Retaining pianistic virtuosity in #MIs: Exploring pre-existing gestural nuances for live sound modulation through a comparative study

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Retaining Pianistic Virtuosity in #MIs: Exploring Pre-Existing Gestural Nuances for Live Sound Modulation through a Comparative Study

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ABSTRACT

This chapter focuses on Reach, a keyboard-based gesture recognition system for live piano sound modulation, and the comparative user testing conducted to evaluate it. Reach is a system built using the Leap Motion Orion SDK, a custom C++ OSC mapper and a Pure Data environment. It provides control over the sound modulation of a live piano feed, taking advantage of pre-existing gestural nuances offering a touch-free experience to the pianist.

The user testing compared the Reach system with two commercially available keyboard-based systems for augmented live sound modulation: Seaboard and TouchKeys. The approach taken during the user tests is illustrated and test results are discussed. The results that emerged suggest an underlying importance of recognising and utilising the musician’s existing technique when designing Digital and Augmented Musical Instruments (#MIs), and the potential of reducing the requirement to learn additional instrumental technique. The comparative user testing discussed in this chapter is part of a larger research project that seeks to study and understand how a low degree of invasiveness in digital systems for live sound modulation can reduce the learning curve of new systems, allowing greater access to music making with technology.

1. INTRODUCTION AND AIMS

This chapter looks at the evaluation of Reach, an augmented keyboard instrument that provides control over the sound modulation of a live piano feed. The chapter builds upon existing research previously presented at the Innovation in Music conference that took place in London, September 2017 (Granieri et al., 2019). The comparative user testing discussed here investigates if and to what extent invasiveness in Digital and Augmented Musical Instruments (#MIs) affected the ability of pianists to improvise at a first encounter with the instrument freely. To do so, the Reach v1.0 system, mounted on an acoustic grand piano, was compared with two existing keyboard interfaces. The keyboard interfaces chosen, TouchKeys (McPherson, 2012) and ROLI Seaboard (Lamb and Robertson, 2011), enable real-time sound modulation with different levels of invasiveness. Six jazz pianists took part in the test.

The user test investigates different aspects of the relationship between pianists and the musical instruments playing through two improvisational scenarios. There were different aspects of this relationship that were a focal point of this study. These ranged from the ability of users to improvise freely on a keyboard-based #MI without extensive prior experience with it, to the importance of the mean of interaction provided by the instrument itself. While different gestural controllers have varying levels of precision and control over the sound, the tests examine, through the final interviews with the participants, the importance of dimensionality (Zappi and McPherson, 2014) of the instrument when compared to the affordance provided. The concept of dimensionality, as used by Zappi and McPherson, is to be intended as the number of dimensions of control over sound that an instrument or interface provides. The ability of the pianists to freely...
improvise at a first encounter with the instrument was also compared with the low degree of invasiveness, providing a fertile ground to transfer the instrumental technique developed.

The first two key points sought to investigate three concepts regarding instrument interaction: *freedom of playing*, *learning curve* and *aural invasiveness*. While these elements require longitudinal studies with the tracked progression of the musicians, in this user study these concepts are to be applied solely to the first encounter that the musician has with the instrument. In this specific user testing, freedom of playing describes the amount of freedom that the user felt in the first encounter with each particular interface and is directly linked with the ability of the pianists to use their pianistic technique to control the novel interface. The freedom of playing also explores and facilitates the spontaneous exploration of extramusical gestures. Extramusical gestures, in this context, are to be seen as gestures that do not pertain to the instrumental vocabulary and are usually required by the interface. Video recordings of the improvisations and the responses during the semi-open interview will explore these aspects.

Similarly, the concept of learning curve is to be interpreted as the amount of time needed for the user to get acquainted with the interface during the first encounter. This point was investigated mainly throughout the interview process and ties back to the freedom of playing. The aural invasiveness aspect of this exploration followed the results of the initial user testing, as described in Granieri et al. (2019). Classical pianists struggle more with the aural elements of the system than the gestural ones. In this comparative scenario, further exploration of the topic with all the proposed interfaces aimed to elicit the importance of aural invasiveness.

### 1.1. INSTRUMENT CHOICE

The study compared three instruments that pertained to three distinct keyboard-based digital instruments categories. The Seaboard was chosen to represent a keyboard-based digital musical instrument (DMI) with some major changes regarding both the hardware and the interaction. The instrument—apart from taking the keyboard layout as inspiration—modifies everything else: from the key spacing—smaller than a classical keyboard layout—to the wedge shaped keys (Dahlstedt, 2017) all the way to the key interaction that shifts from the classical moving keys of a keyboard to a pressure and position sensitive silicone slate. With this different interaction plane, the Seaboard combined with a bespoke musical instrument digital interface (MIDI) communication protocol, was chosen to be the instrument in the test that provided control over the piano sound with the most amount of gestural learning curve. Being so different from a traditional keyboard it had been noted previously by researchers like Dahlstedt (2017) that the technique required was not that of a pianist, making it an instrument tailored mainly to non-musicians.

The TouchKeys, an augmentation of an existing keyboard, was chosen to represent the apparent gap between Reach, an augmentation of an acoustic piano, and Seaboard, a keyboard-based DMI. While both the TouchKeys and the Reach system could *potentially* be mounted both on a digital keyboard and an acoustic piano, the choice of having them mounted on two different instruments was purposeful. While TouchKeys is marketed as being able to transform any piano-style keyboard into an expressive multi-touch control surface, most of the use cases showcasing the system in action used the system applied to a MIDI keyboard.

There are multiple prototype systems that provide the user with gestural control over sound modulation that will be explored in next section of this chapter, however the test was aimed at considering only instruments that could have been used in a real-world scenario. For this reason, prototypes not easily available to the general public were not taken into consideration and the TouchKeys used was the one sold pre-mounted on a Novation Impulse 49.
2. BACKGROUND AND PREVIOUS WORK

The ability of performers to communicate through their instrument depends on the fluency the performer has with the instrument itself (Tanaka, 2000). Fluency, in this case, is seen as a combination of technical proficiency and expressive charisma, which in turn depend on the time spent practising an instrument and ways of incorporating ancillary movements that are known to convey expressiveness in musical performance (Miranda and Wanderley, 2006).

In recent years, several innovative keyboard interfaces have been developed that range from augmented keyboard interfaces to redesigns of the traditional keyboard interface. The ROLI Seaboard redesigns the keyboard interface entirely by turning discrete sound activators into a continuous controller with a touch-responsive silicone slate. The TouchKeys augments an existing keyboard’s interface by covering the keys with capacitive sensors.

Alongside these two commercial devices, many prototype devices exist. One such device is the system developed by Yang & Essl (2012), providing the pianist with multi-axial gesture controls over audio processing of the keyboard sound using a combination camera-based hand detection and visual projections. Another device is the PiaF (Zandt-Escobar et al., 2014) that combines machine learning with camera based technology to recognise body gestures providing control over audio processing parameters, noting how a pianist’s interpretation communicates both the sound produced as well as body gestures. The ancillary gestures used in this research show potential for the intuitive control of audio processing with movements not directly related to sound production. Reach develops this concept further focusing entirely on ancillary hand gestures, as a means of manipulating sound processing.

The Reach system was used to conduct four case studies with creative practitioners of different musical background (Granieri et al. 2019). The creative practitioners, a composer and two songwriters, through collaborative design workshops helped define the current state of the Reach system. The gesture-sound mappings implemented in the Reach system for this test were investigated and used in the live performances resulting from the case studies (Knibbs & Granieri, 2018; Stenton & Granieri, 2018a, 2018b; Tunley & Granieri, 2018).

3. THE REACH SYSTEM

![Figure 1. Overview of the Reach system.](image)

Figure 1 presents an overview of the Reach system. The Reach v1.0 system uses a custom-made homonymous application, written in C++ using the JUCE framework and Leap Motion’s VR oriented Orion SDK (Guna et al., 2014), to capture hand tracking data from the Leap Motion. The Reach was developed to work on a variety of computers, including embeddable development boards such as the LattePanda (2019), to provide the broadest options to the users in terms of computational power.
The Leap Motion is placed approximately 30cm above the piano keyboard, where positional data is tracked by Reach, encoded and transmitted as OSC messages. The OSC transfer protocol has been chosen over MIDI because of its ability to transmit data with a higher resolution, thus maintaining a higher level of precision when mapping the gestural data to sound modulation parameters. This tracking data, coming from the joints of the fingers, palms and wrists, is then received by a Pure Data patch, and mapped to sound modulation parameters. For this comparative study, the Reach system had a fixed set of gesture-sound effect couplings to make the comparison with the other instruments coherent.

Due to the high level of precision of the Orion SDK, there was no need to de-noise the data. Instead, real-time peak detection audio analysis was conducted on the incoming piano signal in Pure Data. When hitting a note, the positional data received from the Leap Motion was ‘re-centred’, meaning that no audio modulation would occur unless the hand moved away from the current position. If the hand moved and a key was struck, the process repeated. This approach prevented constant and erratic behaviour in audio processing.

A description of the mapping of gestural data to sound modulation parameters follows. Lateral movement of the hand after a note had been played was mapped to a pitch-shifting algorithm ranging +/− 75 cents of a tone, where movements to the right raised the pitch and movements to the left lowered the pitch, creating a vibrato effect. The height of the palm when fingers touch the keys on the keyboard was inversely mapped to the amplitude modulation and the reverb effect. When the pianist’s hands were positioned in a regular playing position, a clean, unprocessed piano sound was sent to the loudspeakers. As the pianist moves his or her hands vertically away from the piano, reverberation is applied to the live piano sound, with the amplitude of the unprocessed piano sound being inversely proportional to this.

4. THE COMPARATIVE USER TESTING

4.1. THE SETUP

The three systems used in the testing, the Reach system mounted on a Steinway & Sons grand piano, the Seaboard and the TouchKeys, were placed in a triangular shape, in order to...
accommodate the pianist in the centre and comfortably switch from one system to the other as seen in Figure 2. All three systems were active at all times, to limit the amount of setup time during the actual test. Three Genelec 8030A speakers were positioned at each end of all three keyboards. One speaker was placed at each vertex of the triangle, meaning that each system shared one speaker that was switched between one and the other via software routing in between the individual tests.

The sound fed into the Reach system was captured by an Audio Technica AT4040 cardioid microphone and fed into a Mac Mini 4,1 through an Edirol UA-25EX. The Leap Motion data, parsed through Reach on a Lenovo ThinkPad Yoga 260, was then fed in via Ethernet to modulate the sound parameters. To split the computing power between more machines, and to avoid any overloading issues, the audio once processed and effected was sent out to a Macbook Pro 11,4 through a TC Electronics Impact Twin audio interface to be recorded. The recording was solely a precautionary measure to avoid losing data during the tests; the system had been run through a single laptop setup before with success. The latency of the system was below the perceivable threshold of 15 milliseconds and was thus disregarded; the destructive nature of the effects and the loudness of the acoustic piano itself had been observed to mask any delay occurring in previous tests and case studies.

Both the Seaboard and the TouchKeys were configured to play piano samples. The sample library used was the one included with the ROLI Equator software due to the good quality of the samples, ease of setup, mapping of parameters and compatibility of the software itself with other MIDI Polyphonic Expression (MPE) devices.

4.2. THE EFFECTS

The effects used to modulate the sound was coherent between the three systems with minor adjustments to each keyboard interface as detailed below in this section. This choice enables the user to be aware of the trade-off between the three keyboard interfaces; the more invasive the interface, the more control and options. The Seaboard, which was considered the most invasive interface of the three because of the complete redesign of the keyboard itself, covered in touch and pressure-sensitive material, was set up to enable sound modulation with four different gestures:

- Vibrato Effect - Lateral swaying of the finger(s)
- Amplitude modulation - Pressure of the finger(s) (if done fast enough, tremolo effect)
- Detuning Effect - Vertical slide of the finger(s)
- Continuous Glissando - Glissando on the bar above and below the keys

The TouchKeys was setup to enable sound modulation with three different gestures:

- Vibrato Effect - Lateral swaying of the finger(s)
- Amplitude modulation - Pressure of the Finger(s) (if done fast enough, tremolo effect)
- Detuning Effect - Vertical Slide of the finger(s)

The Reach system maintains two gestures in common with the other systems while offering a third gesture. This approach makes users aware that while touch-free interfaces lose control and precision when modulating effects, as shown by Wilson (2010), they can expand the gestural
variety; in this case, the ability to track the natural leaps of the hand above the keyboard and controlling the amount of reverb. The gestures implemented were the following:

- **Vibrato Effect** - Lateral swaying of the hand(s)
- **Tremolo Effect** - Height of the palm(s)
- **Reverberation** - Height of the hand from the keyboard

### 4.3. METHODOLOGY

Each test was designed to last approximately one hour, with the shortest test lasting 52 minutes and the longest 1 hour 30 minutes (due to some software issues). Subjects were briefly interviewed about their pianistic background, current knowledge and experience with electronic music and #MIs. Users were also asked to describe any prior knowledge of the three systems, and if they had previously played or performed with them. This background information was later linked to the ease of use, learnability and approachability questions. In addition, users were also asked if they had played and/or improvised any of the two proposed pieces: *Goodbye Pork Pie Hat* by Charles Mingus, and *Musica Ricercata n.7* by György Ligeti.

![Figure 3. Excerpt from the Goodbye Pork Pie Hat score.](image)

While considering the common background between all the users, the decision was made to push the two improvisations in two different directions to elicit different ways of playing from the musical performances.

The first piece shown in Figure 3, *Goodbye Pork Pie Hat*, was chosen as representative of a jazz standard. Moreover, the blues connotation of the piece containing a ‘blues-like’ melody is

![Figure 4. Excerpt from the Musica Ricercata No. VII score.](image)
usually associated with wind or brass instruments due to its original version being played on the saxophone, making the tune hard to play expressively on a piano. This melodic line with vocal characteristics aimed to encourage expressive playing. Users were expected to be familiar with the piece and thus brought to perform a typical jazz improvisation. This approach intended to boost confidence while improvising and engage with jazz vocabulary automatisms that would have triggered the three systems in different ways, without asking the pianist to think about the gestures to perform. On the other hand, Musica Ricercata n.7 was chosen for the modal nature of the melody and supposed unfamiliarity of the tune. All the elements apart from the melodic line had been removed from the score, as seen in Figure 4. The intention was to lay the ground for a freer improvisation, that explored all the encountered effects in the previous ten minutes of playing on the instrument.

After the pre-test interview and a brief explanation of the system the order in which the users would have played the three systems was revealed. The order in which each pianist played the three #MIs was randomised to reduce the effect that playing one keyboard first could have on the following. Having three separate systems and six pianists, each pianist played the three systems in a different order. The pianists had five minutes to try the system and get comfortable with the sound and effects coming from the speakers. When the users felt they were comfortable with the systems and all the gesture-effect couplings, the pianists were asked to perform two five-minute improvisations.

The first improvisation was on Goodbye Pork Pie Hat by Mingus. The user was asked to play the main theme and follow the score once, and then to improvise freely for the remaining time. All of the users were asked to play the theme once in order to have a similar baseline that could have been compared side by side. The second improvisation was on Musica Ricercata n.7 by György Ligeti and followed the same process as the first improvisation. After each test, users were asked to complete a User Experience Questionnaire (UEQ) (Schrepp et al., 2014) to evaluate the experience. The post-test interviews provided us with further information about their experience and level of invasiveness of each system.

5. RESULTS AND DISCUSSION

At a first approach, most of the pianists appreciated the ability to modulate sound parameters with their gestures on all three instruments. This happened consistently across all three keyboards, regardless of the order in which the pianists were asked to play them. This resulted being also independent from the musical background of the musician itself: whether the user-owned
electronic gear, or was completely extraneous to the environment, this kind of gesture recognition technology remained fascinating.

The UEQ evaluated the user experience through efficiency, perspicuity, dependability as well as aspects of the user experience such as originality and stimulation through a Likert scale between -3 and +3. Figure 5 below shows the average values from all the six users, for each keyboard, focusing on the attractiveness, perspicuity, efficiency, dependability, stimulation and novelty of the interface. The y-axis of the plot represents the mean of the data gathered through the UEQ questionnaire. This questionnaire, composed by 26 items, assigned a score between -3 and 3 to every question with 0 being the neutral answer.

In the same graph, as noted in the legend, the three interfaces are represented with three different colours: blue for the Reach system, red for TouchKeys and green for Seaboard. Overall, the Reach system is considered the one with the better user interface, in the specific case of playing and being able to modulate in real time a piano sound. It is clear that, as for the first test iteration, the high values throughout the board were due to the non-invasive character of the system and the ability to play on an acoustic piano.

A similar trend can be seen in the rankings, shown above in Table 1, of the three systems according to three factors: interest, freedom of playing and learning curve. The users ranked the three interfaces according to these factors during the interview. While overall the Reach system was ranked higher than the others, one user considered it tied with the TouchKeys both regarding the interest factor and the ease of learning. In the table, a tied ranking has been arbitrarily shown as the highest rank for both the tied interfaces. For example, in the mentioned case where Reach and TouchKeys were considered equal regarding the learning curve, a first mark has been assigned to both interfaces in the table. The same can be seen between the Seaboard and Reach where the two interfaces tied on the interest factor, while the TouchKeys was considered the easiest interface to learn and approach. The data, while not statistically valid due to the limited pool of users, suggests a possible outline of what the data from a larger user group might look like.
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<th>Reach</th>
<th>TouchKeys</th>
<th>Seaboard</th>
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<td>2</td>
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<td>Second</td>
<td>1</td>
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<td>1</td>
</tr>
<tr>
<td>Third</td>
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</tr>
</tbody>
</table>

Table 1. Interface ranking according to three factors

5.1. THE FEEL OF THE ACOUSTIC PIANO

During the interview process, at the end of each test, several topics surfaced that shone a light on the results of the questionnaire. In particular, one user said:

The first thing I notice about an instrument is the feel [of the keys]. That’s the reason why I find many keyboard instruments really bothering to play. You don’t have the same feel of a piano or a Rhodes for example, that has much more (tactile) feedback. I notice the difference of feel also from piano to piano.

(Participant No. 1)

This appeared to be a recurring theme throughout all the tests and interviews where all users were drawn towards the Reach system because of the ability to play on an acoustic piano along with the flexibility of live sound manipulation. While at first this element could be seen as source of bias in the test results, it is nonetheless a verification of the limited ability of the current state of keyboard-based #MIs. Reach is seen by most of the participants as a first step in improving the lack of keyboard-based Augmented Musical Instruments (AMIs) by taking full advantage of the accessibility and non-invasiveness of acoustic piano sound and feel. As explored by Dahl (2016, p. 77) this kind of practice could be considered a design exploration; ‘[d]esign exploration seeks to explore possibilities outside of current paradigms, to transcend and provoke’.

The provocation, in this research, is to incite and push the development of keyboard-based AMIs alongside the development of the existing paradigms: whether referring to innovative DMIs such as the Seaboard or more niche AMIs such as the TouchKeys. The test aimed to look at keyboard-based #MIs in a more holistic way. As discussed above in the introduction, one of the main goals was to analyse how performers would approach the proposed instruments at the first encounter and to what extent they would have been able to improvise on two different pieces: a known jazz standard, and a modal melody. With the improvisation at a first encounter as the main
focus of the comparative test, the learning curve of the interfaces and precision in sound modulation have been considered and analysed throughout the semi-structured interviews.

In response to a question that sought to investigate why the ease of use of the Reach system was better for him, compared to the other two interfaces, another user said:

Because the touch and everything is so familiar and feels good, the new elements are much easier to control because you don’t have to think about that as well as the interface itself.

(Participant No. 5)

The same user underlined how the familiar interface of the acoustic piano helped him shift attention on the novelty of the gesturally controlled interface without having to focus also on his pianistic technique.

5.2. DEGREE OF INVASIVENESS, LEARNING CURVE AND ADDITIONAL TECHNIQUE

Closely tied to the feel of the instrument itself, another investigated aspect was how the invasiveness of the interfaces affected the ability to approach the instrument, learn the instrument and how much of the pre-existing instrumental technique could be implemented. On multiple occasions, users commented on this aspect throughout the testing phase, and the same topics were then dealt more in-depth in the interview. One user, after having described the TouchKeys as really hard to control, described his first approach with the Reach system saying ‘Oh loved it! So much easier!’ The user in this specific case, found the interaction with the Reach system easier from a cognitive point of view. During the interview, it became apparent that the new sonic elements provided by the Reach system were easier to control because the user felt that he did not have to think about the interface, that the acoustic piano was an environment in which the user felt completely comfortable. The pianists were able to just focus on exploring the system and its effects, forgetting about the actual pianistic technique that had been consolidated in many years of study. Regarding the additional technique usually required to play AMIs and DMIs, one user said:

My technique doesn’t work there, I need to take one week with it, after one week I can go and play it. But I have one concert today, and if I need a piano, I don’t take this and this (pointing at the Seaboard and the TouchKeys).

( Participant No. 2)

Similar comments were made by other users, that pointed the need of additional practice to build up the required technique to play the instruments. None of these comments were made regarding the Reach system. On the other hand, two users out of six spontaneously asked if they could employ extramusical technique on the Reach system to trigger it in various ways. One user later explained his experiments by saying:

[...] there were times when I was trying to do two gestures at once: I was trying to get the reverb to stay on and put some pitch bend in there. (he was covering one hand with the other)

( Participant No. 6)
This spontaneous search for additional technique to implement in the improvisation, reflects the level of accessibility and ease of use of the Reach system. It also highlights an emergent feature of the system and shows how the transparency of the interface allowed the user to explore musical and gestural ideas. Transparency in this context is the ability of an interface to disappear to the eyes of the performer enabling him or her to interact directly with the sonic and musical output. Similarly, the accessibility of the interface combined with the confidence of the user to approach the described interactions led to an exploration of possible extended technique outside of the proposed gestural nuances. These extramusical gestures—sought by the participants themselves—did not provide a disruptive gestural element. The affordance provided by the instrument itself helped the user transition from the nuanced gestures embedded in the pianistic technique towards sound controlling gestures outside of the traditional movements of the performers.

In a similar way, verbally the way in which the users approached the three systems was very diverse. All of the reactions of the users when trying the Reach system for the first time were positive and of interest towards the sounds and processes behind it. Most of the immediate reactions of the same users when approaching the other two interfaces were referring to the difficulty to transfer their skills to that environment, or to the unconventional design of the interfaces themselves.

5.3. CONTROL PRECISION

Analysing the data gathered revealed that regarding the level of precision in terms of parameter modulation, the Reach system was the least precise. For this reason, it was essential to investigate whether this difference in precision was an acceptable trade-off considering the low degree of invasiveness. When asked, five out of six users mentioned that they would prefer a less precise system that would give them more freedom of playing. A user specifically stated:

I would definitely go for the Reach system. I am all about the sound and feel. If we’re speaking about piano sound, there are no keyboards that will hold up the comparison. If I play here (indicates the piano) I feel so much better. It’s not only a question of control, but it’s also a question of aesthetics and inspiration. How can you be inspired or play the piano on something like this (indicates the Seaboard).

(Participant No. 1)

Another user also stated:

I thought that precision matched the freedom on your system. I feel like it was easier to be precise on your (Reach) system compared to the others.

(Participant No. 5)

This quote could be linked to the test limitation discussed the next section in regard to the balance between wet and dry signal.

6. USER TESTING LIMITATIONS

Even though the test provided useful insight around the relationship between interfaces with a low degree of invasiveness and the ability to play freely and improvise at a first encounter, it
presented a few limitations that need to be addressed. This section aims to acknowledge the limitations and explain the reasoning behind certain structural choices.

6.1. SOUND BALANCING

One of the main limitations was the balancing between the wet sound (or processed live piano sound) and the dry sound (or unprocessed live piano sound). When designing the test tasks and structure, a decision was made to leave the digital piano sound to its default settings. This choice was made keeping in mind that the default state of the plugin for the piano sound would have been crafted and designed to work well with the Seaboard and any other MIDI Polyphonic Expression (MPE) devices (i.e. TouchKeys).

During the test we uncovered that the difference in sound balance between the three systems had an effect on the perception of the system itself. The Reach system, with a prominent clean sound coming from the acoustic grand piano and a more nuanced effected sound coming through the stereo speaker combined with the natural ability to hear clearly both the wet and dry sound, provided the pianists with a different aural experience compared to the other two systems.

In retrospect, to provide a more equal sound experience to the users, a second audio track playing back the clean piano sound without any modulation could have been created in the Digital Audio Workstation (DAW) providing the Seaboard and the TouchKeys with a similar sonic experience in terms of dry/wet balance.

7. IDEAS FOR FUTURE DEVELOPMENT

Feedback received from the users was directed not only to the investigated mean of interaction and invasiveness, but also to the most practical aspects of the instrument itself. One user that took part in the user testing, towards the very end of the interview, asked about the actual setup of the system. After having explained the inner workings of the system, the pianist discussed the importance of having an all-round accessible musical instrument. As soon as the word software was mentioned, the user reacted by saying:

You still need a software? I am speaking as a musician. The cool thing about a contact mic is that it’s immediate. You stick a microphone on the piano, plug it into a pedal, and you’re set. So, I’m wondering, how would you go and make it even more “compact”? (…) It would be really cool to have something really small without too many things. I hate computers in live settings. You are dependent to something that could crash every second.

(Participant No. 1)

The elements that make an instrument accessible are not limited to the interaction with the instrument itself: accessibility is an all-round feature. From the most practical elements, such as portability, size, setup time and reliability, to the most musical elements, such as interaction, and freedom of expression. This concept was later fortified with each other participant in the test. Having to deal with performing musicians, each and every one of them had a personal aspect of the instrument that they found extremely important for the instrument to be considered accessible.

8. CONCLUSIONS

Having seen and analysed all the results from the comparative testing, a connection has been established between the invasiveness of the digital system, comfortableness of the instrumentalist to approach the instrument and ability to freely improvise and transfer previously learned skills
and technique. There have also been cases where this comfortable experience has led to a spontaneous exploration of extra-musical technique to control the system in different ways. Out of the investigated topics, the most surprising results were gathered when asking about the trade-off between precision of modulation in relation to the invasiveness of the system. All of the jazz players that took part in the test seemed to prefer a less precise mean of modulation in favour of a less invasive interface. This was later linked to two main factors: the first one being that an overly precise mapping of the fingers resulted in disrupting the flow of the improvisation, and a second one that not being able to precisely predict the outcome of the modulation the pianists treated the system almost like another musician with which they could interact. From the comparison of the results from both the user testing sessions, it is clear that users are more likely to prefer less invasive AMIs or DMIs in favour of a less disruptive experience.

During the first round of user testing (Granieri et al., 2019), when testing Reach alone, users noticed that the system put a strain on the aural part of playing, making it difficult for users to predict the outcome of their gestures. When instead, compared with existing interfaces, the Reach system was seen as the least invasive instrument to play effectled piano, with an acceptable comparison between low degree of invasiveness and control precision.

Even though initially there was no particular musical genre suited for the system user data suggests a tendency toward a compositional and improvisatory approach with the Reach system. When compared to existing keyboard-based systems, the Reach system has been identified as the most user friendly, and easiest to approach and explore at a first encounter. However, the current setup has been seen as not user friendly, and a major flaw in the system to make it accessible all round.

The UEQ data from both rounds of testing have shown how the approach of lowering the degree of invasiveness of the system by basing its mean on interaction on pre-existing instrumental technique, is not only valid but inspiring and useful. Users even though unfamiliar, were quickly able to take control of the system and effect the sound with a minimal amount of guidance.

9. REFERENCES