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Haptics for Guide Dog Handlers

Bum Jun Park, Jay Zuerndorfer, Melody M. Jackson

Animal Computer Interaction Lab, Georgia Institute of Technology

bpark31@gatech.edu, jzpluspuls@gmail.com, melody@cc.gatech.edu

Abstract

Guide dogs have the important responsibility of connecting their visually-impaired users to their immediate surroundings. However, it is often difficult for guide dogs to accurately communicate information to their human partners. This experiment aimed to enhance the platform for communication between guide dogs and handlers by investigating the best vibration feedback methods for handlers to receive information from their guide dogs. We created four different prototypes to test a human's ability to distinguish between four randomly selected vibration patterns. A total of 12 users participated in this pilot study, each receiving 8 minutes of training for familiarization with the prototypes. The results of the pilot study were evaluated based on the users' ability to correctly identify the vibration patterns when prompted, and a questionnaire posed to the users at the end of the experiment. This pilot study yielded an overall accuracy of 97%. It was also found that the smart-watch prototype produced the highest accuracy, while the guide dog harness bar prototype was the most preferred design among the participants.

Keywords

Augmentative and Alternative Communications (AAC), Blind/Low Vision, Information & Communications Technology (ICT)

Introduction

Guide dogs, as defined by the international assistance dog organization ("Guide Dogs"), are trained to assist visually impaired people by guiding their partners and avoiding obstacles to ensure their safety. Although guide dogs are highly trained to respond to various obstacles in their environments, it is difficult for guide dogs to inform their handlers about the nature of these obstacles. For example, a bus going by would be a temporary, or "wait" obstacle, whereas a fallen tree would be a "go around" obstacle. Clear communication from a guide dog to a handler would allow for better decisions to be made on how to proceed. Our previous work on the FIDO project (Jackson et al. 1) explores the possibility of implementing wearable sensors that dogs can accurately activate in either a specific situation or on a command. This unlocks a new method of communication between guide dogs and their partners. Guide dogs can activate a sensor attached to their guide dog harness to let their human partners know that an obstacle is in their path. It is hence imperative that the human partner has a reliable method to receive this information as clear and unobtrusive. Since audio-based devices can be highly disruptive to a user's surroundings, vibrotactile interfaces are used instead to ensure that the communication remains solely between the dog and the handler. A vibrotactile interface also allows the dog to alert the handler without interfering with other audio-based devices such as navigation support.

The main goal of this initial study is to establish the most reliable design to deliver vibration feedback to a handler's hands, allowing guide dogs to better communicate with their handlers. Furthermore, we aim to find answers to the following questions: "Can people receive haptic signals with their hands and wrists?" and "What modality is the best for the handler?". There are three different phases in this study required to understand the designs. The first phase, described in this paper, is testing which haptic feedback mechanisms are most effective. The second phase will be understanding the dogs' perception and the influence of haptic feedback on dogs, if any. Lastly, the third phase will be conducting the end-to-end field study with the results of the previous two phases.

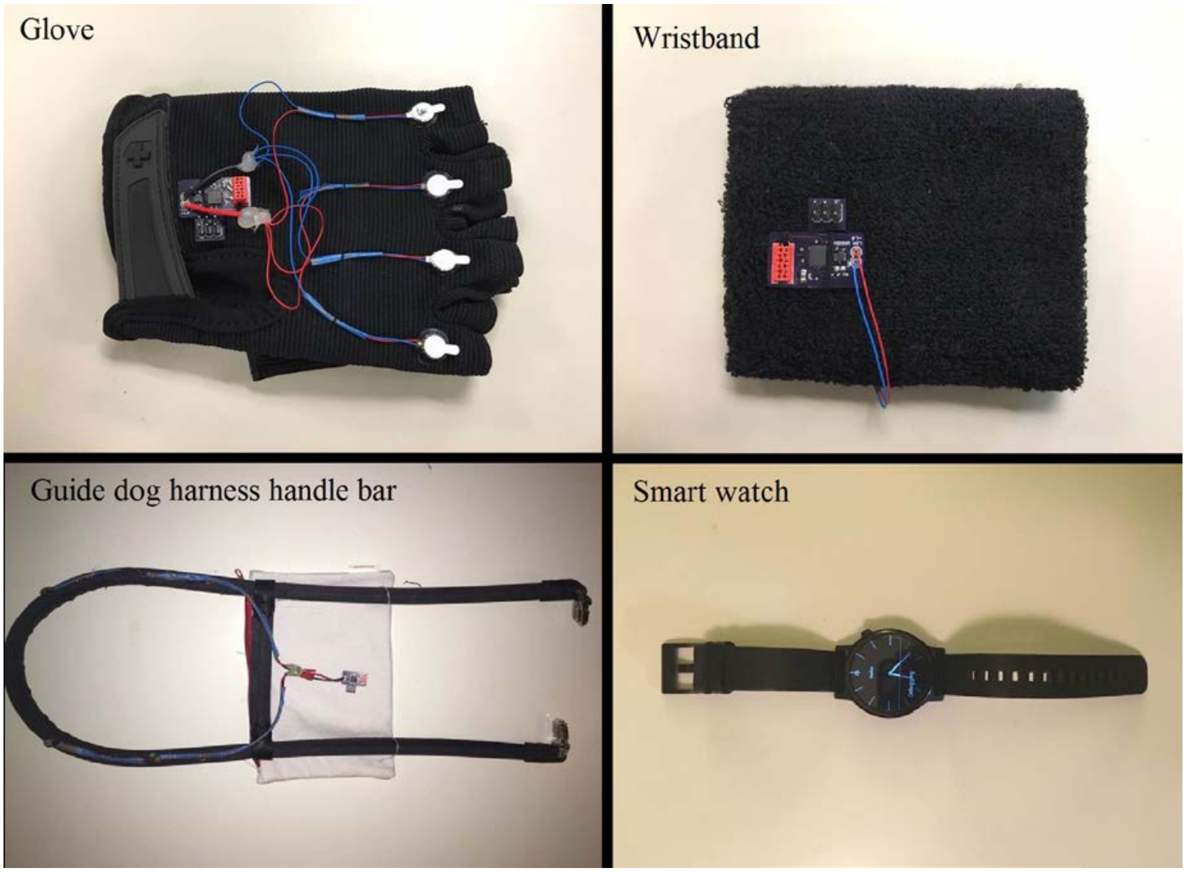

Fig. 1. The four prototypes (glove, wristband, guide dog harness handle bar, and smart watch)

We created four different prototypes for this study (Figure 1). Each prototype integrated vibration motors through different modalities consisting of: A glove, a wristband, a guide dog harness bar, and a smart watch. The effectiveness of each prototype was evaluated by testing the participants' ability to distinguish between four distinct vibration patterns (Figure 2).

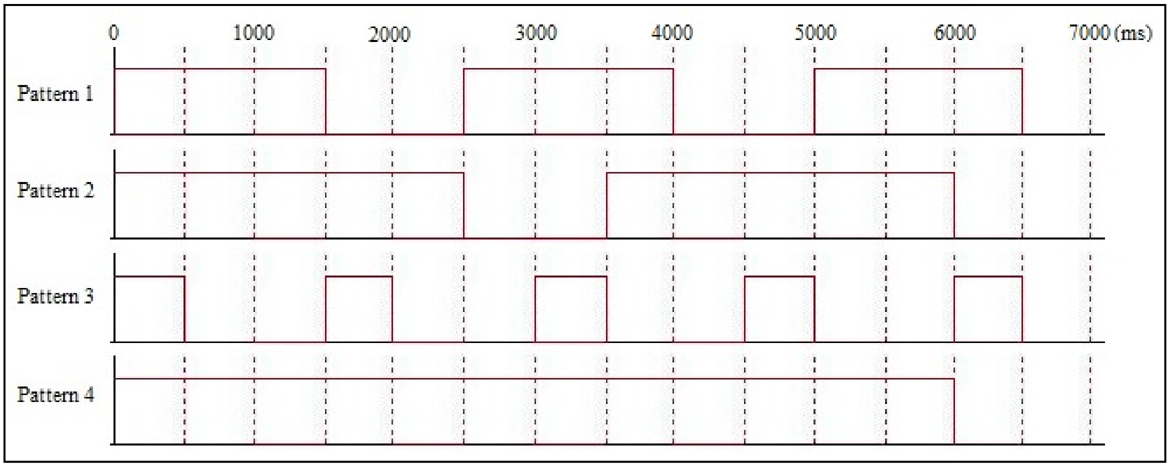

Fig. 2. Four vibration patterns.

Related Work

The applications of haptics signal wearable devices have been studied extensively in various fields. A study by Lee and Starner (2010) shows that temporal patterns are the easiest to distinguish among four parameters (intensity, starting point, temporal pattern and direction). Kajimoto, Kanno and Tachi (2006) explore the possibility of substituting a person's sense of sight with tactile displays. In addition, Lee and Starner (2010) reveal the possibility of wrist-worn wearable tactile displays to distinguish 24 tactile patterns.

Method

Materials

The main piece of electronics used in the study was a custom-designed vibration controller board (Figure 3). This board was used for three out of the four prototypes (the glove, wristband and guide dog harness handle bar). The vibration board used an ATmega328p chip (“ATmega328P”) as its central microcontroller. A DRV2603 haptic controller chip was used to control a LRA motor (“8mm Linear Resonant Actuator - 3mm Type”). Figure 4 is the schematic of the vibration board.

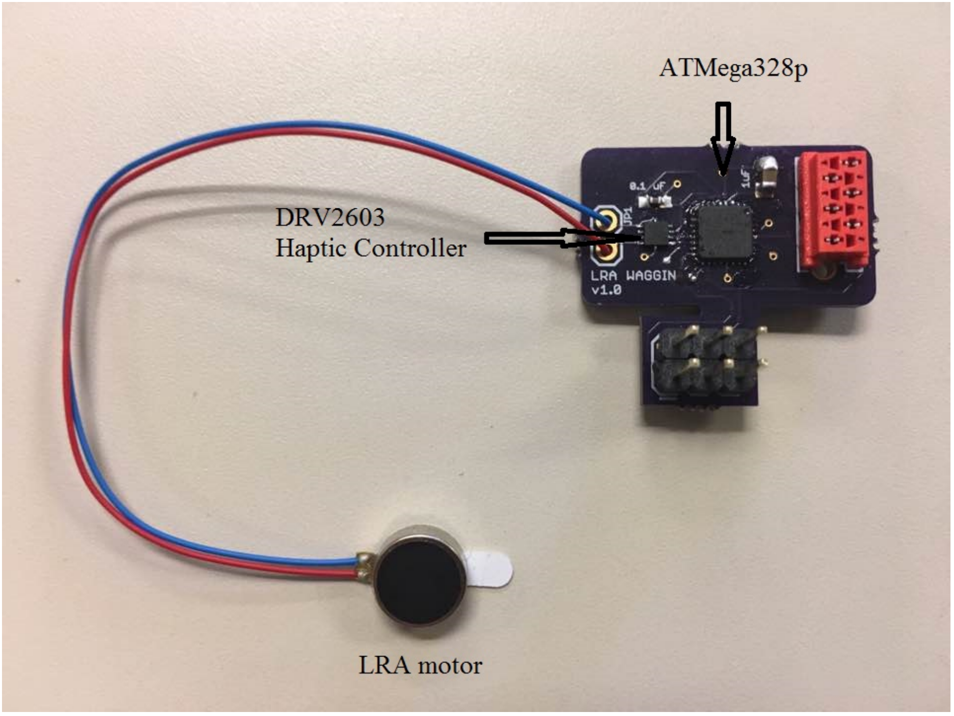

Fig. 3. Custom vibration board with a LRA motor.

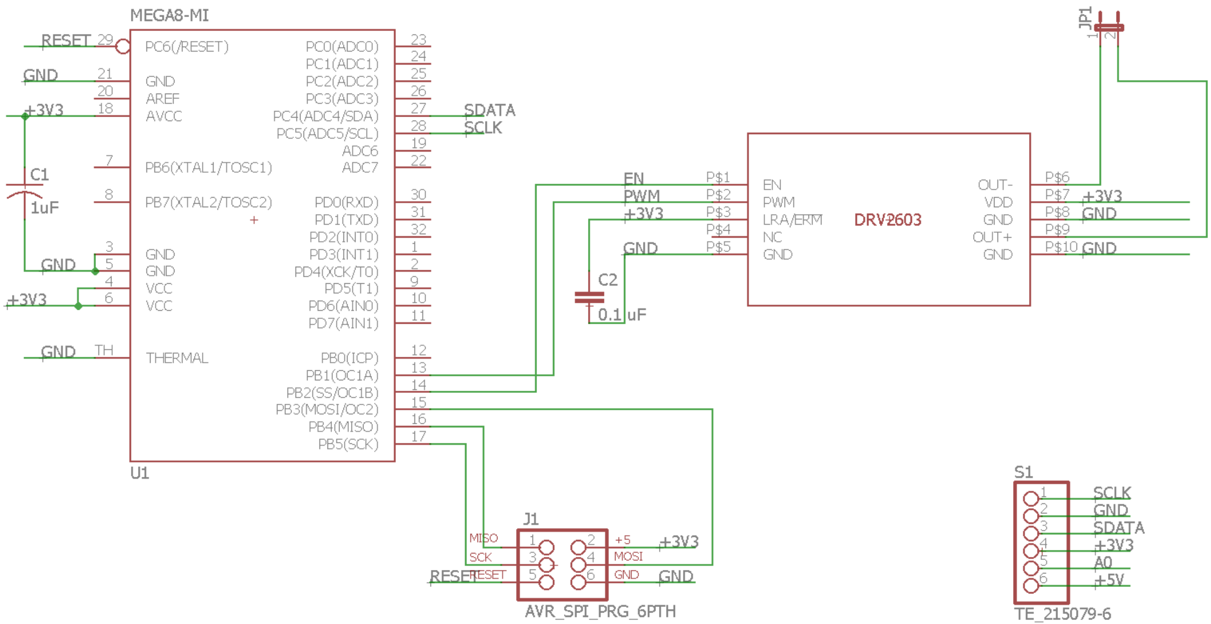

Fig. 4. Schematic of the custom vibration board.

The electronics consisted of four elements. The first was an Arduino UNO R3 with a customized shield. We built a custom Arduino shield, which allowed for quick and easy "plug and play" prototyping. The shield acted as a hub to handle power and communication protocols. This allowed us to plug and play a variety of different sensors, such as accelerometers and haptic sensors. The second component was a Bluetooth modem known as *BlueSMiRF Silver* manufactured by SparkFun ("SparkFun Bluetooth Modem - BlueSMiRF Silver") to create a Bluetooth connection between a smart-device and an Arduino UNO R. The third and fourth components were a custom-designed vibration board and a 9V battery pack respectively.

Prototypes

The glove, wristband, and handle bar prototypes sensors were attached to an Arduino UNO board (Figure 5). As illustrated by Figure 6, the smart watch prototype and Arduino UNO board are connected to a smart device by Bluetooth connections, depending on the type of prototype used.

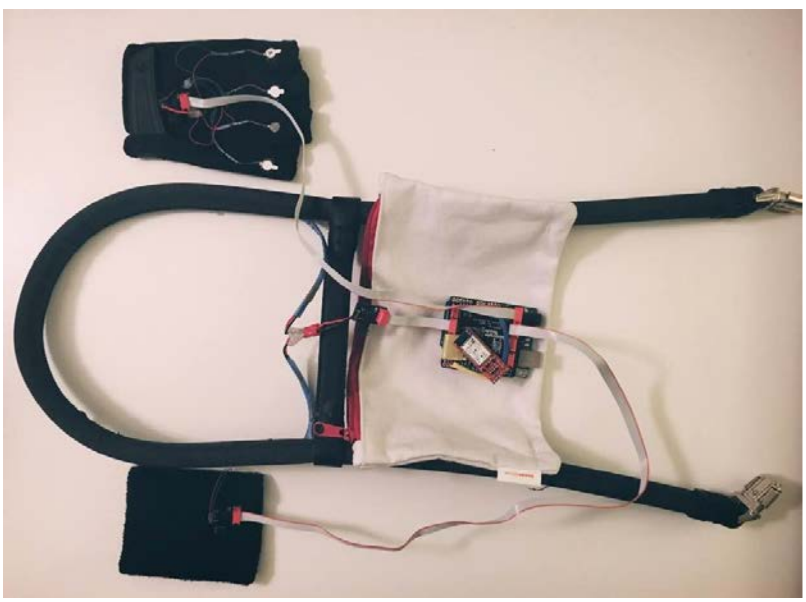

Fig. 5. Guide dog harness handle bar, glove and wristband prototypes connected to Arduino UNO board with a customized shield with a *BlueSMiRF Silver* Bluetooth Modem.

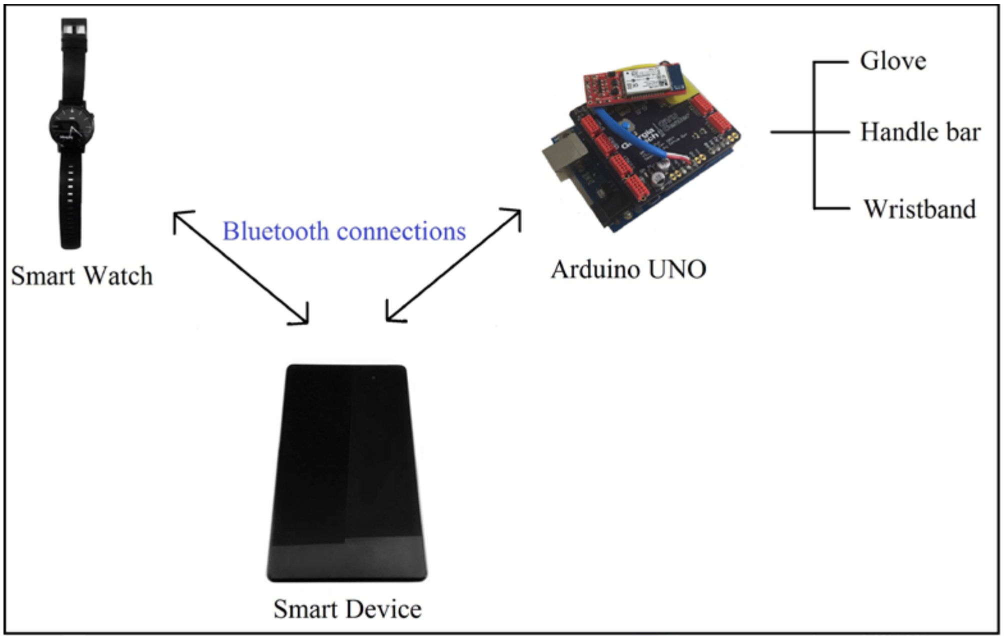

Fig. 6. Bluetooth connections between smart watch, smart device, and Arduino Uno.

Prototype 1–Guide Dog Harness Vibration Handle Bar

The guide dog harness handle bar prototype was the simplest prototype design used in this study because it did not require any additional components. The handlebar had one LRA motor located on each side (Figure 7). One major limitation of the handle bar design was that it required the user to place his/her hand on the handlebar to receive a message.

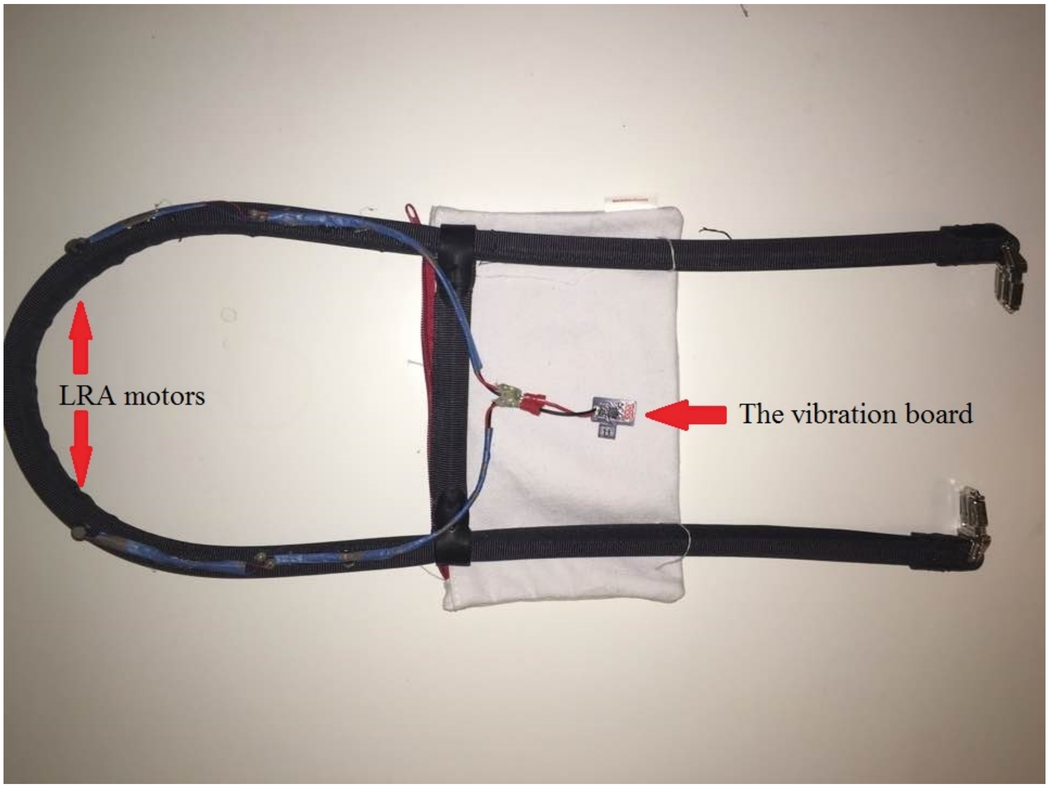

Fig. 7. Guide dog harness handle bar prototype with two LRA motors and one custom-designed vibration board.

Prototype 2–Glove prototype

The glove prototype had one custom-designed vibration board and four LRA motors (Figure 8). The glove was a commercial half-finger gym glove which had a leather palm protection layer and "StretchBack^{TM} performance mesh" on the back of the hand. Every finger except for the thumb had one LRA motor placed between the knuckle and first finger joint.

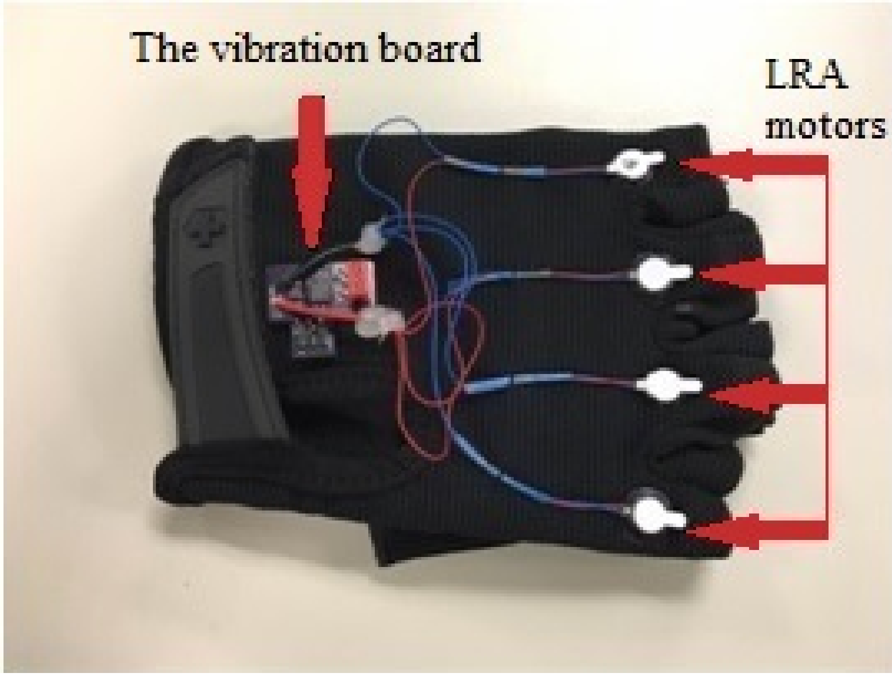

Fig. 8. Glove prototype with four LRA motors and one custom-designed vibration board.

Prototype 3–Wristband Prototype

The wristband prototype had one custom-designed vibration board and one LRA motor placed against the inner wrist (Figure 9). The wristband was a commercial cotton sports wristband. We asked the participants to place the motor on the underside of the wrist to increase their sensitivity to the haptic feedback (Lee and Thad).

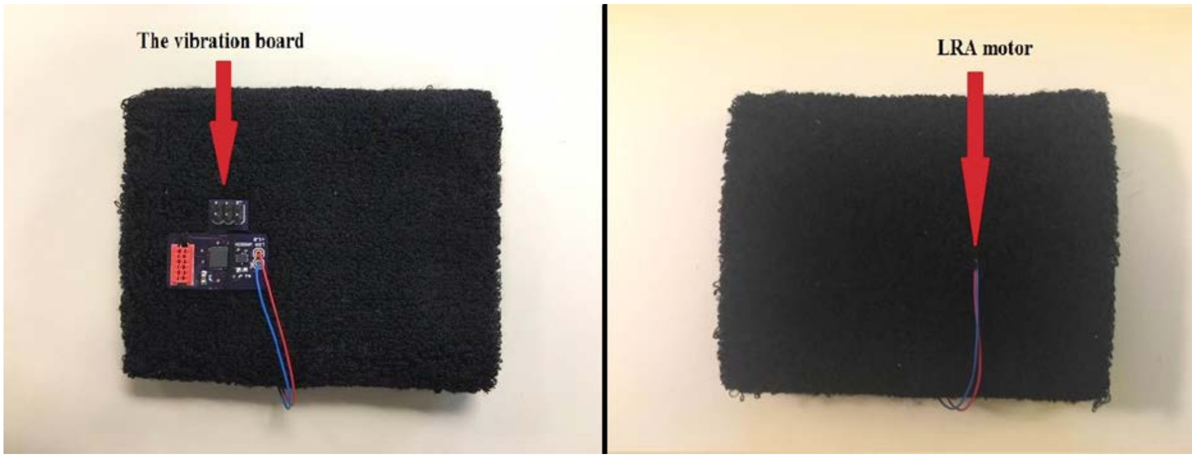

Fig. 9. Top and bottom views of wristband prototype with one custom-designed vibration board and one LRA motor inside of the wristband.

Prototype 4–Smart watch Prototype

The smart-watch prototype used a commercial smart-watch Moto 360. This product allowed for pairing with an Android smart-device using a default Moto 360 application. To send vibration signals, this pairing system created a Bluetooth connection between the smart-watch and an Andriod smart-device.

Participants

A total 12 number of participants were used for this pilot study. None of the participants were visually impaired, and were aged between 20 to 27. There were 5 female and 7 male participants. All participants are pursuing bachelor degrees or above and are right dominant.

Procedure

In our pilot study, each training session lasted 8 minutes, with approximately 2 minutes allocated per prototype. The initial training sessions allowed participants to familiarize themselves with each prototype and the four vibration patterns. Since most guide dog handlers place their left hand on the guide dog harness' U-shaped handle bar (Martin), all the prototypes were designed to test the participants' sensitivity to vibration feedback on the left hand. For consistency, all participants were required to hold the U-shaped handle bar regardless of the type of prototype worn (Figure 10).

Fig. 10. Testing position with a glove on (left) and with a wristband (right).

In the testing session, the participants received 30 randomized instances of the four vibration patterns for each prototype after their training session. Each prototype had its own distinct, pre-scripted set of 30 vibration patterns. Although each individual script did not contain an equal number of patterns, all the participants were given each pattern 30 times throughout the whole experiment.

To keep the experiment consistent, a specific test order was used to test all the prototypes. All participants were asked to use the guide dog harness handlebar prototype first, the glove second, the wristband third and the smart-watch last. However, it must be noted that we recognize that this uniform testing order was not an ideal procedure because of the learning effects introduced by the repeated patterns, thus possibly influencing the apparent effectiveness of the four prototypes (MacKenzie).

All participants were required to complete a questionnaire form at the end of each session for applications in the future design process. As illustrated by Table 1, the questionnaire contains five basic demographic questions and seven user experience questions. The feedback obtained from the questionnaire and the experimental data collected were used to determine the optimal design.

Table 1. Questionnaire questions.

Number	Question
1	Gender?
2	Age?
3	What is your dominant hand? (Right or Left)
4	Do you have a guide dog?
5	Do you have a visual disability?
6	How do you feel about cell phone vibration feedback?
7	Do you have any other device which gives vibration feedback?
8	Which prototype do you prefer?
9	How valuable do you find this feedback?
10	How likely are you to use this interface if it were created?
11	Which signal was the easiest to distinguish from the others?
12	What kind of message do you want to receive from your guide dogs?

Results and Discussion

Following this testing process, we analyzed the accuracy for each prototype using the total number of signals sent to the participant (N) and the number of correct responses (A) for the individual prototype. We also ranked the prototypes from the highest to the lowest accuracy for each participant. In addition, we calculated the overall accuracy of each prototype using the data obtained from all the participants.

Table 2 shows the accuracy of the participants' responses to the various vibrations for each prototype. The participants' ability to correctly identify the vibrations was the least accurate when using the wristband prototype. The overall accuracy average was over 97%.

Table 2. Accuracy results from the participants.

Prototype	Accuracy (%)
Smart watch	98.06
Guide dog harness handle bar	97.50
Glove	96.94
Wristband	95.83
Overall Average	**97.08**

The accuracy of each prototype was found to be over 95%. In order to explore the significant differences between all the possible pairs of prototypes, we used T-testing to obtain the T-value on the accuracy results of each prototype for each participant (see Table 3).

Table 3. T-Value of all possible pairs of two prototypes.

Prototypes compared	T-value
Handle bar and glove	0.279
Handle bar and wristband	0.842
Handle bar and smart watch	0.342
Glove and wristband	0.546
Glove and smart watch	0.658
Wristband and smart watch	1.330

Table 3 shows the T-test results of all possible pairs of the four prototypes. A significance level (known as alpha or α) of either 0.05 or 0.01 is commonly used to understand the results of a T-test. Since all six possible results were greater than both 0.05 and 0.01 alpha values, there is no significant difference between any pair of prototypes. However, it is hard to generalize the result because a sample size of 12 participants is too small to allow for any accurate generalizations of the overall significance level.

The participants did not use the full 8 minutes of training to familiarize themselves with the four distinct vibration patterns. Instead, most of the participants spent 2 minutes to learn the four vibration patterns for their first prototype but took less than 1 minute for their second, third and fourth prototypes.

From the questionnaire, we found that 10 out of the 12 participants displayed a preference for the guide dog handle bar as the most effective method to receive haptic feedback. The participants reflected that the vibration from the guide dog harness handle bar “Feels the most distinct and direct” and “gave the strongest vibration”. Although the guide dog harness handle bar prototype had the 2nd highest accuracy rate among the four prototypes, this prototype was the most preferred design for the participants. With the questionnaire answers and the accuracy results, we could argue that the learning effect took place during the pilot studying. In other words, if we had followed the Latin square method to randomize the order of prototypes for the pilot studies, the accuracy results might arguably mirror the questionnaire responses more closely.

As illustrated by Figure 11, the most confusing a pair of vibration patterns was pattern 1 and 2. The overall probability of confusion between patterns 1 and 2 was more than 7% and the probability of confusion for patterns 1 and 3 had the second highest rate of 3.6%. The length of the vibration intervals for the two patterns differed by 1000ms. In addition, the number of vibrations for pattern 1 was three, and the number of vibrations for pattern 2 was two. It is likely that the difference in the length of vibration intervals between these two patterns was not significant enough to be easily distinguishable. The results also show that the most distinguishable pairs of patterns were patterns 1 and 4, patterns 2 and 3, and patterns 3 and 4.

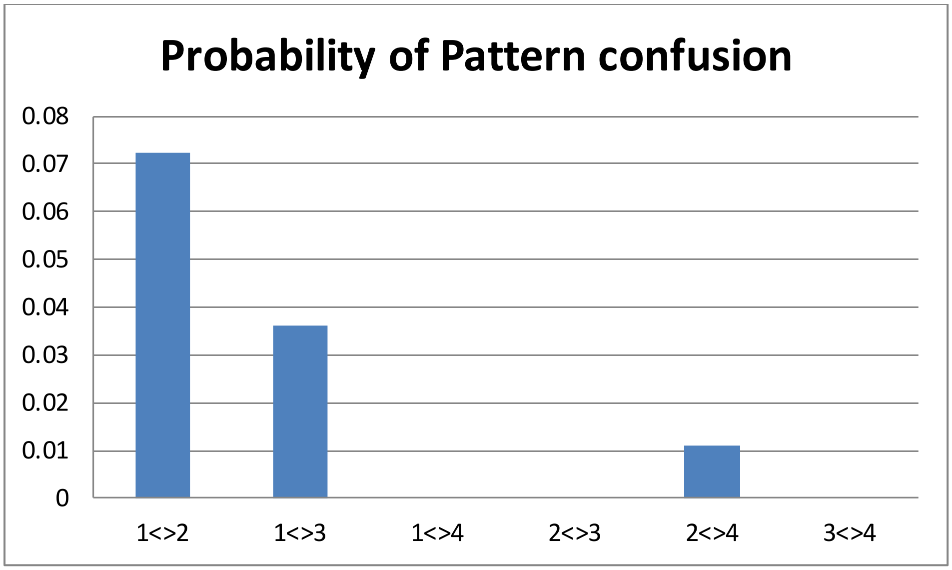

Fig. 11. Probability of pattern confusion from all participants for every possible pair of vibration patterns.

Each prototype displayed unique characteristic during the pilot study. The handle bar prototype shook the whole guide dog harness whenever it received any haptic feedback. It would be useful to consider the effect of haptic feedback on guide dogs for future work.

For the glove prototype, it was found that two out of the 12 participants had hands that were too big for the glove. This meant that the motors did not properly make contact with their skin, thus resulting in weaker haptic feedback.

The wristband had the weakest vibration force of the four prototypes. This was because the cotton material absorbed the vibration force, thus reducing the overall effectiveness of haptic feedback for the participants.

Lastly, we noticed that the smart-watch not only vibrated, but also created a loud buzzing sound whenever it received a signal. This allows the participants to identify the pattern of any given feedback solely through their sense of hearing.

Conclusion

This initial pilot study was a proof of concept for the first phase of our study. We wanted to explore the effectiveness of haptic feedback for guide dog handlers before moving on to the next phase of the study. This study achieved an overall accuracy rate of more than 97%. Even though the accuracy rate of each prototype did not reflect significant differences, the participants' experiences showed that the handle bar prototype was the most preferred design choice. In addition, the results showed that all four prototypes are equally usable for guide dog handlers to receive haptic feedback. However, this study was only conducted in a lab environment without any noise or distractions and all the participants were not visually impaired users. Furthermore, the accuracy rate results and the questionnaire answers showed that there was a learning effect during the pilot studies. Further studies should consider the Latin square method and field study environments. We also plan to study the effect of vibration signals on guide dogs to determine which interfaces are the least obtrusive for dogs.

Acknowledgements

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