Ergonomic Music: Where Does it Fit In?

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ABSTRACT

In this paper we present the idea of *ergonomic instruments*: musical devices that focus on minimising the learning curve of musicians by mapping inherent musical actions to the creation of music. We situate *ergonomic instruments* in the context of existing relevant work, and then discuss a new methodology towards the development of musical instruments including exploration of a musical goal which we call *direct expression*. Next, we offer a prototype of an *ergonomic instrument* called the Ergonomic Electronic Percussive Padboard (EEP Padboard) and include an exploratory evaluation with ideas for further development.

Keywords

ergonomic instruments, interface design, musical interaction, direct expression, learning new instruments, design concepts and principles

Figure 1: A user experiencing *direct expression* using the EEP Padboard, an *ergonomic instrument.*

1. INTRODUCTION

Life is permeated with rhythm – with music. One of the first organs to grow in the fetus is the one most associated with rhythm, the heart. Even at the cellular level, there are biochemical and electrical oscillations. Sometimes, that ebb and flow of chemicals, the pulsing interaction of our various biological systems, sometimes it leaks out: and there we have nodding, tapping, dancing, humming, and ultimately, *music* [17]. But music is usually much more complex than this and involves instruments with thick artificial interface layers that would-be musicians must transcend. This paper presents and explores *ergonomic instruments*, those which leverage the innate human musical flows and tendencies, minimising these artificial layers that separate the musician from the music.

Talented musicians sometimes reach a point where the music flows with a natural feel and with little thought being put into the physical act of generating music. At this point these musicians, through a combination of rigorous training and talent, have lowered the cognitive load necessary to perform and have approached what we call *direct expression*: their instruments have become intuitive extensions of their bodies with the physical interface challenges of the instrument being essentially erased. This means that the musician has a) overcome the physical challenges of interacting with the instrument and b) deeply and intuitively understands which noises will be produced from their actions.

Ergonomic instruments utilise our natural musical tendencies such as tapping, dancing, humming, and so forth, and intuitively map them to the creation of music. Their aim is to minimise the distance between the musician and the ability to create music. By design, the goal of *ergonomic instruments* is to enable musicians of any age, experience, or skill level to approach *direct expression* easily and comfortably. This approach is different from devices which automatically generate music through gesture or body motion analysis (such as [7, 14]) since automatically generated music is more incidental and less direct.

The *ergonomic instrument* attempts to become an extension, amplification, and intuitive abstraction of the human musical inclinations rather than a device which arbitrarily translates non-musical actions into music or forces a user to fit the characteristics and constraints of the instrument. In this paper we discuss how *ergonomic instruments* fit into existing understandings of instrument creation and use, present a methodology for understanding and developing *ergonomic instruments*, and present a proof of concept called the EEP Padboard.

2. RELATED WORK

While no work we are aware of has presented *ergonomic instruments* in the same fashion as we do, there is work which has similarities in both the approach and the implementation. There are many instruments which have exhibited special ergonomic properties (such as [2, 5, 7, 14, 18], among others), as well as ideas about musical design which touch on some of the issues that we do. In this section we present the current state-of-the-art research related to ours and discuss how *ergonomic instruments* present a novel approach to understanding and designing musical instruments.

2.1 Intuitive and Easy

Norman, in his many books and articles [12, 13], discusses the reasons behind why and how things are intuitive and easy to use. In particular, Norman's description of affordances [12] implies that objects can have physical properties and cues such as shape and form which make their use obvious and easy to understand. Norman suggests that much of this happens on the instinctual, visceral level, where human tendencies are "wired in, consistent across people and cultures", and that designers can take advantage of this understanding to make their products successful. In addition, by incorporating emotion and aesthetics, devices can be more appealing and actually more useful and easy to use [13].

2.2 Mappings and Taxonomies

The idea of mapping musical actions to music is not new, and there is a plethora of devices which take this approach, including mapping boxing, dancing [9] and headbanging [1] to music. These excellent devices allow people to modify or create music while doing actions they enjoy. These projects typically include a natural musical reaction component, such as dancing and headbanging, alongside a constructed component, such as boxing and guitar moves. Some of these projects include a largely arbitrary mapping of motions to music [7, 14] where the artists are creating interesting correlations between their actions and musical output. Focusing more on the physical musical properties of objects, Crevoisier [5] has presented a project where the existing musical and tangible properties of instruments are leveraged to create new instruments. One instrument of particular interest is the Buchla Thunder [3], a midi controller which has the triggers fitting the shape of the human hand. This instrument has multiple pads per finger, and allows the user to tap the device to create the music.

Virtual musical instruments, as presented by Mulder [11] are instruments which attempt to increasingly decouple the human gesture and motions from the physics of sound generation. Mulder claims that instruments modeled on acoustic properties are often limited and not expressive enough in comparison with the capabilities of advanced computer systems. This idea is furthered by Machover's hyperinstruments [10] which use technology to gain the "most amount of subtle control" of musical performance, focusing on applying the abilities of modern technology to expand musical expression beyond human abilities, automatically following the intentions of performers. Hyperinstruments strive to have a low initial learning curve, but the instruments scale such that as the users' skill advances the expression possibilities continually increase. Hyperinstruments aim to enable the modern musician to be a combonation performer, improviser, composer and conductor while seamlessly changing roles. One hyperinstrument, the "Bug-Mudra" [10], is a glove with sensors on each finger to track finger movement and whole-hand gestures for performance, allowing the musician to shape the overall sound of an orchestra including loudness, spatial placement, and effects.

In a different direction, Bowers and Archer draw a picture of how there is recent interest in moving away from advanced technologies where designers are simplifying both the instrument and the tools used to create the instrument [2, 4, 8]. This relates to the sometimes named *reductionist* movement in improvisation [2], and represents a general trend in some groups toward simplicity in music. Bowers and Archer present infra-instruments which constrain the interactive possibilities of the musician such that there are only a few things an artist can do to make noise, and also restrict the power and fidelity of the instrument.

2.3 Ergonomic Instruments

While we present the idea of viewing and building instruments and designs in terms of their ergonomic properties, ergonomic instruments have existed for quite some time. The simplest example that comes to mind is the human voice. While it may take years of training and practice to master this instrument, even an infant can use their voice to output music and make appealing musical noises. The physical barrier to using the voice is low, and the output is near expectations. Another good example is the traditional hand drum. This device responds pleasingly to being struck, and even a beginner can hit out a beat and accompany other music.

2.4 Where We Fit In

The related work section above speaks to the level of activity surrounding the creation of musical instruments, some of which resemble our *ergonomic instruments* work.

From Norman's perspective of design [12, 13] *ergonomic instruments* have a high chance of being both useful and successful as they have very good affordances. They use devices which allow a user to utilise their *visceral* musical tendencies naturally and they output expected sounds, minimising the effort needed to understand the use and mapping of the instrument. In enabling users to create music, *ergonomic instruments* are also very appealing on the emotional level and fall under Norman's emotional design ideas where aesthetics and appeal help devices to be more useful [13].

We design *ergonomic instruments* to be easy and intuitive to use. Some discuss the trade-offs between "easy-to-master" instruments and the pleasure associated with playing or hearing them. They suggest that part of both the musical creation and appreciation experiences is in the challenge [15, 19]. First, we suppose that this argument is forwarded with only vituosic artists in mind. Second, ergonomic instruments do not strive to remove the challenge from creating music, but only the challenge represented by the physical distance from the player to the instrument. The path through the woods is still long and difficult, but we want to give artists a better machete. Indeed, we argue that there is already a plethora of instruments which have the potential for immense development and complexity, yet have a simple interface. Take, for example, the long-endured success of the Japanese taiko drum – the simplicity of its design in no way inhibits the enjoyment of master players.

Many people have explored ways to map actions to musical noise. We do not contradict, but rather build on this interesting work, limiting the scope to actions which result from a person's inherent musical reactions, avoiding arbitrary or abstract mappings. In particular, Crevoisier's tangible acoustic instruments [5] in themselves are highly ergonomic and can be used in context of our ideas. Lugo and Jack's headbanging work can be simplified (removing the guitar) to make an *ergonomic instrument*, and the Buchla Thunder mimics a natural ergonomic hand-on-table model.

While this paper provides a unique view on how to approach instrument development, our ideas can also be used as a mechanism to evaluate existing or in-progress instruments, or as a methodology to allow designers of existing instruments to improve aspects of their designs. Many instruments which exhibit ergonomic properties can be better understood and evaluated using our ideas. Also, contrary approaches such as the construction of hyper instruments [10, 11] can be coupled with our approach to incorporate ergonomic controllers or ergonomic dimensions in the more complex instrument. Hyperinstruments, like ours, attempt to be easy to use for beginners and lower the cognitive load of the musician.

Ergonomic instruments relate to the reductionist and simplification ideas discussed by Bowers and Archer [2]. While the explicit aim of *ergonomic instruments* is not to create simpler instruments but to create easier-to-use instruments, these ideas have an overlap. *Ergonomic instruments* have fewer toggles, controls, and avoid anything which cannot be easily mapped to musical reactions, and are following the general reductionist trend outlined by Bowers and Archer.

3. ERGONOMIC INSTRUMENTS AND DIRECT EXPRESSION

Although *ergonomic instruments* represent an approach to musical instrument design, it is not the case that either an instrument is an *ergonomic instrument* or not. Rather, instruments and musical devices have properties and characteristics which make them more or less *ergonomic*. For example, the human hand itself in combination with a striking surface could be seen as a highly ergonomic instrument while an electric guitar is generally not but has ergonomic properties where a user can intuitively tap the pickups, strings, or body of the guitar to create percussive noises.

Given the subjective and complex nature of defining music and musical instruments it is difficult to precisely define *ergonomic instruments*. Rather than attempting to do this, we offer a set of guidelines and heuristics for both designing and classifying *ergonomic instruments*. This results in a fuzzy class of *ergonomic instruments*, where instruments can have partial membership:

- **Physical invisibility** – *Ergonomic instruments* are designed to minimise the physical challenges involved when interacting with an instrument.

- **Inherently musical** – *Ergonomic instruments* have their mapping inspired by musicians' natural musical inclinations such that the instrument makes sense in terms of the music it creates for the input it is given.

With these two points in mind, we also point out that *ergonomic instruments* do not require any particular device or hardware. There are likely no constraints as to what can be used to build an ergonomic instrument with enough imagination and creativity. For example, the human's voice or simply a table could be construed as *ergonomic instruments*. Also, instruments can have ergonomic characteristics rather than simply being ergonomic or not.

The *physical invisibility* heuristic refers to the ease with which a musician can interact with an instrument, and is about enabling musicians to intuitively and easily generate music. The more *physically invisible* an instrument is the less effort a user exerts into controlling the instrument and mapping their physical actions, allowing them to focus on the music and approach *direct expression*. For example, a piano, a penny-whistle, a table top or a drum are all much easier to produce sound from (have more *physical invisibility*) than, say, a flute or a cello. We argue that the closer the physical mapping gets to a musician's natural musical tendencies, the more *physical invisibility* it will have.

The *inherently musical* heuristic refers to the notion that the artist can trust that the input they give to the instrument will produce the output they expect, meaning that the musical output from the musician's natural input should be intuitive. For example, while a facial expression [7] is a natural action, it is arguably not a reaction to music, rhythm or melody, and it is difficult for an artist to expect any musical output from such an action. On the extreme end of the scale consider a midi synthesiser where a user has no understanding of the noise that will result until they play with the instrument. These examples break the *inherently musical* criteria as the user has to think heavily about which sounds will result from their physical actions. An *inherently musical* instrument, such as a drum or a table, produces a noise obvious to the musician where the artist does not need to learn the mapping.

These requirements, however, do not limit *ergonomic instruments* to existing percussion-based music creation methods such as tapping or stomping. For example, head-banging is arguably a natural reaction to music, yet as an action creates very little (if any) noise. However, when this action is intelligently mapped to an *inherently musical* reaction we have an *ergonomic instrument*

3.1 Direct Expression

Let us briefly relate these heuristics back to the idea of *direct expression*. To achieve *direct expression* a musician needs to overcome physical interaction barriers (thus *physical invisibility* in instruments), mental action-to-sound barriers (thus *inherently musical* mappings), and must have a *familiarity* with the kind of music they wish to create. Therefore, given an *ergonomic instrument*, beginner musicians should ideally only require *familiarity* to achieve *direct expression*

For more advanced music, if the piece has been mastered then the performance itself requires minimal cognitive effort and the performer has achieved *familiarity.* For improvisation, the artist must be familiar with the stylistic or technical parameters he or she is working in to achieve *familiarity.* Once reached, the freedom of *familiarity* allows the musician to add nuances to both their music and their actions, coming out both in the sound and the visual performance. Tribal drumming and dancing are good examples of *familiarity*, where a repetitive beat is quickly learned and a performer can enter a trance-like state, enjoying the music they create and allowing their consciousness to wander away from the physical act of creating the music.

3.2 Levels of Expectation

To develop the idea of the *ergonomic instrument* and how it applies to *direct expression*, it is important to note the subtle interplay between various levels of *expectations* in regards to musical instruments. Our *expectations* about the intrinsic results of our physical actions directly affect our relationship to instruments and therefore to music. This is analogous to speaking in some respects. When a person is speaking, say, answering a question on the fly, they simply talk without thinking about the action of talking. Usually we do not respond to the question "Hey, are you hungry?" by thinking, "Ok, how am I going to answer this guy? What words should I use? How can I sound good?". Rather, we just say, "Ya, let's grab a bite", because we *expect* the words to come out, our voice to be heard and understood. It is inherent and natural. Likewise when we play an instrument, on some level we *expect* to produce notes with fidelity. It is often that *expectation* that is challenged when we pick up a new instrument. One may not be able to make a sound out of a flute, try as they might, and toss it aside in frustration. On the other hand, one can take a spoon, three glasses with different levels of water, and easily play "Mary Had a Little Lamb." This frustrated *expectation* causes a distance between the user and the music – thus the interface has failed. It is this problem we are addressing with *ergonomic instruments.* It's important to note that we are not suggesting the user *expects* to instantly produce a symphonic piece, either. Similarly, one does not necessarily expect to make a witty quip, turn of phrase, or for that matter, make a speech every time they open their mouths.

4. EEP PADBOARD

The *Electronic Ergonomic Percussive Padboard* (EEP Padboard) is an attempt to provide a mapping between a person's natural rhythm and the activity of creating beats and rhythms. The goal of the design is to leverage the natural human tendency to tap along with music and to allow users to seamlessly transform this into the creation of music. To do this, we devised an instrument that conforms to one's natural tendency to tap along with music. It essentially mimics a table-top, but is a little more versatile. The EEP Padboard is different than existing tapping interfaces such as the Buchla Thunder [3] as it not only responds intuitively to the act of tapping but minimises the learning barrier by avoiding *shift* keys and complex multi-finger combinations, only having one action per finger. In addition, the EEP Padboard maps directly to percussive sounds and the user does not modify these during a performance.

(a) The EEP Padboard controller unit.

(b) The controller unit connects to the breakout box which connects to a drum module.

Figure 2: The EEP Padboard system.

4.1 Implementation

We decided to implement the EEP Padboard from scratch rather than using existing devices such as the Buchla Thunder [3] as it provides a very complex interface to the user. We also could not use tabletop computers such as the DiamondTouch [6] or the SMART Board [16] because they do not respond differently to light or hard touches and do not allow for easy differentiation of fingers.

The entire device was constructed over the period of a week and consists of a padboard connected to a breakout box and a drum module. The padboard connects to the breakout box via a 25pin D cable, and the breakout box provides ten standard $\frac{1}{4}$" ports which can be connected to any drum or midi module.

The main body of the padboard, as shown in Figure 2, is constructed from a fishing tackle box. It was chosen because of its light weight and durability: a user can hold the device in their lap, hit on it quite hard without risk of damaging the unit, and it is very portable. The top layer of the device consists of two layers of plastic held together with small nuts and bolts, with the tapping pads sandwiched in the middle. One corner of the top layer has foam placed in to reduce vibrations within the unit and crosstalk across tap sensors.

The pads are constructed to give a user a soft-yet-firm feel when they tap the pad, and use piezo wafers to detect impact and force. Each pad is hand-constructed and has four layers in the following order from bottom to top: foam, piezo wafer, foam, rubber pad. The foam was rescued from an abandoned couch, the rubber pad was cut from a car tire tube, and the piezo wafers were removed from varying electric buzzer assemblies. All layers of the pads are sandwiched between the two layers of plastic in the cover of the EEP Padboard, with the top layer of plastic having finger holes. The elasticity of the pads' foam and rubber allows the pad to swell out of the hole and assume the shape, giving each pad a pleasing elevated and bevelled feel.

The piezo pads are individually wired to a 25-pin D port on the side of the unit which, via a cable, connects the padboard to the breakout box. The breakout box does a simple wiring of each piezo to an output port, where the ground (negative terminal) is shared among piezos. In our current configuration, we use a Alesis D4 drum module.

This setup allows each of the individual fingers to be tied to a different instrument, such that when a user taps the pad a sound is triggered. Furthermore, depending on the sample, a harder tap will result in a relevantly different sound to reflect the strength of the strike. In our setup, we had the thumbs set to bass drums, the first and ring fingers set to toms, the middle fingers set to snares and the little fingers set to a cymbal. While we used varying piezos in our pads, the drum module we used allowed us to tune the gain and level of each input individually so we managed to balance the sensitivity across pads.

5. EVALUATION

As the EEP padboard is our first implementation of an *ergonomic instrument* we performed an exploratory initial experimentation with just a few users. With the results we obtained, we plan to create improved *ergonomic instruments* including a second generation version of the EEP Padboard, and to design and execute a more in-depth study involving more participants.

Our exploratory study involved having users attempt to use the EEP Padboard system to provide percussive accompaniment with a selection of popular rock music. The only instruction the users were given was that the machine generates percussive noises when the black pads are tapped. There were four users, two who had musical experience and two who did not.

Interestingly, all four users had a similar experience. The first two to three minutes were spent playing with the machine, and the playing slowly turned into the generation of music. All four users were able to follow and play along with the music by the third song. In addition, at one point one user started chatting while tapping, making comments about the system. The users also made comments about the easy usage of the machine compared to real drums. One user commented that it "really felt right" when he could tap harder to get a heavier and harder sound from the machine. This evidence suggests that with a small learning curve the EEP Padboard can be easily used to create rhythms with the complexity of modern rock music that are satisfying for the musicians to generate.

The users also had many negative comments about the system. Every user complained about the mapping we provided from a particular finger to a particular drum sound and gave suggestions for an 'improved mapping'. There were also concerns about having to tap on a plastic box, and that the users had to keep their hands in a particular shape. One user in particular, who had a previous regular habit of tapping, complained that he could not tap his fingers in the shape he was accustomed to.

Considering these results in relation to our heuristics presented in Section 3, we find that the instrument is fairly *physically invisible* and *inherently musical* but could be improved. It is *physically invisible* as users can quickly learn the instrument and can use their existing skills of simply tapping a surface to create sound without worrying too much about the mechanics of the device. Also, it is *inherently musical* as mapping the action of tapping a surface to a sound is copying a natural musical phenomenon, including the fact that increased force results in harder sounds. In this way, the EEP padboard does not significantly challenge the user's expectations in any way. These properties lend well to allowing a musician to reach *direct expression*, and indeed, first author Dustin enjoyed several sessions where he "got lost in the music"(as shown in Figure 1).

However, the model falls short in a few areas. Firstly, any mapping of finger tapping to existing drum samples such as a tom, bass drum, and so forth, is arbitrary in terms of an *ergonomic instrument*. So, since the sound event produced by the EEP is unnatural compared to those produced from, say, a tabletop, a learning curve results where the users learn the mapping between fingers and sounds. Also, the forced layout of the hand and the spatial restrictions of the board itself impose more limitations than would be expected from creating music through tapping.

Despite these problems, the EEP Padboard is a highly ergonomic instrument which can be used by beginner musicians to create interesting music and to have a fun experience, while not greatly limiting creativity. We expect that similar results will be found across any *ergonomic instrument* and will be improved upon as designers find interesting and creative ways to make their instruments ergonomic.

6. FUTURE WORK

We plan to continue to explore *ergonomic instruments*, using implementation and evaluation cycles to further develop our methodology while building better *ergonomic instruments*. In particular, we will start by creating a second generation EEP Padboard to try and address some of the issues raised in our exploratory evaluation, and we plan to explore the relationship between *ergonomic instruments*, rhythm, and melody.

Currently, we plan to improve on the EEP Padboard concept by converting it to a textile format. A glove, complete with an array of haptic sensors, enables the user to tap on any surface, thus eliminating the problem of spacial constraints and hand shape while bringing the instrument closer to the intuitive idea of tapping. With a glove, musicians have freedom to move around and to tap on any surface, including themselves or an audience, adding an additional performance edge to the instrument. Similarly, we plan to improve the mapping to the output sounds, possibly restricting them to fewer tap-related sounds only, in an attempt to allow the user to think very little about which finger can be used for which instrument.

From a wider viewpoint, we hope to explore the idea of collaborative *ergonomic instruments* where multiple people interact on a single instrument. We are curious as to how to try for meaningful and involved collaborative music while keeping the cognitive load low and the instrument easy and intuitive to use. Similarly, we are interested in how *ergonomic instruments* influence and effect the performance aspect of music creation, through both the versatility of the instrument and the physical actions of the musician resulting from *ergonomic instrument* design.

7. CONCLUSION

In this paper we explored the idea of *ergonomic instruments*, a new approach to designing and evaluating instruments and musical interfaces. Through following design principles to make instruments *inherently musical* and *physically invisible*, we lower the barriers required for musicians to reach *direct expression*. As an example we presented the Ergonomic Electronic Percussive Padboard (EEP Padboard), an *ergonomic instrument* implementation, and gave the reactions and thoughts by a set of sample users. These initial results were promising, suggesting that there is merit in our approach and that we should continue to develop *ergonomic instruments*.

By taking advantage of innate human musical tendencies, *ergonomic instruments* aim to allow musicians to intuitively create music while keeping the learning curve low. They bring the musician closer to the music they are creating, allowing for users of any age or skill level to be creative and to enjoy the pleasures of creating fun and interesting music.

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