Two-Way Communication between Working Dogs and Their Handlers

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Imagine a scenario in which Schubert, a search-and-rescue dog cross-trained to scent both living people and cadavers, has been sent to find Michelle, a child lost in the woods. In alerting the authorities, her parents mention that Michelle is autistic and that the presence of a dog might startle or scare her. Upon finding the child alive, Schubert tugs a sensor on his vest that alerts the handler to his GPS coordinates. His handler responds by remotely activating a small motor that causes a vibration on the left side of Schubert's vest: a command to remain in the area without approaching Michelle. Schubert maintains a considerable distance from the girl until the authorities arrive to bring her safely home.

A vibration of the right side of Schubert's vest would have meant that he should approach the child. Had Michelle no longer been alive, Schubert would have tugged a different sensor located on the other side of the vest, and his handler would have activated a vibration on his chest, meaning he should return to his handler.

In the Facilitating Interactions for Dogs with Occupations (FIDO) project in the Animal Interaction Lab at Georgia Tech, we're working to bring such scenarios to reality. According to members of the Georgia Tech Police Department and Dana Kirsch, a veteran search-and-rescue K9 handler, FIDO wearable technology could help with bomb and drug detection and SWAT tactical response. It could also facilitate hearing assistance and visual guidance. Hearing-assistance dogs are trained to alert and then lead their hearing-impaired owner to the source of a sound. However, when a tornado siren sounds several blocks away, the dog can't lead his owner to the siren. FIDO technology could allow an assistance dog to clearly communicate the sound he has heard. Providing assistance dogs the ability to pinpoint the source of a sound could be the difference between life and death in such cases. The key factor in realizing these scenarios is wearable technology that facilitates communication between working dogs and their handlers.

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FIDO RESEARCH

FIDO team research thus far has focused on dog-to-handler communication. In a previous paper, we described four designs for on-body sensors that a dog could activate to communicate information to the handler.[1] These sensors were designed to leverage dogs' natural abilities, such as biting and tugging.

In the next iteration of this study, we used lessons learned in the pilot study to develop five updated sensors, which we tested with a group of eight dogs of various breeds.[2] From this study, we determined which sensors the dogs could activate consistently and which had a low rate of unintentional activations. The most successful sensors—the capacitive and pneumatic sensors—weren't just easily accessible and intuitive to use but also simple for the dogs to trigger while not being affected by the dog's saliva.

To complement this previous research, we're now investigating handler-to-dog communication—ways that a handler can issue commands to a dog remotely. Our aim is to enhance interactions between assistance dogs and their handlers, which could also prove valuable as a means of silent communication between other working dogs, such as military dogs, and their handlers. We're investigating the use of on-body vibration motors to deliver commands to dogs. Although there have been several studies into the use of vibrotactile interfaces on humans, there has been

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relatively little work in this domain with dogs.

Researchers at Auburn University's GPS and Vehicle Dynamics Laboratory (GAVLab) developed a method for guiding a dog remotely to GPS targets through a combination of tones played from a pack on the dog's back and a set of three vibration motors.[3] Our work focuses on remote commands rather than remote guidance; the difference being that the dog maintains a large level of agency in our case.

EXPLORING RESPONSES TO HAPTICS

We're currently developing an experiment to test a working dog's ability to perform distinct tasks in response to vibrations at different points on their body.

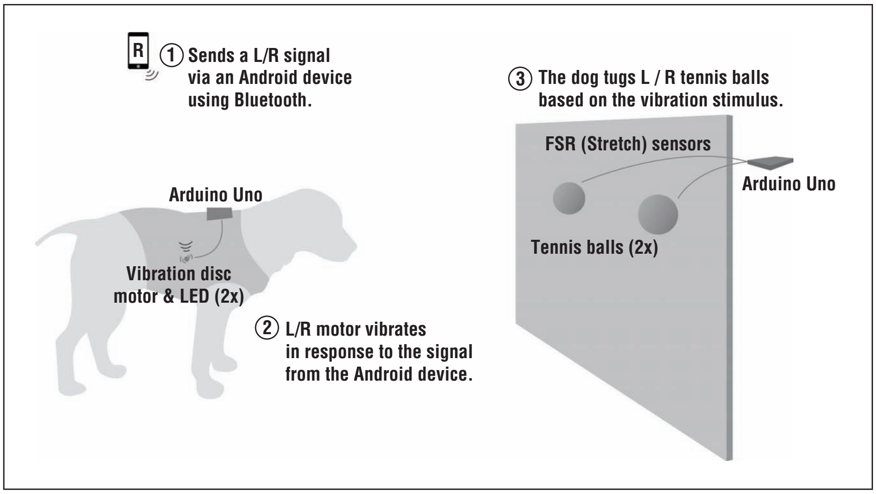

Figure 1. Diagram of the left/right discrimination study setup. The testing panel presents the dog with two balls aligned on a horizontal axis. The dog's task is to tug the ball on the right when it feels a vibration on its right and the ball on the left when it feels the vibration on its left.

Experimental Design

For our initial study, we incorporated two vibrating motors into a dog coat, separated so that one is located on each side of the dog's body to produce a left/right (L/R) discrimination stimulus. To determine whether the dog can discriminate between the different vibration points, we've designed a testing panel that presents the dog with two balls aligned on a horizontal axis. The dog's task is to tug the ball on the right when it feels a vibration on its right and the left ball when it feels the vibration on its left.

The dog that served as our test subject during the design process was a Border Collie who had significant experience in operant training and could generally learn new behaviors quite quickly. Figure 1 shows an overview of the setup for our study. We controlled the motors on the coat via an Arduino microcontroller over Bluetooth.

Wearable Considerations

The first challenge in designing our haptics experiment was the placement of the vibrating motors. We reasoned that vibrations would be best transferred to the dog on bony areas such as the dog's ribs, hips, legs, and shoulders. We activated the motors on these areas and observed the dogs' reactions. The front legs seemed to be the most reliable location for the dog to feel the vibrations. However, after experimenting with a series of Velcro straps, we determined that there was no easy way to affix the motors such that they wouldn't shift as the dog moved. This greatly compromised the ability of the dog to feel the vibrations, so we settled for our second-best location—the dog's rib cage.

For this position, we attached the vibration motors to each side of a ThunderShirt—a commercially available garment designed to comfort dogs during stressful events such as thunderstorms by gently applying pressure around the dog's midsection. The close fit proved to be the most successful in stabilizing the vibration motors. It also allowed for consistent placement of the vibration motors. Furthermore, the ThunderShirt didn't seem to dampen the vibrations from the motor; rather, it allowed them to vibrate solidly through the dog's fur.

The Mind Gap

Perhaps the largest obstacle that we encountered throughout the design process is the cognitive divide between dogs and humans. We have sometimes been surprised when predicting what a dog will find easy and what will cause problems.

For example, when we first started training our test dog on the L/R tennis ball discrimination task, we were impressed by how quickly he seemed to pick up the concept. For that first trial, we were using one standard yellow tennis ball and one green, foam rubber stress ball, as seen in Figure 2. However, when we later altered the test apparatus to include two identical yellow tennis balls, the dog seemed to struggle with the discrimination. Our hypothesis to explain the difference is that in our initial training session, the dog might have been discriminating between the balls by color (or even smell), rather than position. Since we can't know for sure what the dog was thinking, we're now faced with the task of experimentally determining the best way of training the positional task.

Another surprising observation was the dog's uncanny ability to predict the signals that we were sending to his vest. Initially, one of our researchers would announce which side would be vibrated, so that the dog's trainer could be sure to offer a reward if the dog responded correctly. The researcher would then

WEARABLE COMPUTING

Figure 2. Training our test dog, a Border Collie, on the left/right ball discrimination task. Here, the dog is activating a sensor on test panel.

send the signal using a laptop. However, the dog soon began anticipating the vibration before it was sent based on the researcher's verbalizations. Giving cues in Spanish and German didn't seem to solve this problem, as our test dog quickly learned those words as well.

We resorted to sending the signals without a verbal cue, but the dog then learned to tell that we were sending a signal simply from the sound of typing on a keyboard. Our final solution was to send the signals to the vest using Bluetooth from an Android phone, which used a silent touchscreen keyboard. This approach in turn required us to update the visibility of the system's state, so that we could tell which motor was vibrating without expressing it verbally. We achieved this by attaching an LED to each vibration motor, which lit when the motor was active.

GOING FORWARD

We're currently running this initial study as a formal experiment that tests the viability of our haptic system across several breeds of dogs. As we learned in our pilot study, anatomical differences between dogs can determine their capability when interacting with sensors.[2] Translating this lesson to our haptic studies, different breeds will have different requirements from the vibratory feedback. Coat density, body shape, and fat/muscle distribution could affect our results.

Differences in cognition and experience might also be an issue. While training a second and third dog to perform the discrimination task (a Retriever and another Border Collie), we noticed that they were having trouble activating the tug sensors on the board. Although they would often approach the correct ball, and even take it in their mouths, they were very inconsistent at actually activating the sensor. To cut down on the cognitive complexity of this task, we plan to replace the tennis ball sensors with infrared proximity sensors in the next version of the experiment. Instead of tugging a ball, the dogs will simply touch their noses to the correct target, which is a much simpler task.

We hope to contribute to the basic science of haptic interfaces for dogs. Rather than choosing a position for the motors by trial and error, we will run a formal study to determine an optimal placement. There are also studies pertaining to human perception of vibrotactile feedback that we will reproduce in dogs. For example, the *BuzzWear* study evaluated users' perceptive capabilities of on-wrist vibratory alerts.[4] In that study, the researchers varied certain parameters about the activation mode of the vibration motors, such as vibration amplitude, vibration pattern (pulsed versus steady), and activation order. We plan to replicate these studies, replacing the human user with a dog. Additionally, if the dogs can differentiate between different activation modes from a sensor in an unchanging position, we could provide a higher bandwidth of information from the handler to the dog with a small number of motors.

It's also worth noting that vibration motors are only one of many possible methods that handlers might use to issue commands to their working dogs remotely. In future studies, we plan to investigate other sensory modalities for delivering commands, including auditory commands transmitted to an earpiece worn by the dog and scent cues dispersed by a wearable device.

Working dogs have improved the lives of thousands of people. By adding computational capabilities to dogs on the job, we hope to increase their utility while adding minimal cognitive burden to the dogs. We're just now discovering the extent of the abilities dogs have to interact with these interfaces, and we're learning the correct affordances and communication modalities that allow for a richer communication between dogs and their handlers.

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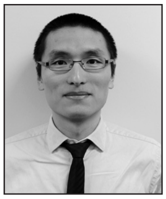

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