Towards Haptic Learning on a Smartwatch

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ABSTRACT
Haptic technology can be used as a tool for learning. Can even the haptic elements in a smartwatch teach a new skill? Here we present a case of using a smartwatch for passive tactile learning. We use the Sony Smartwatch 3 to teach users Morse code while they wear the watch but focus on unrelated tasks. An initial hypothesis forecasted that the stimulation from the smartwatch, typically used for message alerts, would be too subtle to enable haptic learning; however, we find significant improvements in six participants using the technique. Furthermore, we expose participants to two different durations of stimulation and find different results.

Author Keywords
Haptic; Wearable; Learning; Smartwatch; Mobile; Passive; Text Entry;

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
Haptic technology can be used as a tool for learning new skills. Typically, specialized hardware is used to give users tactile feedback, guide users' motions, or provide stimulation while they perform other tasks [6]. Smartwatches also contain haptic actuators. Can smartwatch haptics help users learn new skills?

Here we examine using a smartwatch for passive tactile learning. We use the Sony Smartwatch 3 to teach users 10 letters of Morse code while they wear the watch but focus on unrelated tasks. In this paper, we:

- Provide evidence that smartwatch haptics can convey a new skill and possibly enable passive learning.
- Examine performance differences between two different doses of passive stimulation.

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BACKGROUND
Researchers have used smartwatch actuators for alerts and guidance [3], but it is not clear whether they can be used to enable haptic learning. The smartwatch's haptic element is typically a low-amplitude actuator designed for subtlety and to not drain power from the wearable [2]. In contrast, apparatuses producing stimulation for haptic learning typically include hardware to support higher amplitude stimuli or even physical manipulation [4, 6]. The subtle stimuli from smartwatches may not have the necessary salience, amplitude, or even be in an appropriate location on the body.

Previous work demonstrated passive haptic learning of Morse code using tactile stimuli produced by Google Glass [5]. Here, we use the same application (Morse code) and a similar methodology to examine if a smartwatch instead can produce the necessary haptic stimuli needed for learning. If smartwatches can be used for passive haptic learning, many more users may be able to try this technique.

APPARATUS
A smartwatch and headphones are used to deliver the passive stimuli in this experiment. The watch stimulates a repeated sequence of Morse code on the wrist of the user. Dots and dashes are vibration taps of 100 ms and 300 ms respectively. Each group of dot and dash stimuli representing a letter is prefaced with an audio cue naming that letter. There is a 500 ms pause between each group of stimuli representing a letter. We selected an Android watch for easy, open-source programming. Four of the most common smartwatches including the Moto360, LG G, Sony SmartWatch 3, and Samsung Gear were considered for this study. The Sony SmartWatch 3 was selected for best affordability, battery life, and prevalence among smartwatch users.

Haptics specifications are not publicly available for these watches, so we characterized the watch's stimulation. Data was gathered using an ADXL345 accelerometer and microphone. We used an apparatus identical to Laforce et al., who were measuring the vibration strength and amplitude of common cell phones [1]. The watch amplitude and frequency was found to be 0.517 G and about 210 Hz, respectively. Common haptic interfaces used in passive haptic learning typically have an amplitude of 1.3 G and a frequency of 200 Hz [4, 5]. Activation duration, but not typically amplitude or frequency, can be changed using code running on smartwatches.

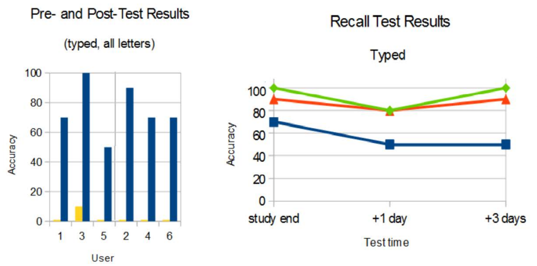

Figure 1. Left: Pre- and post-test results for all users. Yellow bars are pre-test scores. Leftmost 3 users are 16 minute condition. Right: Recall test results. Each line represents a user.

STUDY

We recruited 6 participants (5 male/1 female) to participate in a between-subjects study about learning from tactile stimulation on a smartwatch. We hypothesize that users may struggle to learn from the subtle stimulation produced by the watch. For this study, the smartwatch provides haptic taps to teach 10 letters of Morse code. Stimulation is passive, and users are occupied by a distracting primary game task used in prior research [5]. Users start with a brief verbal introduction to Morse code and a pre-test on all letters. The study consists of periods of passive learning, surrounded by brief tests to assess the user's progress. Letters are split into three words, and each word is taught separately on a loop.

Users are tested on their reproduction of Morse code using a smartphone app. They are asked to enter the "." and "-" combination that represents each letter in the word they are learning. No feedback is given on accuracy. During distraction tasks, users wear the watch and noise canceling headphones, which announces each letter. **Vibration produced by the watch is the sole source of information about Morse code.** We compare two conditions in this study to determine how much time of passive stimulation is necessary for this system. All users receive passive tactile stimulation during the first 8-minute distraction task for each word, and half continue the stimulation during the second 8 minutes ("the 16-minute condition"). The study ends with a post-test of all letters.

RESULTS

We calculated accuracy as the percent of totally correct responses. All users showed significant improvement from pre- to post-test knowledge of Morse code (paired t-test $t(5)=11.62$, $p<0.001$). See Figure 1-left. Users also showed significant improvement between pre- to post-tests of each word. Users showed lower scores on the test of "lazy" at 8 min, and all 16-minute condition users showed a 25-75% improvement after the second 8 minutes of learning on that word (Figure 2). Game scores were logged and were consistent with a prior study using this metric for distraction [5].

Several users agreed to return for recall tests in the days following the study. They were asked not to review any Morse code in between tests. The recall test was identical to the pre/post-tests of all letters. These recall tests were administered 1 day (24 hours) and 3 days after the end of the study session. Results on the recall test were approximately consistent with the user's result on the post-test ("study end" Figure 1-right); no significant difference was found.

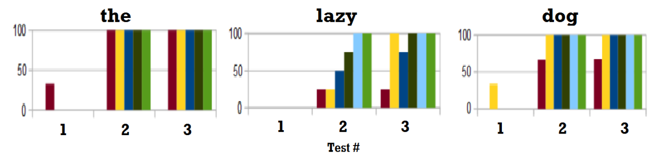

Figure 2. Accuracy (%) for all word tests. Each color represents a user's scores. Yellow, dark blue and dark green bars are the 16-min condition.

DISCUSSION

Instructional stimuli from the watch seemed to help users learn Morse code. Though some errors are made when users reach the final post-test, near 100% accuracies on intermediate tests suggest that the haptic stimuli were clearly perceived. Shorter words ("the" and "dog") were learned in less exposure time than "lazy," which contains nearly double the dots and dashes. This study is the first exploring the effects of time/dose of passive stimulation on learning.

Retention and recall trends are well known for other learning methods; however, a common but unanswered question is "Does the learning from PHL last?" This preliminary probe of recall suggests that learning may be more than short term.

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