A Quantitative Evaluation of the Differences between Knobs and Sliders

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Abstract
This paper presents a HCI inspired evaluation of simple physical interfaces used to control physical models. Specifically knobs and sliders are compared in a creative and exploratory framework, which simulates the natural environment in which an electronic musician would normally explore a new instrument. No significant difference was measured between using knobs and sliders for controlling parameters of a physical modeling electronic instrument. The reported difference between the tested instruments were mostly due to the sound synthesis models.

Keywords: Evaluation, Interfaces, Sliders, Knobs, Physical Modeling, Electronic Musicians, Exploration, Creativity, Affordances.

1. Introduction
The motivation for this research was to investigate physical interfaces for controlling physical models. The research is situated within a framework introduced in among others [2], which approaches physical modeling from a user centered creative exploratory perspective. The framework deals with interfaces which afford creative exploratory processes.

On one hand the framework attempts to analyze the work processes of potential end-users. On the other hand it evaluates interfaces, which facilitate the needs of these end-users.

In our case the end users are electronic musicians which compose music working in an exploratory fashion, feeding off the affordances and constraints of the tools at hand for creative inspiration. Our approach is somewhat similar to the ecological [6] approach of Thor Magnusson, used for GUIs in among others [12].

It was decided to work bottom up, starting with the evaluation of the simplest traditional (continuos) input devices found in musical interfaces - knobs and sliders. In order to give a valid assessment of the differences between the two it was found important to somehow weight the influence of any differences that might appear. This was done by evaluating other influences on the overall impression and performance of musical instruments. For this study they were limited to 1) the influence of more expressive input devices and 2) the influence of the sound synthesis model (in this case physical models described later).

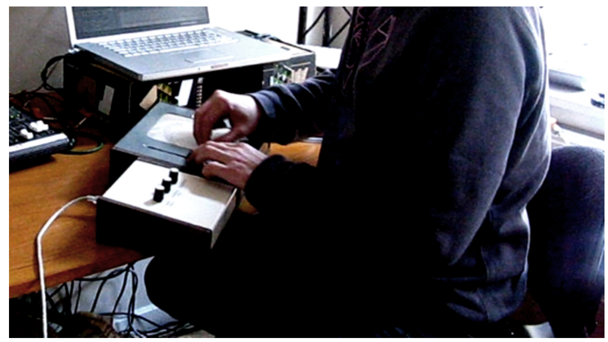

Figure 1. The interfaces were tested by experienced test subjects in their own studio in order to get as close to a real world scenario as possible

The main objective of this study was to investigate if there exist preferences when comparing simple physical interfaces such as knobs and sliders. Our null hypothesis was that knobs and sliders are equally preferred.

The study additionally had two secondary objectives: to investigate if there are physical interfaces, which afford creativity and exploration more than others, and what is the role of the sound synthesizer compared to the user interface.

2. Related Work
2.1. Interface Evaluation
The need for more effective evaluation methods has been addressed in recent years within the NIME community [3]. In [18] methods are proposed for evaluating musical interfaces, which are inspired by HCI research. Among other things the authors propose to use simple musical tasks to evaluate exploratory features.

A very nice overview of the recent literature has already been given in [11] which is a more detailed look at the methodological approach used in [10], where a Wiimote is evaluated as a musical controller. Their approach resembles to a large degree the methodology used here.

In [5] the authors distinguish between traditional usability evaluation (Fitts's Law [18] is a rigorous example) and a broader approach evaluating HQI (how "a user identifies with the product") and HQS (how the "product stimulates the user").

Quantitative and qualitative methods are applied in [15], which deals with evaluation of expressivity of string instrument based musical instruments from a performance point of view. A more qualitative method is proposed in [17] where discourse analysis is used to make qualitative methods more rigorous.

This paper will not deal with the expressivity as such, as it focuses on the compositional side of music making. The users are not merely musicians but also composers of electronic music - a trend that seems very common for electronic musicians. Inspiration has in general been found in the above approaches.

2.2. Interfaces for Controlling Physical Modeling

Physical modeling is a sound synthesis technique that is approached from a physical sound production perspective. Here the algorithms are designed to simulate the actual physical mechanisms, which produce sounds in the real world.

Interfaces for controlling physical models have naturally mostly revolved around input devices which were closely related to physical properties found in the model.

Almost all of these are interfaces designed for a specific project. However, a few attempts have been made towards general interfaces for physical models [4, 14] (each of them being general within subcategories of physical models, each representing different physical phenomena). Former research by the author et al. has examined the possibility of breaking free of these subcategories for a while in order to investigate interfaces, which may apply for physical modeling in general [2].

3. Knobs versus Sliders

Both sliders and knobs are used to control parameters of musical interfaces and they mostly have more or less the same output range. When designing novel musical interfaces one is often presented with the decision whether to implement either one or the other.

Knobs are often used when controlling parameters that have little relation to each other, whereas sliders are used for controlling parameters that are more comparable. Using only one hand, one is able to control multiple sliders at once - this is hard to do using knobs. Multiple aligned sliders can be easily monitored just by a glance, while one has to take a closer look at each knob one at a time in order to get an overview. Knobs on the other hand have the advantage of taking up less space. Using them with rotary encoders also provides the ability of very fine tuning.

These observations might seem trivial. However, the differences might matter a great deal when designing novel interfaces for musical purposes.

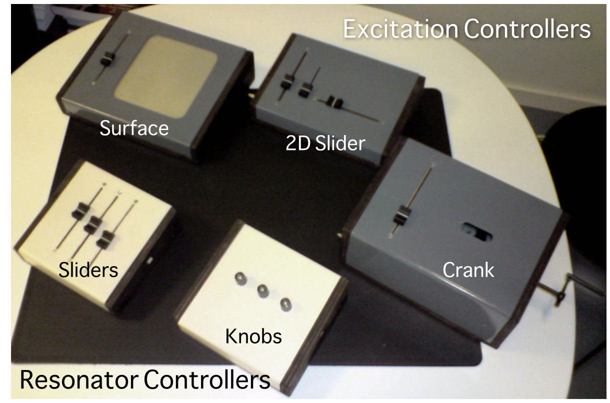

Figure 2. Two resonator controllers (white) implement three knobs and three sliders, respectively. Three excitation controllers (grey) implement a 2D touch pad, two sliders placed orthogonally and a crank, respectively.

4. The Splorer Modular System

Splorer is a custom built set of musical interfaces, which were designed and implemented with the goal of measuring the aforementioned differences. Splorer consists of two modular parts: a *resonator controller* and an *excitation controller* - see Figure 2. The two parts can be connected to form one overall interface - see figure 3. By creating two *resonator controllers* and three *excitation controllers* it is possible to combine your way to 6 unique interfaces to test on. These interfaces are used to control two different physical models (giving a total of 12 unique musical instruments to test on).

By testing the interfaces in these 12 different combinations it should be possible to first of all minimize uncertainties connected to external variables when comparing the knobs and sliders. Secondly it should be possible to identify which other variables influence the overall impression and performance of the instruments.

In order to conduct the tests as close to the natural environment of an electronic musician as possible the interfaces were designed to give the impression of real "commercial" hardware synthesizers. The design was kept as consistent as possible for the different controllers in order to minimize uncontrollable variables connected to visual impressions.

4.0.1. Knobs and Sliders

Two different *resonator controllers* were implemented. One implemented three knobs, and one implemented three sliders - see figure 2. The sensors were interfaced with Max/MSP [1] using Arduino Diecimila [2] data acquisition boards.

4.0.2. Surface, Crank and 2D Slider

Each of the three *excitation controllers* implemented three input devices. Common for all three was that one of these

[1] http://cycling74.com
[2] http://arduino.cc/en/Main/ArduinoBoardDiecimila

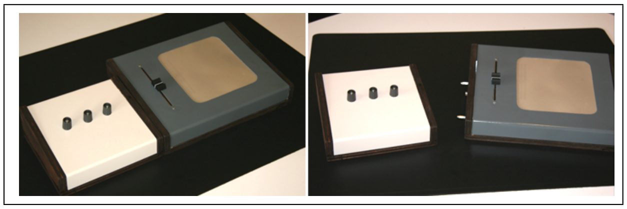

Figure 3. The excitation controller (grey) can be attached to the resonator controller (white). This gives the user the impression of playing one single instrument, while transmitting the sensor data from the excitation controller to the Arduino placed only in the resonator controller.

input devices was a slider. Additionally the *Surface* implemented a 2-dimensional touch pad. The *Crank* implemented a crank, which could be adjusted in and out for an extra parameter. The *2D Slider* implemented two sliders placed orthogonally to each other - though being semantically equal to the trackpad, the controls of the 2D slider are separable, where the trackpad's are integral [9]. See figure 2.

The *excitation controller* and the *resonator controller* are connected to each other in order to strengthen the user's impression of playing one single instrument- see figure 3.

4.0.3. Flute and Friction

Two different sound synthesis models were implemented. The flute model implements two digital waveguides and a simple non-linear exciter [16]. The friction model implements three digital waveguides and a non-linear exciter [1]. Both are borrowed from a previous project and only slightly modified to suit this study [2]. The controller mapping for each model was kept as equal as possible for the resonator part. The excitation mapping was made so that the user had to keep moving in order to sustain sound [3]. According to [8] this can enhance the feeling of playing "an actual instrument".

4.1. Test Subjects

In order to be able to apply the results of this study to the specific target group (electronic musicians) it was very important that the test subjects were chosen carefully.

Two experts were interviewed with regards to suggesting relevant candidates. One is the owner of a respected Danish electronic record label and the other is an editor of the leading electronic music program on the Danish National Radio. Three main criteria were given to the experts: 1)The candidates need to compose their own music. 2)They need to have released at least one record. 3)They need to fit into the overall category of electronic music. The first two criteria made sure that the test subjects were experienced and established artists. The third ensured that they fit into the target group of electronic musicians.

[3] go to http://media.aau.dk/∼stg/splorer to see mapping details

With this information around 40 musicians were found, around 30 were contacted. Hereof 20 musicians were tested in the end.

5. Method

The actual test contained two major parts. The first part was a questionnaire which was used to establish the musical background of the test subjects. This should ensure that they were indeed part of the target group. This was followed by an interview regarding the typical work processes of the electronic musician/composer. The interview will not be elaborated in this paper.

The second part was the actual usability test. Each test subject had to carry out three identical tests - testing three different unique instruments. With 20 test subjects that gave a total of 60 tests. Having to test 12 unique instruments we were able to achieve 5 repetitions for each.

Each test took approximately 20 minutes and consisted of 3 parts:

5.1. A free play and explore session

Firstly the user had approximately 7 minutes to play around with the instrument as he or she wished in order to get an impression of the overall instrument. This was used to simulate the natural way in which a musician would try out a new instrument for the first time.

5.2. Musical tasks

The test subjects were first asked to listen to four samples (we call them *reference sounds*) all created using a software version of the sound synthesis model. Each sample (approx. 10 seconds) represented different timbral changes [4]. The test subjects then had 3 minutes to imitate each *reference sound* using the instrument at hand. This resulted in 4 sound samples from each test subject for each unique instrument - or 4×5=20 samples for each unique instrument.

The samples were rated by how well they resembled the *reference sounds* on a Likert scale from 1-5 (1 being not at all, and 5 being an exact resemblance). The author and an impartial sound engineer rated all sounds not knowing which sound went with which interface/test subject. The average between these two ratings was used to calculate the final sound rating of each sample. In order to find the specific sample rating for each unique instrument, first an average of each of the 5 test subject's sounds was found, giving four sound ratings (one for each of the four reference sounds). An average between these four was then calculated giving one specific score for each of the 12 unique instruments.

5.3. Questionnaire

Test subjects finally filled in a quantitative questionnaire about the perceived difficulty of the task (has not been used for this paper) and the impression of the overall instrument.

[4] go to http://media.aau.dk/∼stg/splorer to listen to the reference sounds

They were asked to rate the overall instruments on a Likert scale from 1-5 (strongly disagree, disagree, neither or, agree, strongly agree) on *accurate control, intuitive control, inspiring, frustrating, nice feel, predictable, whether it gave them musical ideas, felt like an acoustic instrument, used for composition, used for live performance, time to master* and finally *overall likeability*. The different rating criteria were chosen in order to asses features important to traditional HCI evaluation along with features associated with the proposed framework of creativity and exploration. The subjects had the option of writing comments for explaining their answers - these have been used to reflect on the results.

Finally a log of observations during the test was compiled (containing also comments from the test subjects during the test). These observations have mostly been used to gather early/spontaneous impressions of the instruments / interfaces / synthesis models. The observations were used together with the comments for reflecting upon results.

The test was performed 3 times by each test subject, each time with a different unique instrument (combination of *resonator control / excitation control / sound synthesis model*). The combinations were picked randomly making sure that each test subject tried each of the two resonator controllers, each of the three excitation controllers and each of the two sound synthesis models. The order of the combinations was also randomized making sure that for example friction / sliders / crank was not the first to be tested every time.

5.4. Setup

The sound synthesis models were implemented as externals in Max/MSP 5 running on a 2.4 GHz Intel MacBook Pro with 4 GB 667 MHz SDRAM (Mac OS 10.5.6). This was connected to a PreSonus Firebox firewire sound card. Speakers varied, as each test was performed in each of the test subject's own studios - again in order to mimic the real world scenario, as can be seen in Figure 1.

The *reference sounds* used for the imitation task were played from a separate computer. This way the test subjects were able to playback the samples at will, while the test conductor is free to monitor the test using the sound synthesis computer. The *reference sounds* were played back in Quicktime on a 1.5 GHz G4 PowerBook 12" with 1.25 GB SDRAM (Mac OS 10.4.11) with a built in sound card using Beyerdynamic DT 770 headphones.

6. Results

6.1. Test Subjects

20 musicians were tested - 2 female / 18 male. Ages ranged from 20 to 45 with an average of 29.6. 70% were attending or had attended a conservatory for electronic music. The average amount of records sold for the test subjects was 5513 ranging from 0 to around 50000. Five subjects reported that they had sold 0 albums - however, they were all found experienced enough to be regarded for the task based part of the test - interviews and comments were discarded. They reported using an average of 21 hours a week playing/making music. 55% knew what physical modeling was, implying that they would be quite unbiased when evaluating the instruments.

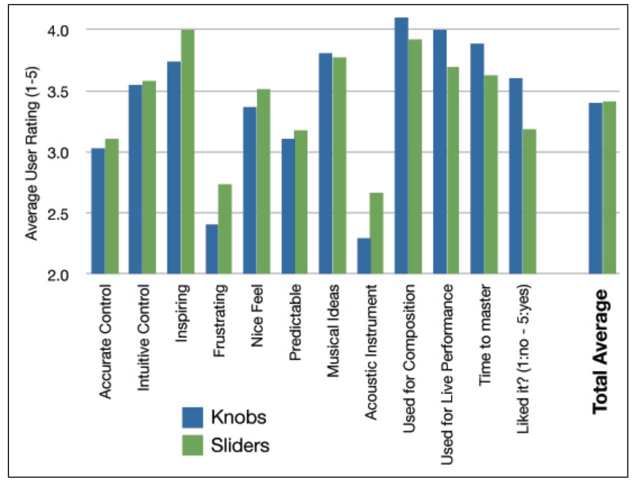

Figure 4. There were no significant differences between user ratings of knobs and sliders.

6.2. Knobs or Sliders?

Surprisingly the questionnaire revealed no significant difference in ratings between knobs and sliders, as can be seen in Figure 4. Slight differences between the two exist- but the quantitative data did not reveal them as significant (p¿ 0.05 in all the comparisons). *Sample ratings* suggest that the sliders were slightly easier to control. However, the difference was not substantial enough to make it conclusive.

There were reported differences in the comments of the test subjects. However they were quite ambiguous. Some said that the sliders provided more control, while others said that the knobs were easier to adjust accurately. Factors that might have distorted the results are most likely found in the quality of the actual sensors. Although an effort was made to make the quality of the two devices equal, there seemed to be different preferences among the test-subjects as to what constitutes high quality - especially when it came to sliders. The amount of passive haptic feedback provided by the resistance of the mechanical parts of the slider seemed crucial when evaluating its quality.

6.3. 2D Slider, Crank or Surface?

The crank received the most positive commentary feedback of the three excitation controllers. Comparing *sample ratings* for the different excitation controllers also indicates that the Crank provided the best control of the sound synthesis models. The crank was rated highest when it came to *intuitive control, inspiring, feel, musical ideas*, and *likeability*. It was also rated least *frustrating* as can be seen in Figure 5.

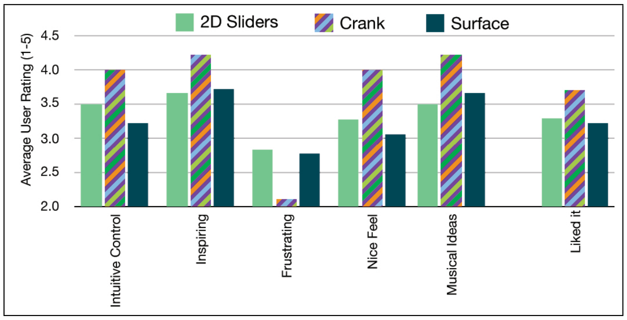

Figure 5. The Crank excitation controller was rated highest in intuitive control, inspiring, feel, musical ideas and likeability compared to 2D Slider and Surface controllers. It was also rated least frustrating.

The 2D slider and the Surface were rated surprisingly equal. The only considerable difference was found in *accurate control*, where 2D slider scored the highest.

The crank definitely had an upper hand in the sense that it is an unused controller for electronic music. Subjects seemed to have an initial impression that the crank was funny resulting in rather low expectations. This was followed by a feeling of "pleasantly surprised" after having tried it. Many expressed: "I would never have thought a crank would work that well for this kind of music". The lower ratings of the 2D slider were most likely due to a combination of the test subjects feeling too restricted in their movements and the controller lacking novelty. As for the Surface, the sensory part of the interface did not live up to the standards the musicians have come to expect from a touch sensitive pad. They had to press too hard to produce sustainable output.

There were very different opinions about the fact that the users had to keep the excitation controller in constant movement in order to produce sound. Some said it felt intuitive and like a real instrument while other reported that too much focus had to be on "keeping the sound going" to really focus on playing/controlling/adjusting the sound - this might have to do with the normal practice of most electronic musicians, where they utilize some sort of automation to keep the sound going, while being free to alter/explore the more timbral parameters of their system. An extended practice time could of course help avoid this.

6.4. The Sound Synthesis Models

The most considerable differences was found between the two sound synthesis models. The friction model was the clear favorite when analyzing the *comments*. Additionally the friction model was rated highest in *inspiring, feel, musical ideas, used for composition*, and *likeability*. However it was rated lowest in *intuitive, predictable* and *accuracy*. See figure 6.

Sample ratings showed that the flute sounds were better imitated than the friction sounds. There seems to be inverted proportionality between how creatively inspiring the sound

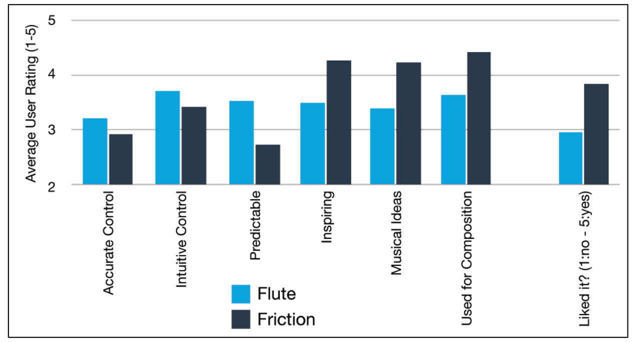

Figure 6. The friction mode was rated highest in inspiring, feel, musical ideas, used for composition and likeability

synthesis model is and how accurate, intuitive and probably most of all predictable it is. This is somewhat equal to results found in [13]. Of course, if one was to design an accurate, intuitive and predictable musical instrument directed towards electronic musicians, he or she would not necessarily fail in making it creatively inspiring. But maybe unpredictability could be a criteria that enhances creative exploration. Further research is needed to be able to confirm such a relationship.

7. Discussion

Although subjects reported having preferences for one or the other surprisingly, no significant difference was found between knobs and sliders. Further research is needed but comments seem to reveal that differences are tightly bound to tradition, habits and routines. Had the knobs and sliders been tested on well known interfaces, which are strongly bound to tradition in regards to choice of input devices (like mixers or envelope controllers), the results would most likely differ.

Interesting differences arose between other influencing variables. They revealed that in order to design novel musical instruments, which afford creativity and exploration, one can't necessarily make the controls as accurate or as predictable as possible - also indicated in [3]. It definitely shows that testing for traditional HCI features alone will not be enough to evaluate the success of interfaces in this highly complex world of (electronic) music.

It was interesting (though maybe not surprising) how important the sound synthesis model is compared to the interface. The somewhat inverse proportionality between intuitiveness, predictability, accuracy and the affordance of creativity and exploration was an interesting observation. The constraints of the interface should not be clear to the point that it becomes predictable. Predictability is a feature that according to this research must be avoided - which makes the quest for "intuitive interfaces" tricky. One must be careful not to mistake predictability for intuitiveness.

The most concerning issues with the methodology were issues of time. The mere fact that the musicians did not have more time to explore the instruments may have distorted the results. It is difficult to avoid the effect of novelty in such a short amount of time. A 20-30 minutes test seems sufficient when testing for traditional usability factors. But in order to asses factors like creative and exploratory affordances tests must be conducted over longer periods. These ”softer” factors closely related to the *third wave* [11] and ”HQI/HQS” [5] are more difficult to asses. Future research will investigate a more qualitative approach where fewer musicians ”borrow” Splorer instruments for longer periods of time in order to get closer to a real world scenario. This could be carried out like in [7] where three subjects were tested over ten different sessions.

Should the same task-based method be used again, the reference sounds should be more intriguing for test subjects. Some participants said that the tasks were somewhat boring compared to the capabilities of the instruments. This definitely has an influence on trying to create a real world scenario. Having musicians from the target group create the reference sounds could lead to better results.

A larger sample will also minimize uncertainties caused by other uncontrolled variables. However this is one of the major problems of gathering solid quantitative data in this field. Reliable test subjects are relatively few and therefor difficult to recruit. Another solution would be to limit the variables - however, extremely simple test scenarios are perhaps too far from the real environment of the electronic musicians to produce valid results.

8. Conclusion

A low level interface evaluation has been presented. The use of knobs compared to sliders for novel musical instruments directed specifically for electronic musicians was evaluated. No significant differences were found between the two. However, different preferences were reported suggesting differences to do with tradition, habits and routine.

The methods used here can serve as inspiration when investigating creative and exploratory affordances - especially when dealing with the relatively complex electronic musicians, the majority of which also compose music. By focussing on the users it is possible to come close to real world scenarios in controlled environments. Evaluating few elements (knobs and sliders) under varying circumstances also produces more valid results. Circumstances can of course vary a lot more than in this test, so further research is needed to establish a more complete picture.

9. Acknowledgments

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