Tactile Teacher: Enhancing Traditional Piano Lessons with Tactile Instructions

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Abstract

Tactile Teacher is a pair of fingerless gloves that senses a piano teacher's finger tapping and actuates corresponding vibration motors on the student's glove. In this paper, we briefly introduce the gloves and report preliminary results from a user study with 13 subjects. The study shows that the system improves the playing accuracy of subjects without musical instrument experience by roughly 13%. However, no significant effects on the subjects with musical instrument experience were observed. We conclude the paper with future works and the potential impacts of Tactile Teacher on real-time active learning.

Author Keywords

Education and learning; Mobile and embedded devices; User study design; Piano learning

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction

A traditional piano lesson consists of a teacher instructing a student by demonstrating a passage of music, then asking the student to imitate it to the best of his or her ability. The student does this by making visual and audial observations through watching the teacher and listening to the sounds

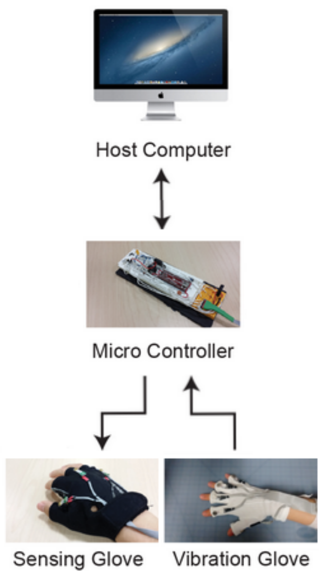

Figure 1: Tactile Teacher's three parts: the teacher's sensing glove, the student's vibration glove, and the microcontroller which interfaces with a computer.

from the piano. A difficult part of this process, especially for beginners, is learning to associate visual and audial cues with the corresponding motor movements required to produce similar sounds. To circumvent this problem, teachers often tap on the back of the student's hands to help the student understand the physical experience of playing the passage of music in terms of rhythm and pitch sequence.

This particular teaching technique is the inspiration behind Tactile Teacher: using a pair of gloves to facilitate sharing the physical experience of playing the piano in real-time. The result is a prototype that augments the traditional piano lesson with an additional medium - the tactile sensation - for the student to learn from. The hypothesis is that students will learn to associate these touch sensations with visual and audial cues and improve learning outcomes.

Related Works

Learning requires multiple channels of communication between teacher and student. Teachers communicate using verbal descriptions as well as physical demonstrations. The use of multiple sensory modalities helps establish communication and facilitate learning by developing a common ground of understanding on different tasks [1]. Increasing the area of common ground between teacher and student has been shown to improve learning outcomes by reducing the cognitive load of learning new skills [2]. Tactile Teacher seeks to facilitate this by allowing the teacher to share his or her tactile experiences with the student.

Mobile Music Touch (MMT) [4] and MaGKeyS [5] are examples that demonstrate the benefits of haptic sensations in improving recall of motor sequences as applied to learning piano. However, in both cases, the finger sequences are predefined and both systems places the student in a passive learning environment. Increasing area of common ground simulates a traditional piano lesson more closely. As shown in Figure 1, the Tactile Teacher system consists of three parts: the teacher's sensing glove, the student's actuating glove, and the microcontroller which interfaces the gloves with the host computer. Tactile Teacher augments the teacher's ability to communicate with the student through the glove detecting the impacts of the teacher tapping on the piano keys and vibrating the corresponding fingers on the student's glove. The design of the gloves and the machine learning algorithm for detecting finger tapping are described in our previous work [3]. As a result, the student can still experience the benefits of having a human teacher - such as visual cues, direct mimicry, and timely correction.

Study Design

The experimental study was designed to investigate Tactile Teacher's efficacy in enhancing piano lessons, namely in its ability to improve a student's accuracy and short term retention of music in an active learning task.

Since the objective was to mimic a traditional piano lesson, the study was designed to be performed in a similar fashion. The teacher demonstrates a passage of music, and the student imitates it. One of the investigators with significant piano training played the role of teacher in the experiment This demonstration-then-imitation procedure was repeated for four tasks with varying parameters, as shown in Table 1.

The experimental tasks were designed to gather data about the student's ability to learn and perform piano playing tasks given different channels of communication. The auditory cues from the teacher's demonstrations are constantly available to the student. However, the availability of visual cues (sheet music) and tactile cues (glove vibrations) were varied to explore the impact of introducing novel channels

	With Sheet Music	Without Sheet Music
Without Tactile Teacher	Task 1	Task 3
With Tactile Teacher	Task 2	Task 4

Table 1: The channels of communication used by the teacher in each task.

Sequence 1	Sequence 2
3 5 2 5	5 2 4 5
5 5 1 1	3 3 5 2
4 1 5 1	1 1 1 5
1 1 5 5	4 1 2 4
2 1 2 1	1 5 2 3

Table 2: Randomly generated sequences of notes used in tasks 3 and 4.

of communication to the student.

Each task has multiple trials with each trial using a longer passage than the one before to help tease apart the effects of memory from active learning. Tasks 1 and 2 are repeated with different musical passages selected from introductory piano textbooks. These selections are randomized between trials to prevent any inherently easier passage from skewing the data towards a particular trial or task. Tasks 3 and 4 used randomly generated pitch sequences among the available pitches, as depicted in Table 2. Two sequences were generated and randomly selected each trial of task 3 and 4. For these two tasks, the teacher incrementally reveals the sequence by compounding the new material with what had already been seen. For example, the teacher demonstrating Sequence 1 from Table 2 would first play 3525, then 35255511, then 352555114151, and so on. Since the student no longer has sheet music available as visual cues for tasks 3 and 4, the process of compounding the music helps keep his or her position in memory.

During the study, two sources of quantitative data were recorded: (1) the time stamps and key codes of press and release events from the keyboards used by the teacher and the students, (2) the classification results of finger tapping events determined by the teacher's glove. The second set of data serves as an indication of what vibration cue the student received. Given the sequence of key presses, window alignment and Levenshtein distances were used to score the results of each student. For each measure, the Levenshtein distance algorithm was used to calculate the minimum number of steps required for the student's sequence of key presses to match the teacher's sequence. Because the student is allowed multiple attempts within a certain amount of time, a fixed window size equal to the number of the teacher's key presses was used for the window alignment. By shifting the window across the student's sequence, the subsequence with the minimum Levenshtein distance was used as the average error percentage for each measure.

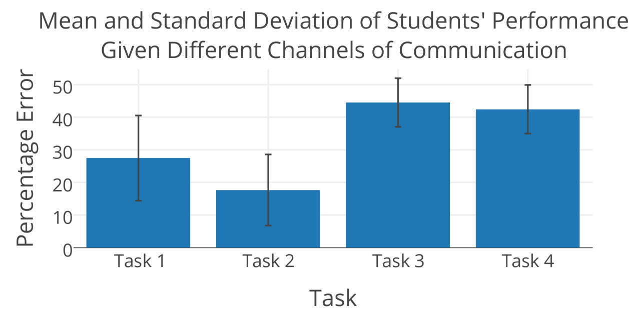

Figure 2: Performance of participants across four tasks.

Data outside of the subject's performance in the trials was also collected. A pre-study survey gathered demographic data, including asking the subject to describe his or her musical background. During the study, each subject was asked to evaluate themselves after each task by giving ratings from 1-9 in five different categories. After the study, a verbal interview with the subject was conducted regarding general impressions of the glove as well as his or her personal approach to each task.

Preliminary Study Results

As of now, 13 subjects have participated in the study. Their mean error rates are depicted in the bar chart shown in Figure 2. This chart shows that the gloves may improve the accuracy of subjects playing musical passages as opposed to random notes when paired with visual cues from sheet music. To investigate the error percentage drop between tasks 1 and 2, each trial was then visualized separately.

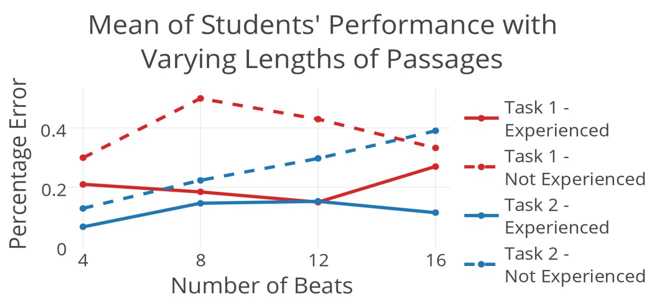

Figure 3: Comparing participants with experience playing musical instruments versus participants without.

	With Sheet Music	Without Sheet Music
With Music Exp.	8.43% improvement	6.23% improvement
Without Music Exp.	13.02% improvement	5.26% improvement

Table 3: Amount of improvement when using Tactile Teacher.

Comparing the red solid line and blue solid line in Figure 3 shows that Tactile Teacher overall does not help those with experience playing musical instruments. In the 4 beat passages, the tactile cues seemed to reduce that group's error rate, and this was reflected in several of the participants' interview responses. For instance, participant 7 mentioned that "having Tactile Teacher turned on showed them where [at what finger] the pitch sequence begins". However, the same group's accuracy was decreased in the presence of the vibration motors during the 16 beat passages. This deterioration was explained by interview responses indicating that the vibration was distracting for the longer passages.

On the other hand, the line graph shows that subjects without experience playing musical instruments benefitted from having the vibration cues up until the 16 beat passages. Participants in this group explained that they were aware of this improvement in accuracy and attributed it to increased number of sensory modalities to observe from, supporting the hypothesis for this group.

Conclusions

This paper described a novel wearable technology designed to enhance active learning by allowing students to experience the physical sensations of their teacher's demonstrations in real time. The preliminary results of a user study investigating the efficacy of this technology were reported, showing that the implementation is effective for participants with no experience playing musical instruments. However, no significant improvement was detected for participants with experience playing musical instruments. While we have not yet gathered a large amount of data, we are excited about these preliminary results and the implications of real-time active learning for motor and music skills. Future work includes improving the prototype, and conducting more comprehensive studies, e.g. studies in real piano lessons.

Acknowledgements

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