Sensory Augmentation for Music Learning

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Abstract
In this paper we discuss a system for haptic music learning. We have implemented and tested six different methods of haptic actuation for the finger. We explore different factors – cultural, accuracy, comfort, perception that play a role in the effectiveness of different haptic methods. Finally we outline an entire system based on the Orff Schulwerk for a wearable exoskeleton for exploratory music learning.

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ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: Miscellaneous

General Terms
Human Factors, Experimentation.

Introduction
Music education has traditionally been linear and authoritative requiring years of rigorous practice. The segmentation of learning lessons by expertise as beginner, intermediate and expert leads to a long process of practice before the user gets any reinforcing

feedback in terms of good music. This traditionally has been a reason why many people don't follow up with their music lessons and give up learning musical instruments. The Suzuki method [1] is a classical example of this systematic and rote learning based approach.

Examining other musical education approaches and theories, we come across Carl Orff's [2] exploratory methodology, used to teach music to autistic kids. Called Orff Schulwerk, this method involves four processes - Exploration, Imitation, Improvisation and Composition. The central idea behind Orff's method is to let the user explore the instrument following their curiosity in a very non-linear manner. There are no expertise-based segmentations, rather the method believes in giving the user instant gratification by making them discover and play chords close to their finger positions. This idea of exploratory music learning is explored further in this paper.

The other aspect that prevents users from proceeding with their music education is the access to a master. Traditionally music education has been privileged and opportunistic. Their exist music tutoring software which provide the user with step by step tutorials, but since music is a very physical muscular activity which requires precise sensory feeling, it becomes difficult to learn music through visual software. The approach this paper takes is that of sensory augmentation for haptic stimulation for non-linear music education.

Related Work

In the precise context of haptic systems for music learning, there have been a few research approaches in the past. Tamaki et.al with their Possessed Hand [3] project have demonstrated finger actuation through electric simulations, the process requiring wiring over 140 electrodes. PianoTouch [4] by Huang et al uses vibrotactile actuators on a glove to program the pattern of playing chords on a piano. HAGUS [5] by Grindlay is a haptic system for training percussion instruments which looks into how sound coupled with haptic can reduce errors by 18%. Liberman in his TIKL [6] system created a haptic rehabilitation coat.

Design

The primary goal of this haptic system is to actuate individual fingers to move ahead or behind on a stringed instrument such as an Ukulele. The actuations would be more suggestive and voluntary rather than having to move the finger involuntary by an outside agent. Secondary goals include not having to modify the instrument in use and an exploratory approach to music learning.

Keeping these goals in mind, the following four types of actuations were chosen - vibrotactile, audio transducers, bone conduction sound headphones and linear actuators. The linear actuators were found to cause pain to the skin, hence the three other actuation methods were explored in depth. For each of the methods, two approaches were implemented - directional and scanning. Directional actuation involves two actuators, which signal the finger to move left or right, the scanning method operates on a change of intensity, when the user's finger is closest to the correct position the intensity spikes up while it remains relatively low on other positions.

Implementation

Below we discuss the six different actuation methods and their implementation.

VibroTactile Directional Actuator

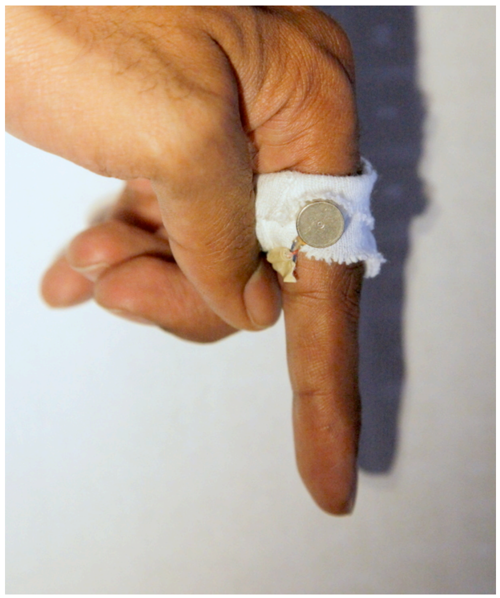

Figure 1. VibroTactile Directional Actuator

Two vibration motors are places on either sides of the finger. Since the fingers are places perpendicular to the direction of the strings, placing the actuators on either side makes for a clear mapping. The actuators signal the fingers to move left or right on the string. The actuators were controlled with a PWM, with each vibrating at a scale of 200/255.

VibroTactile Scanning Actuator

One vibration motor is mounted on the back of the finger. This actuator sends weak actuations throughout, once the user passes the correct position, the actuator peaks up in intensity. The change in intensity shot up from 100/255 for weak intensities to 250/255 for strong, controlled with a PWM.

Figure 2. VibroTactile Scanning Actuator

Transducer Directional Actuator

Transducers are made of surface conductive audio diaphragms that can be controlled in their frequency and amplitude including the types of waves produced -

sine, square or triangle. We found that using square waves at 5Hz yielded the most comfortable feedback.

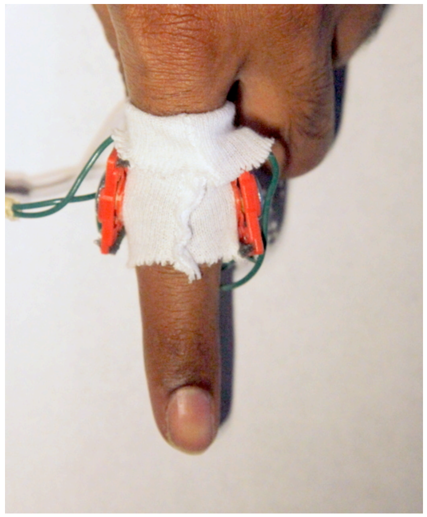

Figure 3. Transducer Directional Actuator

Transducer Scanning Actuator

One transducer actuator is mounted on the back of the finger. This actuator sends weak actuations throughout, once the user passes the correct position, the actuator peaks up in intensity. The change in wave shoots up from 4Hz square wave for weak feedback to 8Hz square wave for strong feedback amplified before feeding the signal to the actuator.

Figure 4. Transducer Scanning Actuator

Bone Conduction Directional Actuator

Figure 5. Bone Conduction Actuator

Bone conduction headphones are worn on the temple leaving the ears free to listen to music. Left and right audio channels are manipulated to signal movement of the finger to the left or right. Since this actuation while the user is positioning their finger and not while playing it doesn't intrude the playing.

Bone Conduction Scanning Actuator

Scanning method is used with the bone conduction headphones where the volume of the sound is manipulated to show different hand positions. Volume changes from weak on wrong positions to medium volume for correct positions.

User Study

The six different haptic actuation methods were tested with a user group of 6 users composed of 3 females and 3 males. Each of them tried all 6 methods, twice each and were given a simple exercise of reaching the right position. They were given a small introduction to each method, but were not informed of the correct mapping - they were to intuitively reach to each actuation. They were measured for accuracy, time and comfort for each method. Additionally verbal feedback was recorded while they were trying out the actuators.

Directional vs. Scanning

While using the directional method, users found it difficult to differentiate between the left and right actuators. Also people reacted differently to the left and right mapping. Most females in the study moved their finger opposite to the direction of actuation while all males moved their fingers in the direction of actuation. When asked, some related the actuation to the feeling of someone pushing their finger while others reacted reflexively going left for left actuation.

Users found scanning much easier, comfortable, and accurate than directional actuation. Having only one actuator, which is on top of the finger, makes it ergonomic to use since the actuator doesn't come in way of the strings or other fingers. Scanning was also more faster since the users could quickly scan their finger across the string and find the right position. Scanning was also reported to be less distracting and effortless.

VibroTactile vs. Transducer

VibroTactile actuators have been traditionally used in haptic actuations. Users felt the buzz of the vibrotactile actuators to not convey much information. While transducers were reported to be more humane due to the tapping action and conveyed information with more clarity. On the flipside, users felt that the transducer was noisy and left a numbing sedation on their fingers. Some users who were brought up in an authoritative back ground felt that the transducer scan method which peaks in frequency for the correct position felt as if some one was psychologically scolding them. Overall vibrotactile were more comfortable but conveyed less information.

Haptic vs. Sound

On trying sound directional and scanning actuation after haptic, all users felt the sound was most comfortable since their fingers were free, most accurate as well since the feedback was direct to the ears and required less interpretation. Although sound was more comfortable and accurate than haptic, almost all user felt that haptic was magical and gave the sense that an external entity is guiding their fingers. Users wanted to use haptic in conjunction with sound in the final system.

Social

Users were asked how would they feel about their social projections if they were seen wearing augmentations for music learning. In events where they are performing even if amateurish, they said they wouldn't want to be seen wearing these aids, while they won't mind wearing them a few hours in a week for training.

Future Work

The current system evaluates the actuators in depth, but doesn't talk about sensing and a learning application that would guide the process. The next steps are to evaluate the feasibility of electromagnetic actuation, which would involve hacking the instrument itself and then looking at sensing and building a complete portable system out of it.

Conclusion

Insights into haptic actuation with regard to ergonomics, methods, gender, cultural background and social projections were evident from the user study. From a utilitarian point of view people prefer sound and visual sensory methods but would strongly want haptic feedback in the system for its novelty. Further user studies will shed more light into the effects of various non-trivial environmental factors on the perception of haptics as well as using haptics for a longer duration

References

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