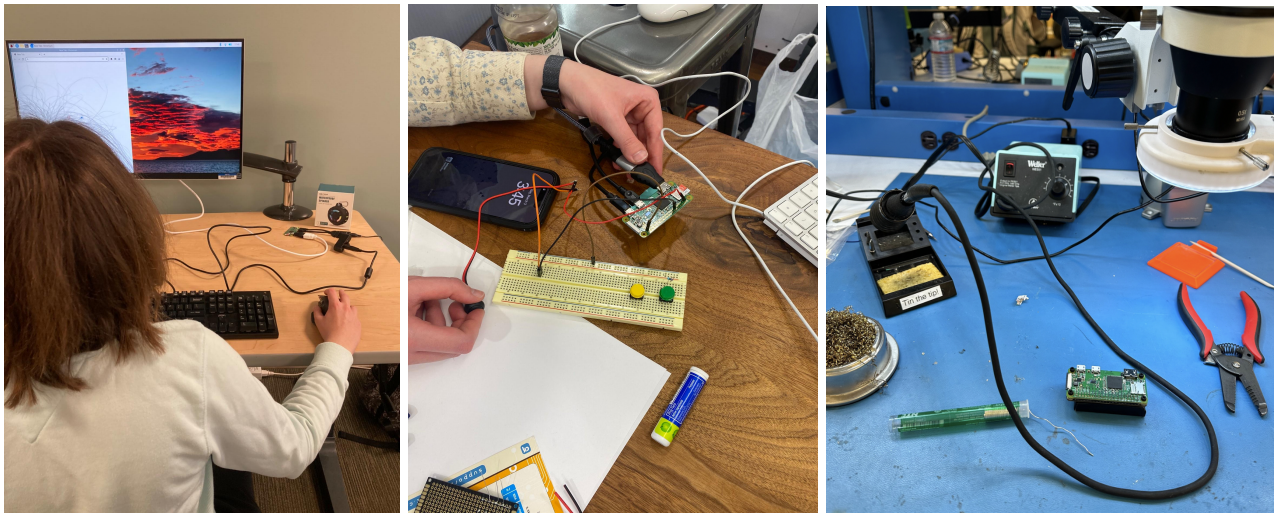


Figure 10: Programming, prototyping electronics, and soldering

The final piece of our prototype was the audio messages. We wrote a few basic scripts and sent them to Abby to get her feedback about the length, tone, and educational content of the recordings. Abby settled on a set of four recordings of varying lengths, three from her perspective and one from Nathan's. We recruited two different actresses to record the messages and chose those we liked better. We trimmed empty space in the recordings to increase response time and decrease message length and performed volume normalization and amplification to increase the maximum loudness.

With each part of the design independently prototyped, we began to refine each part in relation to the others to integrate them into our final device.

Final Design

As discussed, our solution, The DUG, is a two-component design. The first part is the Bluetooth speaker from which the audio messages emanate. The speaker is wirelessly connected to a remote control, which Abby uses to trigger the desired sound.

The speaker we selected is a commercially available speaker. It is durable, waterproof, easy to use and charge, and has a long battery life. It has physical volume controls and a loop for a carabiner, which allows for secure, easy attaching and detaching to a variety of locations. This was especially important to us because Abby switches between different mobility devices and already uses

carabiners for many of her gadgets. The speaker also lights up, adding to its “coolness factor” and visibility.

The remote control has several buttons, each of which triggers a different message. It can be attached to a lanyard or another part of Abby’s mobility devices using a carabiner, in the same way Abby carries lots of other small devices. The buttons are large and in bright, distinct colors, with textured details on the surface, emulating the assistive technology Abby uses in her home to accommodate her visual impairment. The remote control was printed in PC-ABS to provide a high level of durability and strength to protect the internal electronics. Additionally, the remote has a removable silicone casing in Abby’s favorite color to provide a more comfortable and non-slip grip as well as protection against exterior damage if dropped. The remote control has a sleek and clean aesthetic, which contributes to the “coolness factor” of the system.

Inside the remote control is a Raspberry Pi Zero 2 W, powered by a long-lasting portable battery. The battery provides a long battery life and a familiar micro-USB charging interface. The script is implemented on the Raspberry Pi as a systemd service, which allows us to automatically start the script when the Raspberry Pi is powered on and to restart the script automatically if it crashes for any reason. The script, written in Bash, connects to the Bluetooth speaker using its MAC address, sets the speaker as the default audio output sink, and then waits for a button to be pressed, detected via the GPIO pin outputs. When a button is pressed, the Raspberry Pi plays the associated pre-recorded message using PulseAudio.

Figure 11: Final Prototype of Remote (left) and Remote with Silicone Case (right)

Figure 12: Remote and speaker

Discussion

One of the main challenges with the current prototype is the size of the remote. Because of the needed internal electronics, the form factor of the remote is bulkier than we would like. In terms of further development, we would like to find ways to further minimize the size and weight by using custom electronics. The Raspberry Pi comes with many hardware features that we are not using, and is designed for prototyping, not a final product. Thus, designing a custom printed circuit board (PCB) that removes all the non-essential hardware would significantly reduce the size of the prototype as well as use less power. This means that we could use a smaller battery and connect the buttons directly to the PCB, significantly reducing the length of the wires and eliminating the perfboard entirely. A custom PCB would also significantly decrease the startup time for the device — the Raspberry Pi can take up to 3-4 minutes to boot because it is running a full operating system.

In addition, there are a number of nice-to-have features that would improve our prototype. We could add a sound level sensor to the remote or as an optional accessory, and use it to detect the baseline volume of the environment to automatically adjust the volume of the audio messages. In our testing with Abby, our prototype was hard to hear in a location with a lot of background noise (outdoors, ambient music, construction in the area, etc), so we have designed The DUG to be as loud as possible by default, since this is the environment we anticipate the device being

most useful in. Abby can control the volume of the speaker, but it's not intuitive or convenient to do so.

Our prototype could also be improved by showing the user the status of the system. With the long boot time of the current device, it's hard to tell when the device is ready to go. Currently, the device plays a short tune through the speaker to indicate that it is paired and ready to be used, but adding a simple LED to the exterior of the device that is lit up at the beginning of the script would be helpful. We could also add LEDs to signal that the battery is low, or that some software problem has occurred.

Finally, it would be nice if Abby was able to customize the device herself. It would be very feasible to add a simple web interface to the Raspberry Pi that would allow Abby to upload recordings and map them to each button.

Next Steps

We will deliver the final prototype to Abby during Spring quarter. We are really excited to see what she thinks!

If we proceed with the project as a directed study, our primary technical challenge will be to transition towards the custom PCB design mentioned earlier. This will involve migrating our system to a custom hardware platform and developing firmware to enable the required functionality. Achieving this will be a demanding task, needing extensive research on the necessary components and industry-standard implementations used in similar devices like dedicated Bluetooth media players. Given the typical turn-around time of 1-2 weeks for custom PCB fabrication and the need for multiple iterations, we anticipate that the migration to custom hardware will require at least an additional quarter of dedicated research and development work.

Once we have developed a custom PCB and firmware, we will alter the physical design of our remote by significantly reducing its volume. We estimate this will take around three weeks to complete, including the sourcing of new buttons, printing several iterations of the device, constructing a new silicone-pouring mold, and conducting user testing. Assuming that we continue to use a commercially available Bluetooth speaker, these steps will result in a refined

prototype that will be almost ready for mass production. Below is a timetable indicating the expected timeline for the next prototype, which we estimate to take longer than a quarter due to the technical difficulties expected during the first stages of the project.

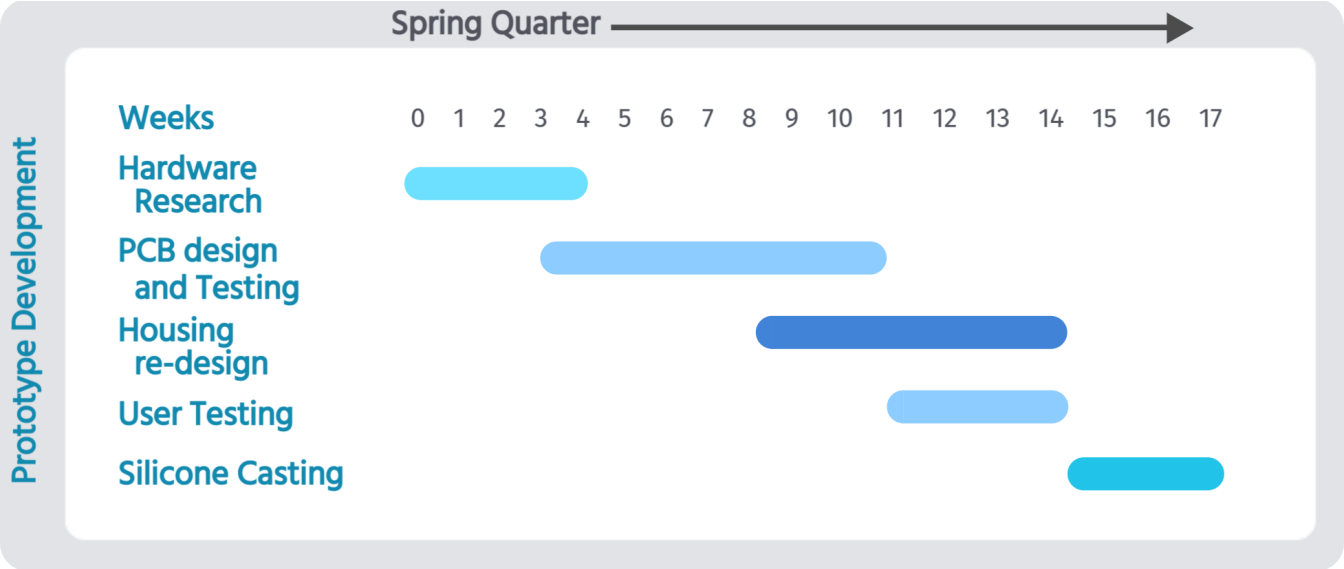


Figure 13: Expected timeline for next stage of prototype

If we intend to continue with this project towards mass production, our first step would be to locate a mass PCB manufacturer and integrate the additional functionalities previously mentioned, such as volume sensing and status visibility. Since 3D printing is unsuitable for mass production, we would explore other manufacturing techniques, such as injection molding, to create the remote's housing. As our device uses a battery, we would need to ensure that we comply with strict battery regulations. To complete the product, we would seek to collaborate with an established manufacturer of Bluetooth speakers to bundle with our remote controller.

Based on the cost of commercially available Bluetooth speakers (~$30) and Bluetooth media players (~$30), we anticipate that the value of our bundle would be between $50 and $75 if sold on a large scale. Considering the scope of the issue we are addressing and the added customization functionality for messages, we anticipate that our product would have a significant market in the assistive technology sector, particularly for people with speech impairments.

References

[1] Velez, Lily. "Service Dog Statistics." *Veterinarians.org*, 16 Feb. 2023, https://www.veterinarians.org/service-dog-statistics/.

[2] Mueller, Laura. "8 Types of Service Dogs and What They Do." *The Spruce Pets*, The Spruce Pets, 20 June 2022, https://www.thesprucepets.com/types-of-service-dogs-4587180.

[3] Deaver, Christina. "How Do I Keep People from Petting My Service Dog in Training?" *ComeHereBoy!*, 30 June 2017, https://servicedogs.comehereboy.com/blog/do-not-pet/.

[4] "Service Dog Cards." *Amazon*, Goettsche Partners, 2011, https://www.amazon.com/gp/product/B006OLNBKU.

Acknowledgements

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We would also like to thank Dave for his support and feedback during this project.

Appendix A: Bill of Materials for Purchased Components

Item Name	Purchasing link	Price
Raspberry Pi Zero 2 W	https://tinyurl.com/5n6c9xep	$87.27
Bluetooth Speaker	https://tinyurl.com/2p8hm7xj	$26.20
Raspberry Pi Battery	https://tinyurl.com/2p58yf45	$43.64
Carabiner (x2)	https://tinyurl.com/9jux4aez	$8.26
Surface mount buttons	https://tinyurl.com/4c9fy3cr	$10.90
Above-Surface push buttons	https://tinyurl.com/y5tavcsd	$14.13
Machine Screws - M2.5 20mm (x2)	https://tinyurl.com/3d6u74nz	$6.98
Enamel Paints (x4)	https://tinyurl.com/5n6e8csf	$7.81
Threaded Heat Set Inserts - 6-32 (x2)	Room 36 Stock	Free
		TOTAL: $205.19

- Raspberry Pi Zero 2 W Specs:
  https://www.raspberrypi.com/products/raspberry-pi-zero-2-w/