A Vibrotactile Proximity Harness To Help Blind Dogs Navigate

Alexandra Zuch (Flintridge Sacred Heart Academy, alexandrazuch20@fshamail.org)

Submitted for publication: May 26, 2020

Abstract

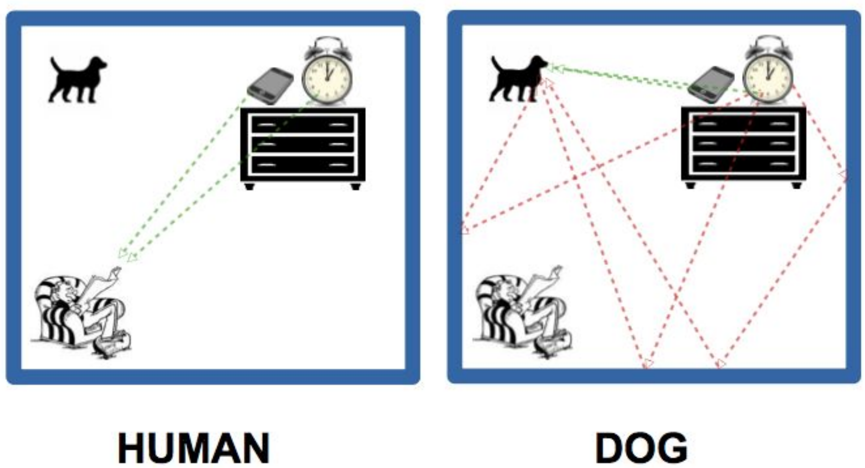
Blind dogs need a way to navigate their surroundings when they are introduced to new environments. This project will review current products on the market, identify where they do not sufficiently address the need and propose development of a new device. This new device is a vibrotactile harness utilizing motion and proximity sensors. The device will be described and testing and training protocols will be introduced. While a fully functioning device is not ready for production, several additional research areas are presented.

1.0 Introduction and Background

Dogs tend to utilize smell and hearing as primary senses, with eyesight being less important. The loss of eyesight often leads to disorientation and blind dogs need help adjusting to their surroundings. Diseases like Cataracts (affecting the opacity in the lens of the eye) and Achromatopsia (loss of the cone photoreceptor function) that can lead to partial or total blindness in dogs can't be prevented because one of their main causes is genetics or aging. Since prevention is problematic, dog owners need effective strategies to ensure blind dogs can maintain a high quality life. Common strategies include: avoiding change in areas already known to the dog, creating safety measures in areas where injury can occur (e.g. sharp corners from furniture), taking time to train the dog, and having tactile and/or noise cues to communicate with the dog (Burke, 2018).

Additionally, devices have been created to help blind dogs navigate their surroundings. For example, the Muffin's Halo, "a custom-designed product to protect blind dogs of all sizes from bumping into walls and objects" is a harness with a halo (working as a bumper), that will hit objects or walls that appear in front of the dog before the dog runs into that object or wall. The product is customizable for every dog with its detachable bumper. Customer reviews suggest that the device is very effective when helping dogs navigate their surroundings.

Another device that was created is called the BlindSight, a 3D imaging sonar transmitter that allows dogs to echolocate. The device sends out signals, and the dog translates the signal's energy into information of how the room is formatted. The signal comes to the dog directly and indirectly. The sound bounces off from around the room and comes back to the dog, thus letting the dog know how the room is formatted (see figure 1). This will help them navigate where objects or walls are in the room and how far those objects or walls are. The device is restrictive since dogs must be able to hear high frequencies in order to use the device. Also, the dog must be able to carry the weight of the product. The smallest size weighs around 44 grams and the largest size weighs around 1 pound. It is also hard for the owner of the dog to know if the device is working for the dog, or if the dog is just getting used to his/her surroundings.



A study by Golan et. al. (2019) has shown that dogs can be trained to respond to vibration commands. This project will integrate a proximity sensing device with tactile vibration motors and a training protocol to alert dogs to nearby barriers. The device and training protocol are described in section 2, with results of the training discussed in section 3. In section 4, an evaluation of the device is presented along with an introduction of additional research areas needed to make the system fully functional.

2.0 Methods

2.1 Device Design

A device was developed to help blind dogs navigate their surroundings. This device is a harness that contains vibration motors that activate when in proximity to surrounding objects or walls. The harness contains two proximity devices and two vibration motors per proximity device (four total). It is necessary that the device includes two directions. With one direction the dog would learn to only spin one way and eventually circle either itself or the room thus being stuck in a loop. With two directions the dog has more precise information as to where to go (left or right). The proximity devices are HC-SR04 ultrasonic sensors connected to an Arduino microcontroller. The sensors are placed on the harness such that they rest on top of each shoulder and are directed at an angle 30° left and right from forward. The Arduino software continuously reads the distances from each sensor. When an object's proximity is less than 100cm then the appropriate motors will vibrate (e.g. left signal, left vibration). In addition, the harness contains a 3-axis accelerometer (ADXL 345) that "measures the static acceleration of gravity in tilt-sensing applications" (Analog Devices). The Arduino software uses acceleration measurements in each axis to calculate a net acceleration to then find a net velocity. If this velocity were to exceed a predefined value, the dog is identified as moving and the device will then turn on the proximity sensors and activation of the vibration motors is allowed. When the stationary state is indicated (no change in velocity), no proximity signals are passed, allowing the dog to wear the device while sleeping and/or resting when in proximity to ordinary objects. The device has two different modes: a training and an avoidance mode, described below.

2.2 Training Mode Protocol

In order to simulate both modes of this device, two test dogs were trained to react to the vibrations accordingly. For this simulation, four vibration motors were attached to a harness (with no ultrasonic sensors). These motors are also attached to a three way switch, allowing the vibration motors to be manually controlled with the switch (either left side or right side). Using the Training Mode of the harness, the owner should use conventional dog training tactics to signify left or right motion in response to either right or left buzzing.

2.3 Avoidance Mode - Human Trial

A prototype device with one handheld ultrasonic sensor and one vibration motor connected to a fabric that wraps around the wrist was created to test the avoidance mode while being worn by a person. For this test the sensor device is pre-programmed and battery powered. The device was tested in the following scenarios (moving towards barrier, moving in open space, standing still near barrier) to test the integration of the accelerometer, ultrasonic sensor and vibration motor.

Initial testing involved general walking around and experiencing vibration. A testing protocol to verify reliability would include creating a testing area with a floor plan. This floor plan will include obstacles along with a scoring metric to evaluate the results of the trial: level 1 is obstacle detected and avoided, level 2 is obstacle detected but not avoided, level 3 is obstacle not detected and not avoided, level 4 is not detected and avoided (representing a "lucky break").

<u>2.4 Avoidance Mode - Canine Trial</u>

Upon completion of 2.2 - 2.3, the avoidance device will be functional and a dog will be trained to respond to vibration cues. The final step will be to test the device on a blind dog. The plan is to place the trained dog with the harness in an adjustable arena with various obstacles (boxes, etc.). The dog will be blindfolded and allowed to navigate the arena, with the same obstacle avoidance scoring metric described in section 2.3 used to quantify the success of the navigation.

3.0 Results

<u>3.1 Training Mode</u>

Two dogs were used to test training. Both dogs are three year female old miniature schnauzers, Friday and Dakota. Dakota has had professional dog training for behavior when she was less than a year old, Friday has not had any type of training prior. Both dogs know simple commands such as sit and lay down. Dakota was sensitive to the vibration device (ears perked up, head turned) but she would not move when the training harness was put on her due to discomfort with the harness. Using the protocol defined in 2.2, test dog Friday was taken through four training sessions. While Friday was also sensitive to the vibration device the four sessions were not sufficient to see progress in response to the vibration cues.

3.2 Avoidance Mode

Informal use of the prototype by a person (described in section 2.3) suggests that an effective methodology has been created. Statistical data regarding how successful the device was was not recorded, but through the anecdotal trials, the device was successful over 50% of the time. While a formal verification did not take place, a protocol has been developed for future researchers to follow.

4.0 Discussion

Significant progress has been made towards the development of a proximity sensing device with tactile vibration motors and a training protocol for use by blind dogs and their owners. The motion sensing function is fully developed and functional, and the proximity sensor and vibration signal is functional but not quantitatively verified. The difficulties encountered regarding dog training and human trials for avoidance are described in the table below.

For this device, dog training is essential. Training will take a long time and that is why it should be done early on. Also just like any other dog trick, consistency is key so that the dog will remember cues and commands. Before giving the dog the final device and after it is trained, it's important to test the software with human trials. Human trials will verify software and consistency with the device code. The following table also includes things to consider when fulfilling these tasks.

TASK	COMPLETED	THINGS TO CONSIDER FOR FUTURE WORK
Order of operations	1. Work on software 2. Create prototype 3. Anecdotal human trials 4. Dog training	1. Dog training 2. Adjustments of software and prototype (with anecdotal human trials) 3. Statistical human trials 4. Dog trials
	Dog Training	
When to train/ time	Dog training was started after work on a human prototype device. Dog training sessions took place every few days for around fifteen minutes per day for about a month.	Instead of working with dogs for around a month towards the end of validation, start training dogs right away. Stay consistent by training every day/ every other day for a set amount of time.
How to train	Different training techniques were tried throughout this process but the test dogs weren't very compliant.	The method of turning on the left/right buzzer and walking around behind the dog to the right/left (opposite side) worked. Instead of just working with a sighted dog, try blindfolding the dog when training or working with a blind dog.
	Human Trials	

Process	With closed eyes and wearing the device, walk around.	Having a space made for trials filled with obstacles. These obstacles will be unfamiliar for the tester.
Recording results	Anecdotal results: Walls and objects were avoided during testing	Statistical results: Create a floorplan and then record where different obstacles are located and give each obstacle a different level of avoidance (this will require help from another person): Level 1: detected and avoided Level 2: detected and crashed Level 3: not detected and crashed Level 4: not detected and avoided

For the future, this device could be adjusted for various types of dogs. While this current prototype is available for a small dog, adjustments such as more buzzers, faster reaction time from the accelerometer, longer distance sensitivity from ultrasonic sensors, and a larger harness would be required for a larger dog. The device could also be heavily adjusted for human implementation as well.

5.0 Conclusion

This project has been created in order to help blind dogs navigate their surroundings. Current products have been identified and reviewed while a new device has been introduced that will address the need more sufficiently. This device is a vibrotactile harness that utilizes motion and proximity sensors. The device has been described and testing and training protocols have also been introduced. While a fully functioning device is not complete, future implementation of a working device along with other research areas have also been described.

6.0 References

Analog Devices. (n.d.). ADXL345 [PDF]. Retrieved from https://www.analog.com/media/en/technical-documentation/data-sheets/ADXL345.pdf

Burke, A. (2018, July 6). Living with a blind dog: Ways to keep your canine companion safe. Retrieved from American Kennel Club website: https://www.akc.org/expert-advice/health/how-to-help-a-blind-dog/

Canine Day Blindness (Achromatopsia). (n.d.). Retrieved from AnimaLabs website: http://www.animalabs.com/shop/dogs/canine-day-blindness-achromatopsia/

Circuito.io Team. (2017, May 22). LEDog Collar. Retrieved from Arduino Project Hub website: https://create.arduino.cc/projecthub/circuito-io-team/ledog-collar-1f8670?ref=tag&ref_id=pets&offset=8

Estimated Blind Dog US Populations, 2010. (2012, January). Retrieved from Deaf Dogs Forever website: http://deafdogsforever.weebly.com/blind-dog-us-populations.html

Garcia, M. M., MS, Ying, G.-S., PhD, Cocores, C. A., Tanaka, J. C., PhD, & Komáromy, A. M., DrMedVet, PhD. (n.d.). Evaluation of a behavioral method for objective vision testing and identification of achromatopsia in dogs. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2814178/

Golan, Y., Serota, B., Shapiro, A., Shriki, O., & Nisky, I. (2019, July). A vibrotactile vest for remote human-dog communication. Retrieved from IEEE database.

Green Acorn. (n.d.). Coping with a blind dog. Retrieved from https://www.vetwest.com.au/pet-library/coping-with-a-blind-pet

Holliday, T. A., Nelson, H. J., Williams, D. C., & Willits, N. (n.d.). Unilateral and bilateral brainstem auditory-evoked response abnormalities in 900 dalmatian dogs. Retrieved from https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1939-1676.1992.tb00332.x

Park, S. A., Yi, N. Y., Jeong, M. B., Kim, W. T., Chae, J. M., & Seo, K. M. (n.d.). Clinical manifestations of cataracts in small breed dogs. Retrieved from https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1463-5224.2009.00697.x

PetRescueMomma. (n.d.). Engineering students want your advice about A collar for blind dogs [Blog post]. Retrieved from Lessons from a Paralyzed Dog website: https://lessonsfromaparalyzeddog.com/engineering-students-want-advice-collar-blind-dogs/

WebMD Veterinary Reference from the ASPCA. (n.d.). Cataracts in dogs. Retrieved from https://pets.webmd.com/dogs/cataracts-dogs

Yee, A. (n.d.). Watch a dog respond to voiceless commands via this vibrating vest. Retrieved from National Geographic website: https://www.nationalgeographic.com/science/2019/07/vibrating-vest-lets-dogs-respond-wordless-commands-haptics-search-rescue/#close

7.0 Appendices

Project Journal:

https://drive.google.com/open?id=1JSHQ3JM5M26CK_OoYtHdYqRYDz_DqgKqzzFZEKm1VgM

Original Proposal:

https://drive.google.com/open?id=1C1zMjXv2BNwGdSqolLGZ-YKpvRpw-TBfOywLR3Qv34g

7.1 Commented Code

Accelerometer Calibration Code:

https://drive.google.com/open?id=13CAqI2eXJdV3S91x_TkPltTNvR3ym6Li

Vibrotactile Proximity Harness Code:

https://drive.google.com/open?id=1FnywqyupGF2SMWu5JLu_9rXISNAMLruy

7.2 Media Documentation

Dog Acceleration Data Video:

https://drive.google.com/open?id=1MUuCPTrcr1iiTdesZ8XyWTVTOY5QiK6z