A NEW DEVICE FOR HAPTIC-ACOUSTIC FEEDBACK

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INTRODUCTION

Music, while understood to be an enjoyable pastime, has been shown to have a multitude of health-related and therapeutic benefits. The frequencies, harmonics and the chord structures attributed to the various notes and pitches have been shown to induce emotional responses; positive emotional responses to sounds produce physiological responses that have effects such as an improved immune response and an increase in natural killer cells and endorphins.

Electronic music production has increased in the recent years due to its accessibility to all skill sets of music. However, electronic musical devices tend to produce sound that has a lower therapeutic value compared to their acoustic vibration-based counterparts; methods for electronically producing music such as Pulse Code Modulation, or PCM, have been proven to harm the listener more than improve their emotional well-being. We propose a speaker based haptic system that not only allows the user to play notes as they would with any instrument but also allows them to feel the vibrations of the note they play. This would improve their experience as well as improve the therapeutic value of non-acoustic instruments [1].

METHODS

Four optical sensors (Marktech MTRS9520)_were attached to sense motion of the cone of a loudspeaker (Faital Pro 5" 5FE120) to detect motion of the speaker cone. The sensor chosen for this device is a Reflective Optical Sensor (ROS), an infrared LED and phototransistor system. Changes in light reflection due to motion of the speaker cone led to changes in voltage in the sensor circuit, which is tracked by an Arduino Uno R3 paired with a Spark Fun MIDI Shield. Changes in voltage reading indicate that the speaker is being touched in one of 4 locations triggers a MIDI Note On message and Note Off serial message, which are sent to a piano synthesizer, whose audio signal drives the speaker. Thus, musical events triggered by touching the speaker are audibly played back through the same speaker to be heard and felt by the user.

	Sensor Voltage Readings vs. Sensor Location Tested					
	A2			A3		
Location Tested	*Rest*	*Tap*	*Push*	*Rest*	*Tap*	*Push*
A2	4.803	4.755	3.898	4.809	4.786	4.77
A3	4.802	4.794	4.776	4.805	4.765	3.978
A4	4.802	4.789	4.677	4.803	4.765	4.757
A5	4.805	4.799	4.782	4.796	4.775	4.745

Figure 1. Voltages Collected for Two ROS (labeled by their Arduino analog pin) while Testing at Various Locations

In order to allow the sensors to receive a clear reading from the speaker, various prototypes and models were created based on the best angle between the ROS and the speaker cone. The dimensions of speaker cone and the ROS were analyzed through a 3D model in Solidworks. The goal was to angle the sensor head at a perpendicular angle to the bottom of the speaker cone without covering the entirety of the speaker basket. Blocking the air flow underneath the cone's basket would reduce the space for the produced sound waves produced to travel through; this would reduce the sound quality as well as reduce the therapeutic value of the sound produced.

We rapid prototyped four 3D printed clips made using Ninja Flex, a highly flexible plastic, to hold the ROS units to the frame of the loudspeaker at 90-degree increments around its circumference. After the measurements of the speaker basket and its holes were record, the clip was designed through Solidworks. Each clip has a length of 49 mm; the main body has a length of 29 mm, and each handle has a length of 10 mm. At its center, there is a 4.5 mm hole sized to securely hold the ROS, which measured at 4 mm. In addition, there are 2 mm slits evenly spaced throughout the band of the clip to decrease air resistance for the sound waves produced by the speaker. The leveling of the slits allows for increased flexibility as the clips are attached to the speaker's circular basket. This model allowed us to attach the sensors directly to the speaker's basket, without interfering with the movement of the cone; when a user pushes down on the top of the speaker's cone, increased reflected light is detected by the ROS, leading to a voltage change. Recording the voltage changes when there was no push, when the push was directly atop the sensor's location and when the push was located at another sensor's location, allowed us to calibrate the system to be able to determine where and how much pressure was applied to the speaker by the user's finger.

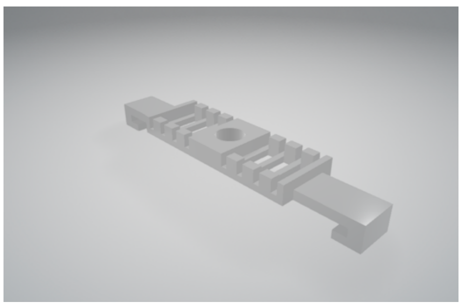

Figure 2. Final Model for the Speaker Sensor Clip; Made in Solidworks

RESULTS AND DISCUSSION

The final model is triggered by touching four points evenly spaced around the speaker's basket; when these points are pressed, a note plays, starting with middle C at MIDI pitch value of 60. Afterwards, the location that is triggered following each played note dictates what the next note will be. As the speaker is played clockwise, the pitch of the note played decreases by 2 semitones; conversely, as it's played counterclockwise, the pitch increases by 2 semitones. The speaker device has a musical range well beyond even the piano synthesizer it is connected to, which has a range of 61 individual keys to play. The program uploaded to the Arduino Uno recognizes and tracks each voltage change and each sensor location, allowing the pitch to accurately by controlled by the location. Each note can be felt by the user at their fingertips as the sound is coming from the speaker's voice coil, connected to the same cone the user plays with.

CONCLUSION

While our current device is modeled to be an instrument, there are various studies that its technology and general foundation can be used for. As stated above, the vibrations produced through the sound of the speaker can be felt by the user; as well as improving user experience, this concept could be further improved by refining the calibration in order to better be able to use the device in the diagnostics of disorders involving sensory and motor loss. As the speaker and its musical outputs are location sensitive as well as pressure sensitive, a user's movements and changes in their finger movements can be tracked with ease.

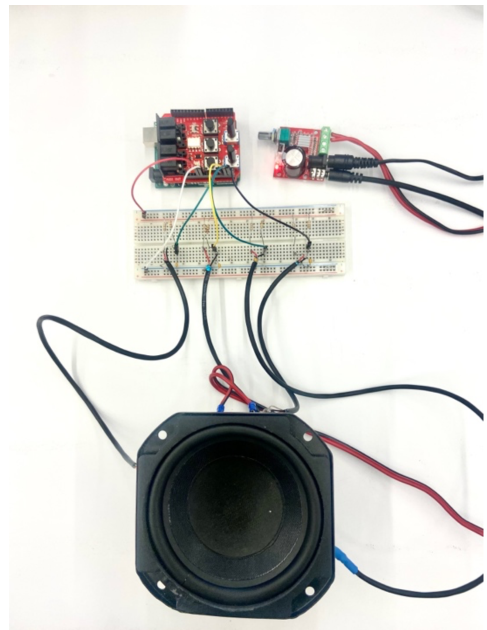

Figure 3. Speaker System, Sensor Circuits and Audio Amplifier Connected to the MIDI Shield Interface of the Arduino UNO

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REFERENCES

1. Diamond, J. et al *The Therapeutic Power of Music.* (2002). Academic Press.