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MUMT 619 – Winter 2016
Final Project Proposal: Passive Haptic Learning for Piano Performance

Objective:

Design and build a pair of Passive Haptic Learning (PHL) gloves and accompanying software interface to replicate and extend two previous studies of PHL for learning melodic and chordal piano passages.

Background:

At the 2015 IEEE World Haptics Conference (WHC), Caitlyn Seim, Tanya Estes and Thad Sterner presented the paper "Towards Passive Haptic Learning of Piano Songs" [1], in which they describe two studies that evaluated the use of haptic stimulation to help users learn to play melodic and chordal piano passages. Following previous work by the authors and others around the use of haptics for motor skill training [2] [3], these studies compared PHL results across different conditions including haptic stimulation alone or haptic and audio stimuli together, one- or two-handed playing, and single-note melodies or chordal passages (with multiple notes played simultaneously).

Both studies were structured similarly: First, participants learned short piano excerpts. Second, they went through a period of *passive haptic rehearsal*, where they concentrated on an unrelated "distraction" task while receiving haptic stimuli through a pair of special gloves equipped with embedded vibration motors on each finger. The stimuli reinforced the phrases that the participants had learned by tapping out the manual fingerings and timing throughout the period. During this phase, participants were subjected to different conditions: control, where no stimuli was given; vibration only; vibration and audio together; audio only. Finally, the participants were given three attempts to play the passage back correctly. A comparison between the number of errors between playing the passage at the end of the first phase and in the last phase - called the error difference score (EDS) provided the measure of effectiveness for the different conditions of passive haptic learning.

The first study, based on a previous experiment testing PHL for learning piano [2], examined whether using haptic stimuli alone (vibration without audio feedback) in the second phase had an effect on the error difference score compared to haptic and audio stimuli together. While all conditions improved the error difference score over the control condition, there was largely no difference between the conditions of haptic alone and haptic and audio together. Participants in the study also completed an evaluation of perceived workload during the distraction phase. Participants assigned a higher rating of distraction during the vibration and audio condition than with the vibration alone condition, suggesting that use of haptics alone is preferable for passive haptic learning.

The second study examined two-handed, chordal playing, and specifically compared two strategies of learning two-handed piano performance: learning one hand at a time and then putting them together, versus learning two hands together from the outset. Previous research suggests that learning both hands together at the outset is preferable, however in practice, learning one hand at a time is more commonly used, especially for more complex pieces. The study had participants go through the same PHL experiment, this time playing two-handed chordal music, under two learning conditions. In the first, the participant learned first one hand, then the other, each followed by a distraction phase, after which they attempted to play the entire phrase back with both hands together. The second condition had participants learn both hands together. Consistent with previous research, the two-hands-together condition returned fewer errors.

Proposal:

For this project, I propose to design and build a PHL glove system to replicate the first experiment described in [1]. The system will include a pair of gloves equipped with embedded eccentric rotating mass (ERM) motors attached to each finger to provide haptic feedback to the user, and a Max application to interface with the hardware (gloves and a MIDI keyboard) to send signals to the motors, record participants' playback, provide the initial a learning phase, and analyze the results and calculate errors for different conditions. So that the results can be compared with the original study, care will be taken to copy Seim, et al.'s experiment as closely as possible, including replication of the learning interval times and conditions, use of the same melodies for learning and GRE exams for the distraction task, and inclusion of the NASA Task Load Index evaluation to assess participants' percieved workload.

Hardware: The gloves with be constructed using custom Arduino-based boards originally built at IDMIL for the iLinx and Musicking the Body Electric projects. The boards will be modified from their current configuration to receive communications wirelessly via XBee modules and power via LiPo batteries. Each glove will be equipped with five (5) VPM2 vibrating disk ERM motors, connected to the boards by conductive thread and positioned to come into firm contact with each finger. A regular MIDI keyboard will also be included in the setup and connected to the computer interface via a standard USB cable.

Software: An application will be built in Max to handle the three main phases of the study: A) learning phase, B) distraction phase, and C) play-back (testing) phase. In phase A, the application will guide the participant through learning of a musical passage on piano, using an onscreen keyboard to indicate the correct sequence of notes, along with audio feedback and the keyboard for the user to practice on. In phase B, the application will provide PHL stimuli for three different conditions: vibration only, audio only, and vibration and audio together. In each session, the participant will receive one of the three conditions of stimuli (or the control – no stimuli) while engaging in a distraction task. Finally, in phase C, the application will capture a play-back test in which the user plays the learned passage back on a MIDI keyboard. As outlined in [1], the result will be evaluated for the amount of errors compared to the initial learning Phase A to assess the effectiveness of the Passive Haptic Learning condition.

Timeline:

- **Mar 6 – 12:** Preliminary electronics and communications testing, components ordered
- **Mar 13 – 19:** Design experiment; storyboard & block diagram application, build software modules, continue electronics testing
- **Mar 20 – 26:** Complete and test hardware prototype. Continue with software design.
- **Mar 27 – Apr 2:** Complete and test software application.
- **Apr 2 – 7:** Pilot testing and analysis of preliminary results.
- **Apr 8:** In-class presentation and demonstration of project.

Desired Outcomes and Areas For Future Work:

This project is focused on building the hardware and software infrastructure to duplicate the two studies described in [1] to see if we will arrive at the same results. However, I also see areas for extending the work to address some limitations of the previous experiments. Most immediately is the issue of complex fingerings and hand positions in piano performance. While the previous works demonstrated a system that validates PHL techniques, the passages were limited to diatonic, single-position piano fingerings. I am interested in addressing some of the cognitive experiments that have come from the Musicking the Body Electric and related projects [4] to investigate how we might design a haptic feedback system and language that could provide passive rehearsal stimuli to afford learning of passages over the full chromatic series of pitches and across multiple hand positions.

Works Cited

[1] C. Seim, T. Estes, and T. Starner, “Towards Passive Haptic Learning of piano songs,” *IEEE World Haptics Conf. WHC 2015*, pp. 445–450, 2015.

[2] K. Huang, T. Starner, E. Do, G. Weiberg, D. Kohlsdorf, C. Ahlrichs, and R. Leibrandt, “Mobile music touch: mobile tactile stimulation for passive learning,” *Proc. 28th Int. Conf. Hum. factors Comput. Syst. - CHI ’10*, p. 791, 2010.

[3] C. E. Seim, D. Quigley, and T. E. Starner, “Passive haptic learning of typing skills facilitated by wearable computers,” in *Proceedings of the extended abstracts of the 32nd annual ACM conference on Human factors in computing systems - CHI EA ’14*, 2014, pp. 2203–2208.

[4] M. Giordano and M. M. Wanderley, “A Learning Interface for Novice Guitar Players Using Vibrotactile Stimulation,” in *Proceedings of the 8th Sound and Music Computing ({SMC}) Conference*, 2011.