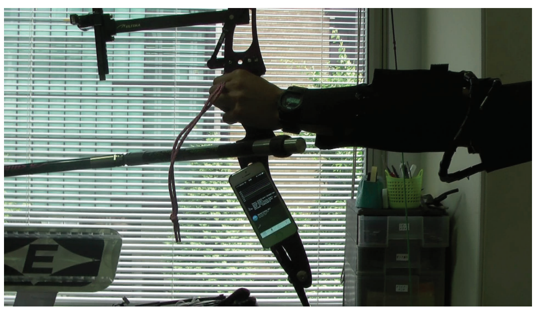
# Towards Performance Feedback Through Tactile Displays to Improve Learning Archery



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*UbiComp/ISWC'15* Adjunct, September 7-11, 2015, Osaka, Japan.
ACM 978-1-4503-3575-1/15/09.
http://dx.doi.org/10.1145/2800835.2800893

## Abstract
In this paper, we explore a specific case of sensory augmentation through substitution techniques. We present an early tactile display prototype designed for novice archers to provide real time feedback on their performance. We evalute the protoype over interviews with 3 experts. Based on the evaluation, we introduce improvments on the initial design. We believe that the rate skill acquisition could be improved by providing the relevant sensor data to the learner through such a tactile interface.

## Author Keywords
Wearable; Tactile Display; Archery; Sensory Augmentation.

## ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: H.5.2 User Interfaces, Interaction Style.

## Introduction
Sensory substitution and the use of tactile displays as interface are not new ideas. However, sensory substitution projects focus primarily on disabled users; researchers have explored circumvention of blindness and deafness through tactile displays. Tactile displays


**Figure 1:** vibrating motor array layout

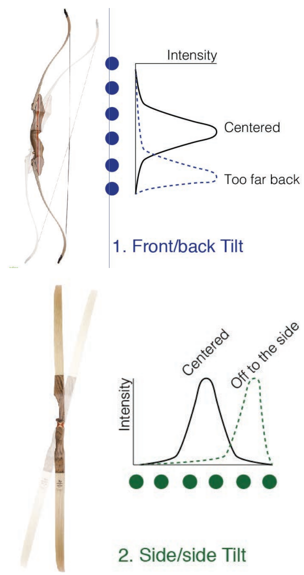


**Figure 2:** Vibration patterns encoding

offer a promising noninvasive, natural method interaction technique. Specifically for the development of motor skills, tactile feedback on the athlete's performance creates a closed-loop system for action modification and preparation. Researches show expert athletes experience an increased temporal resolution of visual perception during action preparation (i.e. baseball players feel time slow when batting a ball) [5]. The phenomenon could be attributed to the tactile stimuli experienced, which triggers faster response than visual and auditory stimuli [6]. Real time tactile feedback for sports have been explored in roller derby through the wrist guard [9] and snowboarding through displays in the torso and legs [7, 8]. Our proposed tactile display provides tactile cues on the posture of the bow, to help train motor preparation of the archer, potentially promoting the development of related motor skills.

The contributions of this paper are as follows: (1) we discuss our approach to give tactile feedback for achery learners, (2) we present an initial, functional prototype of our tactile display, (3) we perform an expert evaluation and, (4) give lessons learned and future design improvements for a system that can be tried in larger experimental setups.

## Related Work

Several projects have investigated sensory substitution, primarily for the use in rehabilitation or overcoming disabilities (e.g. Versatile Extra-Sensory Transducer [1], Brainport [2]). A promising and most recent platform is the haptic vest designed by Eagleman Labs; it is a crowdfunded sensory substitution device that translates sound into vibration patterns on the vest to enable hearing in the deaf. The vest was designed to be adaptable to other sources of inputs and datasets. The study shows that deaf only need 2-3 weeks of training to begin interpreting audio [1]. Other studies also address tactile interfaces that target disabilities [2,3]. They do not investigate sensory substitution as augmentation for nondisabled users for improved learning and skill acquisition. The closest to our work is the research by Spelmezan and Mareike both looking into tactile feedback as instructions for snowboarding [7,8]. However their feedback focuses on legs or back. So far we are unaware of any other research focusing on the use of tactile displays on the lower arms for skill acquisition in sports.

## Approach

To design this tactile interface, we investigated vibrotactile stimulation to interface with the body. To study effect of tactile feedback on skill acquisition, we proposed designing a tactile display for novice archers. Archery is suitable because of its definitive measurement of success and improvement, and the type of relevant data to provide is straightforward: position and orientation of the bow. Converting this data into vibrotactile sensations for the learner might provide meaningful feedback on their performance, allowing immediate adjustment of posture and faster improvement. To minimize the effect of the learning curve for the vibration patterns, we chose an intuitive correlation for the encoding: one to one correspondence between rows of vibrating motors and parameters. With this in mind, we developed an initial prototype to test before further development of the tactile interface.

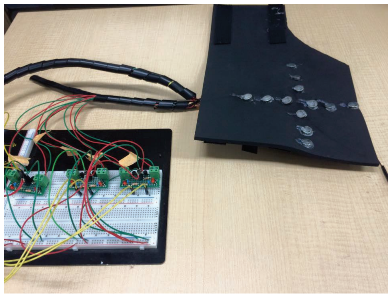

**Figure 3:** inital prototype

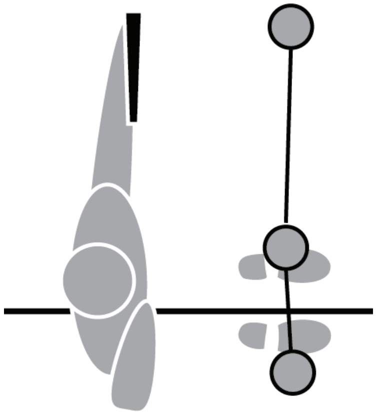

**Figure 4:** ideal stance

## Initial Prototype

The arm guard used in archery is necessary equipment, and a suitable housing for the vibrotactile array (see Figure 3). We also chose the forearm to interface the device for its relative sensitivity and the proximity of bone to the surface, which allows for stronger vibration sensations than the torso. It seemed also a natural positioning to place the actuators on the arm that holds the bow. The orientation of the bow can be measured using the accelerometer and gyroscope. Since one axis is constrained by the wielder's arm, only 2 axes need to be considered: front-to-back tilt and side-to-side tilt about the wrist. Therefore, we chose 2-rows of vibrating motors, positioned orthogonal to each other as shown in Figure 1, to encode this information. The position of the vibration correlates to the tilt of the bow, as shown in Figure 2.

### HARDWARE

We use a total of 12 vibrating motors [FM34F], 6 for the front-to-back tilt and 6 for the side-to-side, all of which are controlled by a PWM LED driver. The TLC5940 driver was suitable for this, with 16 channels to control the transistor switches. Due to the 120mA limit of the driver, we need a separate power supply for the vibrating motor arrays. Figure 3 shows the assembled prototype. The accelerometer and gyroscope data is collected from a mobile phone directly mounted onto the handle of the bow over Bluetooth LE. In the teaser Figure on the first page you can see a user wearing our hardware setup while practicing archery.

### INTERACTIONS

For novice archers, the key practice revolves around correct "setup" or the preliminary action before drawing the string, then maintaining that stance to the full draw. The best stance requires the archer's body and bow to be on the same plane orthogonal to the ground, as shown in figure 4. To maintain correct angle from setup to drawing is a challenge for novices due to the strain of drawing the string. Training improves the muscle memory and sensing the proper stance throughout the drawing process. With haptic feedback on the subtle changes on the stance, the learner can rely less on minute visual cues to know if the drawing process changed the setup stance. The vertical vibrating motor array would inform the learner if the bow shifted within the center plane of the stance. Likewise, the horizontal array would inform the learner if the bow tilted out of the center plane. Both are not ideal. So far the haptic feedback is given towards the direction the user is to adjust the stance.

## First Evaluation

We evaluated the prototype with 3 expert archers and students at an archery studio in Tokyo. All archers that tried the system on liked the basic idea and are eager to see if the tactile feedback can be used to improve their skills. We learned that in the next prototype, it would be beneficial to include a second accelerometer on the forearm, so as to determine the relative angle of the bow to the wrist of the wielder. The experts were interested in repeating shots with same/similar inclination. Moreover, providing haptic feedback on the tension of the bowstring to inform successful full draw of the bow would likely also improve learning.

## Discussions

As a result of the design, development and initial tests of the arm guard tactile display, we identified the following design considerations and requirements:

- The wearable tactile interface has to be light-weight and portable, and cannot be cumbersome that it affects the user's performance and endurance.
- The vibrating motor arrays must be modular, scalable to larger resolutions
- The pattern encoding software must be flexible and scalable to other types and sizes of datasets.
- Instructions to using the device should be minimal or nonexistent, allowing the user to intuitively understand the haptic feedback

While the tactile display is intended to help novice archers develop the correct stance for drawing the bow, it can also be useful for more advanced archers duplicate shots by informing them of a recorded angle. The future model of this device would allow advanced archer reset the recommended angle of the bow as well as the tension of the string to a shot that they would like to reproduce.

## Conclusion and Future Work

In this paper, we showed the design and development of a tactile display to provide real time performance feedback and investigate the possibility to improve skill acquisition for archery. The main contribution of this poster paper is to present a set of design considerations for sensory augmentation while developing a prototype showing a potential application for tactile displays to expand awareness through artificial sensors. We plan to conduct a study to assess the user experience of using the device and measure learning rate due to the haptic feedback, refining and further developing the tactile

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