IMPROVING PERFORMERS' MUSICALITY THROUGH LIVE INTERACTION WITH HAPTIC FEEDBACK: A CASE STUDY

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ABSTRACT

Physical interaction with instruments allows performers to express and realise music based on the nature of the instrument. Through instrumental practice, the performer is able to learn and internalise sensory responses inherent in the mechanical production of sound. However, current electronic musical input devices and interfaces lack the ability to provide a satisfactory haptic feedback to the performer. The lack of feedback information from electronic controllers to the performer introduces aesthetic and practical problems in performances and compositions of live electronic music.

In this paper, we present an initial study examining the perception and understanding of artificial haptic feedback in live electronic performances. Two groups of trumpet players participated during the study, in which short musical examples were performed with and without artificial haptic feedback. The results suggest the effectiveness and possible exploitable approaches of haptic feedback, as well as the performers' ease of recalibrating and adapting to new haptic feedback associations. In addition to the methods utilised, technical practicalities and aesthetic issues are discussed.

1. INTRODUCTION

This paper presents an overview of a study that investigates whether incorporating haptic feedback into musical input devices can result in creative musical outcomes for composers and performers working with computers and sensor-based technology.

Traditionally, instrumental performers require an intimate relationship with their instrument, developed through a long process of development and exploration of this bidirectional relationship [1]. This relationship creates a cause-and-effect feedback loop between the performer and instrument, which is constantly developed and adjusted while playing. The instrument reacts to the energy it receives from the performer by producing both, aural and haptic feedback. Through instrumental practice, the performer is able to learn and internalise these responses.

Appraisal of current musical input devices and controllers shows that the received haptic feedback information is often limited, and does not provide the necessary level of *feeling* required from performers as happens with traditional instruments [3]. An experiment conducted by O'Modhrain and Chafe shows how force feedback improves the ability of the performer to control digital musical instruments such as the theremin [8]. Electronic controllers capture the performance gestures and process them through a computer that reacts to the prior decisions of the composer or programmer. The physical nature of such controllers or devices does not allow a bidirectional relationship with the performer, due to a physical decoupling of controllers and sound producing components. Furthermore, the mapping strategies employed between the controller and the audio processing can change arbitrarily, increasing the difficulty of constructing a relatable familiar feedback channel for performers.

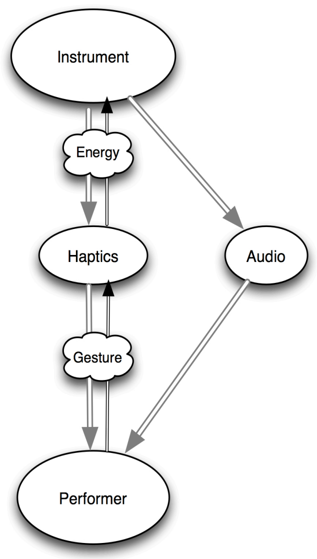

Figure 1. Shows the cause-and-effect feedback loop between the performer and the instrument.

2. CONTROLLING SOUND

Electronic controllers provide the means by which performers' physical gestures are converted into data accessible to use in conjunction with computers. Components like sensors, switches, faders and video cameras might be used individually or in combination with each other. For example, the widely-used Nintento Wii remote offers a combination of sensors, switches, an infrared camera and a wireless connection with which to transfer data to a computer. Bonger provides further discussion of the most commonly-used sensors for music applications [1].

In most cases, electronic controllers are made of plastic, a material that is unlikely to react to the energy provided by the performer. This raises concerns about the performers' experience and related feedback. Chu mentions additional concerns about computer-generated sound being disembodied from the physical object, problematising the formation and control of the sonic properties by the performer [4]. In addition, Tanaka suggests the importance of haptic feedback in creating music coherence in performances [9].

Complications arise upon considering the mapping relationship between the controller and the sound source. This significant aspect of electronic music has been addressed extensively by Hunt, Kirk, Miranda, and Wanderley [5]. Mapping strategies and the possibilities of sound control in real time introduce additional difficulties in the development and use of *controllers as instruments*. Looking at the mapping strategies and sonic possibilities, there are no conventions as to what electronic controllers can affect. However, this flexibility provides opportunities for composers to use the same controller over and over again with different sound results. Consequently, performers face a situation where the development of performance skills, based on the audible feedback, is very unlikely. The creators of such devices often perform with their custom made controllers because they are able to familiarise themselves most to the relationship between controller and created sound [1].

With traditional instruments, the laws of acoustics play a major role in regards to their construction, functionality and sound quality. The physical properties of the instrument, in relation with the aural and haptic feedback, allow detailed exploration of their sonic properties. Two main concerns emerge from this investigation of electronic controllers in music performances:

- The absence of haptic feedback encourages a situation where the performer is only able to have a passive understanding of the sound generated, and
- the constant remapping approaches that the performers experience do not contribute toward a deeper understanding of the relationship of gesture to sound.

These two situations greatly reduce the ability of the performer to effectively realise the musical requirements of the composer.

3. CASE STUDY

3.1 Hypothesis

It is common for composers to combine live electronics with other instruments to create their desired musical result. However, hardware and space requirements of such live electronics components create rehearsal difficulties, especially if the performer does not have their own equipment for the electronics or is unfamiliar with the technology involved. As a result the electronic aspects of pieces receive limited rehearsal. The rehearsal time available for live electronic aspects can often be as little as 2-3 hours 'on the day'. This study will test if incorporating haptic feedback in performances can improve the overall control, perception and musicality of the electronics by instrumental performers—taking into account the limited amount of time available.

3.2 Method

This study is aimed towards a practical utalisation of live electronic performing practice through sensor technology via haptic feedback channels. Different qualitative methods, like interviews and discussions, were employed in this study to examine participants' performing experiences. Six trumpet players, divided into two groups of three, volunteered to take part in a series of semi-open interviews and performing tests. All participants, were undergraduates studying at the Birmingham Conservatoire (Birmingham, UK), were in different academic years, and of both classical and jazz backgrounds. They were from 19 to 22 years of age, and spent between 15 and 25 hours playing their instrument each week. None of them had any prior experience in performing with live electronics. This excludes the possibility of a priori knowledge from influencing the outcome of the study. Each interview, including the performing tests, was approximately one hour and thirty minutes long, after which each participant was compensated with £5. All interviews were recorded with their permission.

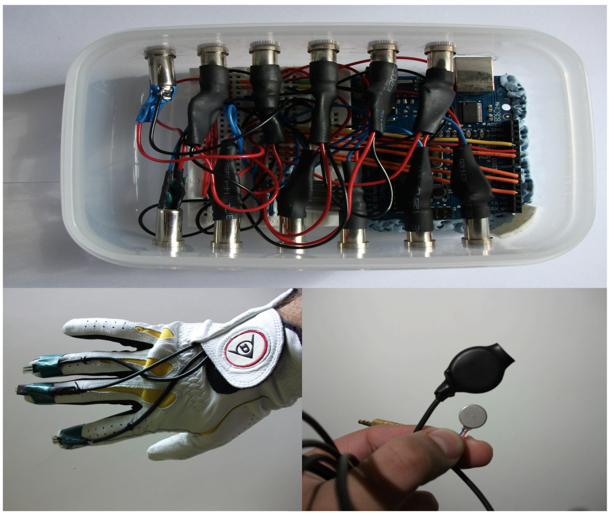

Figure 2. (Top) Inputs and outputs of the Arduino prototype box, (bottom left) glove with pressure sensors attached and (bottom right) vibrating motors with and without rubber shield.

3.3 Hardware Implementation

The prototype box, created by one of the authors, uses an

Arduino Diecimila[1] board, an open source prototyping device. The board is capable of receiving up to six analogue inputs and thirteen digital inputs. The thirteen digital inputs also serve as outputs, of which six can provide Pulse Width Modulation (PWM). Connectivity with a computer is through USB, allowing both power to the board as well as data transfer. The board is housed within a plastic box fitted with female mini-jack connections [see Figure 2].

A pressure sensor glove was created with three sensors attached to the fingertips. As an output source, the PWM function is used to individually control vibrating motors. All sensors and motors use an 1/8” jack adaptor to connect to the Arduino box. Rubber covers were attached to each motor to create a larger surface area as well as to protect them from damage the while in use. The three vibrating motors are attached on the left hand of the performer in different places wrist (inside), forearm (inside) and bicep (inside) [see Figure 4]. The placement was determined through experimentation with a trumpet player (who was not included in the study’s participants) in order to ensure comfort, effectiveness, and recognisability of the vibrations produced. In addition, a microphone, sound card, laptop, and speakers were used.

Figure 3. Music excerpts composed for the performance test.

3.4 Methodology

3.4.1 Preliminary Interviews

The subjects were interviewed before and after a performance test. First, general questions were asked regarding the performance background of each participant, including the amount of weekly practice, how long they have played trumpet, the genre of music they usually perform, and if they play any other instruments. Following this were questions addressing their understanding of live electronics and computer music in general.

3.4.2 Performance Test

The performing portion of the study was divided into two tests, A and B, performing the six musical examples in each test. Both tests use the glove having the pressure sensors controlling the effects. Test A was indicated to be as a standard approach using live electronics while test B utilised haptic feedback. Group one played first the example with the standard approach and then all examples with the haptic approach. Group two performed first the haptic approach and then the standard approach [see Table 1].

	TEST	
Group 1	A	B
Group 2	B	A

Table 1. Shows the order of the tests for each group.

This enabled us to compare the result of adding haptic feedback to both new and previously-learned systems. The brief musical examples provide a range of musical variables, including articulation, note range, phrasing and dynamics [see Figure 3]. The tempo of the examples was unspecified, allowing for free interpretation, which was explicitly encouraged. The composition process was influenced from the trumpet fingerings, as they affected the relationship of the sensors by the notes being played. In example 4, the music requires the performer to use only fingers one and two that control the reverb and frequency shifting effects. In combination with the long notes and the absence of timing the performer is expected to concentrate on how the effect changes with the vibrating relationship. Example 3 was composed to examine how the vibrating functions might work in fast musical passages, and to test the performer’s awareness of the vibration.

Max/MSP[2] programming environment was used for receiving sensor data and transmitting data to the vibrating

[1] www.arduino.cc/

[2] http://cycling74.com/

motors. Incoming sound was processed through Abelton Live[3], modified by the values received from the pressure sensor glove. A one-to-one mapping was implemented between sensor input and sonic effect. Three different effects were used throughout the study. The participants wore the pressure sensor glove on their right hand, which also operated the trumpet's valves. The pressure sensor on the first finger correlated to the amount of reverb added, the second finger affecting frequency shifts, and the third finger controlling the amount of a chorus effect.

The vibrating motors also make use of a direct one-to-one mapping of input to output. In test B, where the haptic feedback layer was added, each sensor's data received from the glove correspond linearly to one vibrating motors. This relationship was explained to the participants as "the more you press, the more it vibrates". A calibration function was created to provide the maximum and minimum values received from each trumpet player before the tests began. This allows the individual calibration of the motors according to the pressure that was applied to each value from the performer. Sound received from the trumpet was monitored in the computer through the microphone. The performer controlled all the parameters of the effects in both tests. Each performing test lasted around 25 minutes, and included two play-throughs of each musical example.

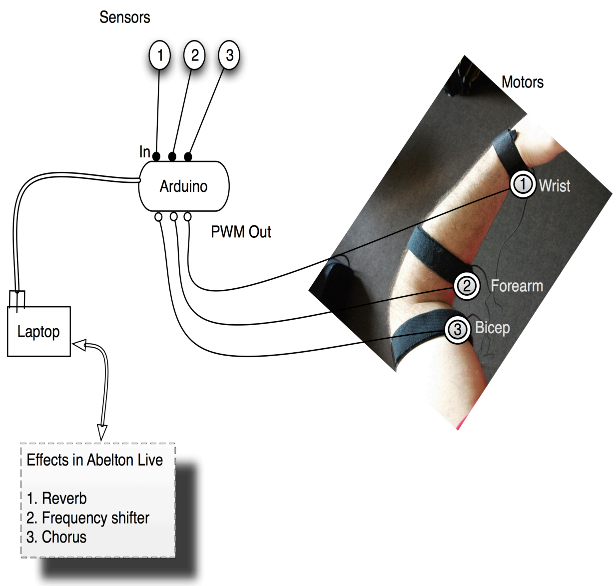

Figure 4. Overview of entire haptic feedback system.

3.4.3 Final interviews

The final set of questions was about the performers' understanding and experience they had while performing the two tests. Participants were asked a variety of questions, including: which system (that with or without haptic feedback) they would prefer to practice with; the difficulty of the two tests; the usability of the technology and hardware used; and their understanding of the sensors' mapping to sound processing and vibrating feedback. In addition, they were asked to evaluate how fast they could adapt, if possible, to the artificially-created haptic relationship and which approach they would prefer to use in concerts.

4. RESULTS AND DISCUSSION

All six participants strongly agreed that haptic feedback created a more understandable relationship between their actions and the ensuing electronics. Apart from the ability to measure the amount of effects processing through vibrations, the participants all mentioned one essential difference between the two tests: the use of haptics allowed them to know definitively whether the electronic effects were active or not. This observation is important in that none of the performers had previous experience with live electronics. Additionally, the lack of audible confirmation about their action, in this case controlling the effects, was evened out through the haptic feedback channels. As mentioned previously, instrumental performers are used to the sensing feedback when they play their instruments. All performers mentioned that the calibrating effect was important in order to accommodate the amount of vibration received from the motors.

Four performers immediately became aware of the expressive possibilities while using the sensor glove with the vibrating feedback. They noticed that while the expression generally comes from the mouth, having the glove one is also expected to think about the pressure applied on the valves. One performer commented that "…expression comes from the mouth and you have to think not only how use the mouth but also the finger pressure to allow expressive changes of the sound". Another performer observed that "…with a bit of practice (using the vibrating motors) I can learn to manipulate it properly". They also noted that "you had something coming back, you could feel and you know physically if something was happening or not". One musician indicated that he could not hear the individual effects in test A but when he could feel it, in test B, he could then press the valves more-or-less accordingly. Another performer suggested the following during the interview: "From doing this now, I don't think that I will need additional practice time to get used to the motors. You could feel individually the effects through the vibrating feedback where in the run without the motors I was not able to know what was happening".

Four of the six performers indicated that, given the option, they would choose to use haptic feedback in the preparation and performance of live electronic works. To them, there was a substantial difference between test A and test B. Specifically, they mentioned the awareness of control they had through experiencing haptic feedback. With the remaining two performers, one preferred to focus only on the notated music having someone else to control all aspects of the computer processing. The remaining one had no distinct preference between the two systems.

[3] http://www.ableton.com/

Furthermore, results of this study support the hypothesis that incorporating haptic feedback in live electronic performances may improve the overall control, perception and musicality of the electronics by instrumental performers. Even though we had two different groups with no prior experience in live electronics insufficient evidence was acquired to provide statistically significant results regarding the amount of improvement, control and perception in performances. However, qualitative responses illicited through interview give an early indication that the application of the haptic feedback system significantly improved the way the performers respond musically to the live electronics. The performers displayed an improved understanding of their actions in relationship with the pressure sensors and resulting sound produced. Consequently, our findings support the theory that haptic feedback can enhance musicians' expressivity in performances involving live electronic music.

The performers were questioned about how they perceived the basic understanding of the data flow from the controller, the sensor glove, to the resulting sound. Interestingly the performers having the haptic approach (test B) first, formed a clearer understanding overall. In addition, the participants were also asked if they thought that an understanding of the technology involved could improve their approach in performances. None of the performers were able to fully confirm this theory given the short amount of time available.

The results of this study suggest that haptic feedback has the ability to provide a framework for experimentation and improvisation with live electronics. After completing the tests, four of the performers asked us to further explore the haptic relationships. At one point, a performer realised that pressing the valves halfway through, the sensors were activated providing data to the computer. When asked, the performer mentioned that the vibrating feedback made him aware of the sensitivity of the pressure sensors. He was then able to slide between notes, using the half valve technique, creating interesting and unanticipated musical results with the effects. Another performer realised that it was not necessary to press the valves to activate the pressure sensors. Consequently, the performer was able to play with all three effects by pressing on the hard surface of the trumpet. However, this also meant the performer was only able to play notes within the trumpet's natural harmonic series.

Overall participants reported that the glove was comfortable enough and did not produce any problems while performing even in fast passages.

4.1 Future work

Future work will develop the technical aspect of the device used in order to minimise minor technical issues as well as increase functionality. On the current hardware an external driver should be added between the Arduino's PWM output and the vibrating motor in order to securely provide more power to the motors, as power management was not optimised in the current device. Additionally, a new version is planed that includes a wireless Bluetooth connection as well as battery power [7]. The wireless hardware will provide flexibility of movement in performances with no need to wear the glove or attach the motors while on stage. The issue of latency between the sensors and the vibrating feedback should be explored further to minimise the response time as well as creating a more consistent device. However, it should be noted that none to the participants reported any noticeable latency problems when asked. Latency issues might be more apparent when vibrating feedback is used to indicate sections, cues or tempo in the score, as this would require temporal synchronisation to be accurate.

It is anticipated that using the sensor glove with the trumpet, composers will explore creative ways of musical expression in relationship with the fingering, the effects processing, and the haptic feedback provided to the performer. In addition, providing haptic feedback regarding electronic effects, composers can utilise vibration as a channel of communication between the performer and the computer to inform them of specific temporal cues, duration of events, functionality of running computer processes, as well as the positioning of electronic sound in space. Moreover, vibrating motors can be attached on more that one performer creating a haptic feedback network channel that can provide information to the performers independently or allow the exchange of information and gestures within the ensemble.

As discussed earlier, another study using the same hardware could examine the difference, if any, in the performing aspect of a piece with and without haptic feedback from the audience's perspective. Additionally, audio input could be utilised as another method to control the haptic feedback provided to the performers.

5. CONCLUSIONS

In this paper we have presented a study that attempts to establish whether adding haptic feedback to live electronics control improves the musicality of performer interaction. Our results suggest that adding haptic feedback to a glove-based controller can significantly improve a performer's understanding the relationship between control sensors and resulting sound produced. Additionally, the use of haptics suggested new musical possibilities not previously considered by the performers using non-haptic systems. Although using haptic feedback introduces an additional layer of complexity in live electronics systems, we consider it essential to pursue further research in this area so that standard methods of providing haptic feedback can be established. With haptic feedback in the control path, interaction is enriched allowing performers and composers to develop new relationships with live electronics practice.

Acknowledgments

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6. REFERENCES

[1] Bonges, B. Physical Interfaces in the Electronic Arts Interaction Theory and Interfacing Techniques for Real-time Performance. In: M. M. Wanderley and M. Battier, eds. *Trends in Gestural Control of Music*. [CDROM], Paris: IRCAM Centre Pompidou. 2000.

[2] Castagne, N. Cadoz, C. Florens, J. Luciani, A. Haptics in Computer Music: a Paradigm Shift. *In Proceedings of EuroHaptics, Munich Germany*, June 5-7, 2004.

[3] Chafe, C. Tactile Audio Feedback. *Proceedings of the International Computer Music Conference (ICMC)*, 1993, pp.76-79.

[4] Chu, L.L. Haptic Feedback in Computer Music Performance. *Proceedings of the International Computer Music (ICMC), 1996*, pp. 57-58.

[5] Hunt, A. and R. Kirk "Mapping strategies for musical perfor- mance", in *Trends in Gestural Control of Music*, eds. M. Wanderley and M. Battier, IRCAM, Paris, 2000, pp. 231–258.

[6] Miranda, E. R. and Wanderley, M.M., eds. *New digital musical instruments: control and interaction beyond the keyboard*. Middleton, Wisconsin: A-R Editions, Inc. 2006.

[7] Modlier, P. and Myatt, T. Haptic Feedback for Improved Positioning of the Hand for Empty Handed Gestural Control. *Proceedings SMC'07, 4th Sound and Music Computing Conference,* 2007, Lefkada, Greece.

[8] O'Modhrain, S. and Chafe, C. Incorporating Haptic Feedback into Interfaces for Music Applications. In *Proceedings of ISORA*, World Automation Conference, 2000.

[9] Tanaka, A. Musical Performance Practice on Sensor-based Instruments. In: M. M. Wanderley and M. Battier, eds. *Trends in Gestural Control of Music*. [CDROM], Paris: IRCAM Centre Pompidou. 2000.

[10] www.crackle.org/ (Michel's Waisvisz web site)