Dynamic Haptic Glove: An Active Haptic Learning System to Learn The Piano

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Abstract

UPDATED—May 11, 2019. We present Dynamic Haptic Glove (DHG), a solution which aims to help teach users how to play piano melodies via dynamic haptic feedback. We term Dynamic Haptic Feedback as the DHG is a lightweight, haptic music instruction system consisting of: a fingerless glove, a MIDI controller, and a software program that can be run on a computer. Passages to be learned are loaded into the computer and passed to the software program. Then, the program converts the passage to haptic vibrations. As each note of the music plays, vibrations on each finger in the glove indicate which finger is used to play each note. The user must play the correct note in order for the song to progress. We present one study on the efficacy of DHG measuring 4 subjects' ability to play a passage after using DHG for 2 minutes. The DHG system was found to effective at improving subjects' performance.

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Introduction

Playing music can provide many health benefits such as stress relief, creative inspiration, and overall happiness [3]. In addition to these benefits, playing an instrument exercises fine motor skills in the hands. Learning how to play an instrument can be time-consuming and often expensive. For example, in San Francisco a one hour piano lesson can cost between $40 and $60 [2]. For many, these weekly lessons are not an option due to the cost and time constraint. Thus, many people interested in learning to play do not, and therefore, do not reap the benefits that can come with playing. To mediate this problem, we propose an active haptic system to learn how to play the piano.

Related Works

Recent advances in the music and haptic technology fields have made it possible to develop novel learning system. Literature in the field of human computer interaction (HCI) has explored the potential of these systems. In particular, many works have investigated the effectiveness of passive haptic learning (PHL) systems to improve learning and retention. In PHL, motor skills are acquired with out active attention. In these systems, a user receives a repetitive haptic lesson while they are engaged in a daily activity (e.g. studying, driving, working) and thus learns the lesson automatically.

Previous (PHL) research used a haptic glove to passively teach subjects' how to play a short musical sequence [1]. In this study, 16 participants with no piano experience were taught two simple musical sequences (two measures). Each sequence was constrained to 5 musical notes to avoid lateral movement on the piano. At the start of each session, each user was asked to place their hand on the keyboard while they listened to the sequence and received tactile cues from the glove which corresponded to the correct key to press. After this initial exposure, subjects' performed the sequence and their results were recorded. Next, the subjects engaged in a reading comprehension task for 30 minutes while wearing the glove and listening to the sequence on repeat. Half the subjects received a haptic lesson during the session and the other half did not. After each session, the subjects were asked to play the sequence, and their performances were recorded. Dynamic Time Warping (DTW) was used to measure the total number of errors between the ground truth sequence and the subjects' performance for each performance (before and after the session). The cost of an incorrectly played note (e.g. a note insertion, deletion, or substitution) increased the total error score by 1. The results showed that many tactile performances improved, while many non-tactile performances did not. A two-tailed paired t-test comparing the improvements of the tactile and the non-tactile performances showed a p-value of 0.0001. The mean improvement of tactile group was 3.44 notes with a standard deviation (SD) of 2.25. The mean improvement of the non-tactile group was -1.63 with a SD of 3.30 [1].

Hardware

In order to construct the glove, we began with the prototyping phase

Initial Prototype

The first prototype used a left=handed heavy-duty ski gloves for the body. Incisions were made in the middle of each finger's first knuckle, on the top side of the hand. Vibrating disc motors were placed in each of these holes and secured with duct tape. The motors were soldered to an Arduino Nano which contained Mary Had a Little Lamb preprogrammed to play on-start.

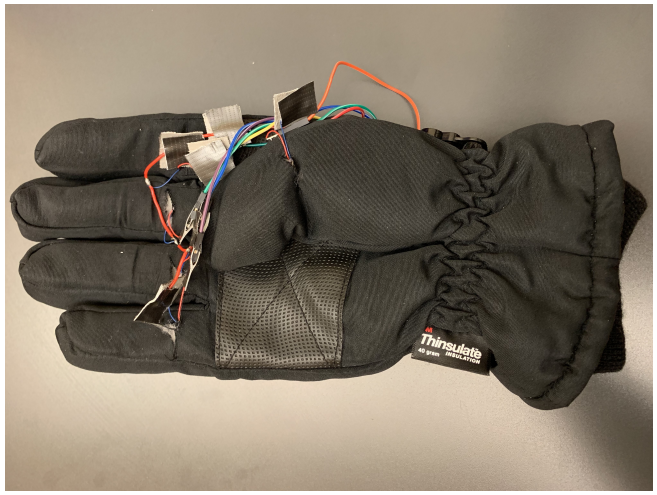

Figure 1: This is the second iteration with the disc motors mounted underneath the hand rather than on top

Prototype II

The next iteration was made from the right-handed glove which came with the initial prototype. Rather than attach the motors on top of the knuckle, we decided to mount the motors on the inside of the glove under the knuckle. This allowed the motors to make direct contact to the finger so that the user would have less confusion as to which note to play. This glove, unlike the initial prototype, included the thumb as a finger.

Final Design

After two iterations, we decided it would be important for the user to be able to play the piano with the glove on. Because of this, we elected a lightweight, fingerless gloves made from cotton and polyester. The disc motors were mounted on the top of the knuckle again because the thinner material

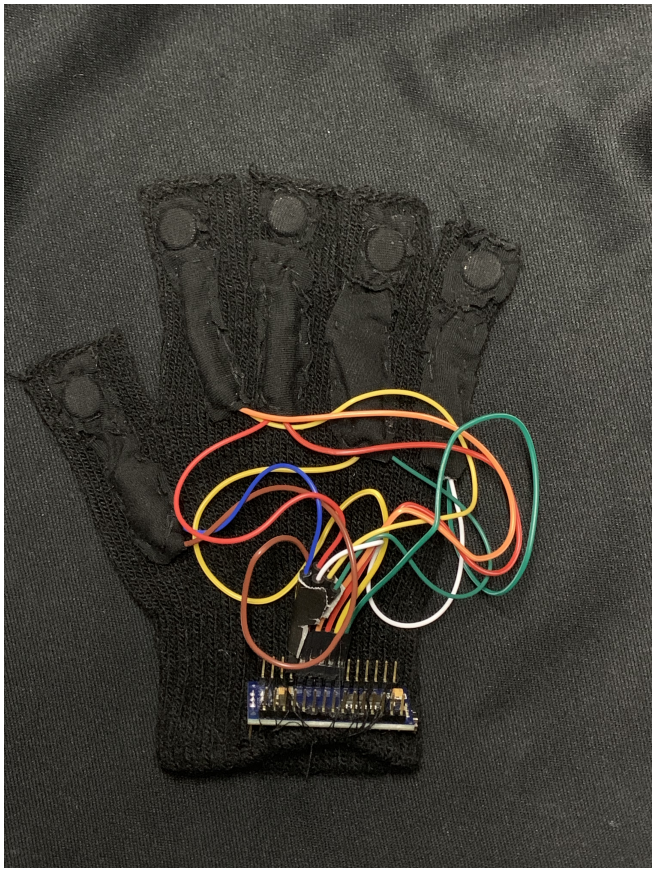

Figure 2: A top-down view of the final iteration of our haptic glove.

allowed for a stronger signal strength and accuracy. The Arduino Nano is mounted on the top of the wrist and the user is tethered via Mini-USB connection to the computer.

Methodology

We begin the experiment by having the participant take a four question pre-experiment survey. The questions in this survey include:

1. Do you have experience with piano?
2. Do you have experience playing any musical instrument?
3. Would you be interested in learning how to play the piano?
4. Are you a fast reader?

If the participant answered "no" to having piano or music experience, the song they were given to learn for the experiment was "Mary Had a Little Lamb". Conversely, if the participant answered "yes", they were asked to learn a more difficult song that still only contains the first five notes in the C key. In order to test whether the participant has improved playing the given song, they are asked to listen to the song twice. Next, they are asked to put on the haptic glove. When the participant is ready, the glove will begin to prompt the participant to press the correct note, which is indicated by a vibration on the associated finger. Once the participant has pressed the correct note, the glove will begin to prompt the user for the next note and until they have completed the song. This process repeats for two minutes. After this two minute learning period, the participant takes off the glove and listens to the song one last time. They are then asked to attempt to play the song they have been learning on piano without the help of the glove. We compare the accuracy of the notes they played to the notes they were suppose to play, and determine whether their score improved from the first time they attempted to play the song. After the experiment is over they then fill out a likert scale survey that asks the user on a scale of strongly disagree to strongly agree:

1. This glove is comfortable to use.
2. This glove helped me learn how to play the given song on piano.
3. I would use this glove again to help me learn piano.
4. The vibration pattern given on the glove was too fast-paced.

Results

Participant	Phrase	PreError	PostError	Improvement
0	Mary.mid	19	10	9
1	Mary.mid	28	15	13
2	Random.mid	11	4	7

A pair sample t-test was done to determine if there was a significant difference between the performance error before and after the DHF session. The p-value was 0.03171. With a significance level of 0.05, our results are significant.

Conclusions

We found that using our glove for 2 minutes greatly improved the recall and performance skills among our participants. Using Dynamic Haptic Feedback (DHF) has the potential to accelerate the learning process.

Future Works

We plan to extend this research by increasing the learning time given to the user while wearing the haptic feedback glove. Providing the user with more time may allow them to become more accustomed with the feeling of the glove. We are also looking into segmenting the audio phrase during the learning process so that the user can learn one measure at a time. This methodology will require us to be able to detect live accuracy results so that the program may dynamically progress through the phrase.

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