LADISLAV SUTNAR
FACULTY OF DESIGN AND ART
UNIVERSITY
OF WEST BOHEMIA

BACHELOR THESIS

Media and Experiments
Body Sounds

Barbora Burianová

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Supervisor: doc. akad. mal. Vladimír Merta

Declaration

This is a translation of my defended thesis from Czech into English. To the best of my knowledge, the translation accurately reflects the contents and meaning of the Czech original, which can be found at the university's digital library[1].

[1] http://hdl.handle.net/11025/42002

Title: Media and Experiments – Body Sounds

Author: Barbora Burianová

Program: Fine Arts, **field:** Multimedia Design, **specialization:** New Media

Department: Department of Fine Arts

Supervisor: doc. akad. mal. Vladimír Merta

Abstract:

In my bachelor thesis, I decided to study the theme of "Body Sounds" as a part of the topic "Media and Experiments". The work consists of two parts: the art piece itself and the theoretical analysis which serves to describe the art piece. The purpose of "Body Sounds" is to find a connection between a sound and a human body through experimental musical instruments. It is a continuation of my long-term fascination with sounds and their physical nature.

I designed and constructed three instruments that are physically connected to the human body. The instruments are (i) the Bodychord, (ii) the Idiophones, and (iii) the Tension. The Bodychord consists of four four-stringed chambers attached to human arms and legs. A spinning motor located at a chest resounds the strings as they cross the motor's path – the sound hence echos as a performer moves. The Idiophones are four metal hemispheres laid on the ground, which create bell sounds when hit by two small spheres. Each sphere is attached to a performer's finger by a short chainlet. When fidgeting–an unconscious act of a hand or feet when nervous or concentrated–the spheres copy the movement and create the bell sounds as they bounce back and forth between the idiophones. I enjoyed exploring the idea of focusing on something which remains mostly unconscious. The Tension is a minimalistic one-stringed instrument that reacts to Pythagoras' monochord. The instrument changes its sound frequencies by stretching the string between the hands and the whole body.

Instead of accenting a musical knowledge, the "Body Sounds" instruments require a performer to focus on their physical movement. This shift from the technical precision back to the instruments' physical nature is a crucial aspect of my work. It may elicit enlightening moments in the audience and further emphasize that rather than conveying austere information, the instruments should enable the bodily sound experience.

Keywords: sound art; musical instruments; experimental music; chordophone

I would like to thank Jakub Černý, who created the tuning program for the bodychord, and who both technically and psychologically supported this work.

Contents

1

Context of My Prior Work

Resonance is a phenomenon in acoustics when a system amplifies the sound waves corresponding to its own natural frequencies [1]. Metaphorically, in the process of familiarizing ourselves with ideas of profound meaning to us, our fascination with the topic grows stronger. We say the topic *resonates* within us – we find a value in it, and it becomes an unceasing driving force of our actions. Both interpretations unite in my musical instruments and sound objects. For them to resonate, I aim to design a system that facilitates resonance. At the same time, creating the artwork itself is my undying passion, which inspires me to further explore the possibilities of acoustics and its boundaries.

1.1 Artistic motivation

I can not say exactly when my interest in the nature of sound was born. The fascination started slowly, during my childhood. My father is a patient and precise luthier who specializes in string musical instruments, and I have always enjoyed watching him work and trying what I learned from him on my own. In my work, I did not have a clearly defined focus until I made my first string instrument on the occasion of the open air exhibition. It is a self-portrait – lyre (see Appendix A.1). This initial impulse encouraged me to deepen my interest in musical instruments, and I began to construct them during my studies at the New Media Studio. The head of this studio is doc. akad. mal. Vladimír Merta, who himself is a luthier too. I was therefore fortunate to being able to consult not only the content, but also the craft or technological side of my art with him. Instead of following the traditional production of musical instruments, my goal was rather to experiment with different forms and approaches.

1.2 Created artworks

Musical instruments. I soon realized that in order to improve quality of my musical instruments, it is essential for me to better understand not only the craftsmanship but also the physical laws of acoustics. I dedicated my next instrument – a monochord – to a search for a link between these two aspects. According to Pythagoras, a monochord is more of a study aid than a full-fledged musical instrument. Having a single string, the monochords are used to understand how the pitch of the tones changes with the tensioning of the string, how the ratios can be used to derive tones, or where flasolas are formed. After I created the first monochord, I started designing instruments of a similar type with more strings, allowing for more intricate style of playing. I refer to these simple-shaped instruments together as "chordophones" (see Appendix A.2). I believe I achieved my goal with the trichordophone – an instrument with three strings of the same length and a slider. Playing the trichordophone is physically demanding. To change the instrument's pitch using the slider, the player has to move along its entire body spanning across two meters. The physical nature of the trichordophone inspired me to concentrate more one the connection between the body and sound, or a player and an instrument. In addition to string instruments, I spent several months experimenting also with wooden instruments that create sound primarily by the vibration of themselves (idiophones) and wind instruments (aerophones). I found out how the wood itself can be tuned and how to influence the color of the tones. The color becomes very pleasant to the human ear when a wood with good idiophonic properties is used. To achieve this, it was necessary to use different types of wood of different length and thickness. Moreover, I created several bamboo flutes from the aerophone category. Unlike chordophones and idiophones, the color of tones they produce depend on the size of the air column and the speed of the air flow. Their pitch is regulated by means of holes.

Sound experiments. With the growing interest in acoustics, my desire to engage in sound experiments grew too. One of them are the frequency drawings (see Appendix B.1). The drawings are a result of searching for patterns arising from the resonance of metal plates at the moment when the playback frequency resonates with the frequency of the plate. Another experiment, the rain dissonance, is an experiment in time. On a rainy day, I filled eight glasses with water so that they are tuned to a major scale, and I placed them in front of our house. I played a short melody with the tuned glasses and then repeated the same sequence at different time intervals. Due to the rain the glasses were filled unevenly with water, and each subsequent play hence resulted in a different melody.

1.3 Sound art

My study of sound can be considered a part of the so-called *sound art* movement. As an artistic medium, we can trace the roots of sound art back to the beginning of the 20th century. The Intonarumori by Luigi Russolo [2] is often cited as a milestone art piece that first prompted the contemporary art community to regard the construction of sound objects as an art. His series of 19 mechanical instruments producing different kinds of noise supports his futuristic manifesto "The Art of Noise". The 1960s, led by John Cage, marked the heyday of sound works and events. In connection with Cage and experimental musical instruments, I was mainly influenced by his compositions for prepared piano, in which various objects are inserted between the strings of the piano. So instead of the expected harmonic play, we hear unpredictable tones and sounds of a percussive nature. On the Czech scene, Milan Grygar focuses on the relationship between space and sound. With works such as Acoustic Drawings, Antiphons or cycles of scores, he emphasizes the ubiquity of sound. However, one of the most remarkable personalities in the field of experimental musical instruments for me personally is Harry Partch, who made his instruments on the basis of his own microtonal scales (see Appendix D). Although the term sound art began to be used only in 70' [3] in connection with works using new recording and reproduction audio technologies, today it refers to the whole spectrum of works which main component is sound.

2

Conceptualization of the Topic

In my bachelor thesis, I decided to study an interaction between the human body and sound. The choice of the topic was influenced by my long-term interest in sound and musical instruments that embody such an interaction. My interpretation of the connection between the body and sound is that the instrument should become a subconscious extension of the body, rather than a tool for making sounds and noises. I believe that a topic that explores this connection is a natural culmination of a process of finding my artistic self.

2.1 Aim of this thesis

The main goal of this work is to explore how humans physically relate to sound and vice versa. I find the sound aspect of life essential as we progressively become more and more overwhelmed by city noises and sounds in our daily lives.

More specifically, I aim to design a series of musical instruments and sound objects that interact with a body and reflect my mental journey that led to their creation. Each instrument or object is meant to be played differently from what is commonly regarded as a traditional musical performance.

3

Preparations and Realization

Once my topic – the connection between body and sound – was finally clearly identified, I fully immersed myself in a study of relations between acoustics, human psychology, and art. As a part of getting prepared for the realization, I willingly concentrated on (as much as possible) depersonalized perceptions of my reactions on various sound forms, e.g., noises and clamors, stillness, or regular and irregular rhythms. Soon I started constructing sketches based on findings gained through both the theoretical study and the introspection. I began experimenting with a plurality of techniques. As a next step, I attempted to look for potential associations between the sketches.

However, the earliest approaches proved pointless. I came to realize that I became too obsessed with relating the individual objects of the sketches together. The ideation process became too calculated. I hence decided to move from intentional, constructive design into a more intuitive method of creation. I ceased to rationalize why I chose a particular shape or technique. The first sketches (see Figure C.1) still show some signs of the pseudo-scientific approach, though. They contain multiple notes and comments, consisting of either truthful facts or primary impulses for the design itself, but I leave them intentionally open to interpretations. I chose this approach to remind even myself that instead of conveying austere information, I aim to enable the bodily sound experience.

I moved to the workshop with only vague ideas of what I would like to achieve. This decision allowed me to explore different techniques and refine my designs on the go. My prior experience with woodworking was more than sufficient to reach my goals. However, the sketches also required me to build the electronic circuits controlling one of the instruments. Working with electronics proved to be the most challenging part of my project. But with the help and advice of my friends, I achieved results that exactly met my expectations (see Chapter 5).

4

Characterization of the Artwork

The created art piece consists of three *figures*, which can be judged from two formal standpoints. A figure in fine art is a term denoting a body, which is depicted by a plurality of techniques and media. In musical terminology, on the other hand, a figure means a short musical phrase. It is usually shorter than the whole composition, but by repeating itself it unifies it [4]. From a visual point of view, the instruments on the human body create the impression of figures or moving sculptures during the performance. At the same time, their sound are short, consecutive musical figures.

Instead of musical skills, playing the instruments requires concentrating on one's own physical movements. Conscious and focused perception of movement and sound is a major aspect of my work. Inadvertently, this can lead to enlightening moments moving between seriousness and playfulness.

4.1 Bodychord

The Bodychord (see Appendix E) consists of four chordophones, i.e., wooden resonance chambers, with four strings on each of them. The strings are divided into two sets within each chordophone and tuned intuitively with the help of the tuning system described in Chapter 5 in the paragraph dedicated to the Bodychord. The chordophones have geometric, but still anatomic shape, and are clamped on the arms and legs of the player. A rotating motor with an arm that resounds the strings is attached to the chest. The sound resonates when the strings cross the circumferential path of the arm. The speed of rotation of the arm can be regulated, thus controlling the intensity and allowing to reach a seemingly overwhelming sound. Composition and rhythm are entirely controlled by movement and gestures.

The specific type of playing the instrument is thus also reflected in the visual impression the artwork makes. The player expresses themselves through various movements, which can cause the mentioned enlightenment in the audience.

4.2 Idiophones

The second instrument is formed by four metal hemispheres, the Idiophones (see Appendix F), resounded by small metal spheres. The spheres are fastened to the player's fingers with a chain and they copy the fingers' movements when fidgeting, i.e., toe-tapping or foot-wagging. Under normal circumstances, humans make these movements completely inadvertently and they are caused by nervousness or just deep concentration. When playing the Idiophones, the same slight movements produce distinctive ringing sounds when the spheres hit the Idiophones. The play hence gives rise to a dichotomy between the very essence of unconscious oscillating movement and the focus attracted by the sharp sounds.

It is not possible to measure the pitch of Idiophones with accuracy because they produce many aliquot harmonic tones at once. The individual tones then vary in duration over time. The wide frequency range of hollow Idiophones can also have a number of beneficial side effects. Several kinds of Idiophones are used in meditation, for example in form of so-called Tibetan bowls. Sound provides the sensation that the mind focuses on, which is the essence of many meditation practices [5].

4.3 Tension

My last figure is the Tension (see Appendix G). It is a minimalist musical instrument that consists of only one string and its fastening base. It responds to the Pythagorean monochord (see Section 1.2), but the tuning now depends on the force the player exerts to tension the string. This creates tones with audible rises or, conversely, descents that can never be controlled perfectly to achieve clear tones.

The player becomes the body of the instrument while tensioning the string. Thus, similarly to the Bodychord, it is not only sound that the audience perceives, but also various movement creations.

5

Analysis of Employed Techniques

In creating the artworks, I employed several woodworking methods and challenged my technical skills. For each of my instruments I will describe the process of making it, which technological problems I faced and how I overcame them.

Bodychord. The instrument consists of four chordophones with four strings each, and a central motor with an independent power source and a speed controller. For making the chordophones, I used spruce wood due to its good resonation properties. Spruce wood is soft and hence emits denser bass tones. Due to the small dimensions of the instruments, the softness of wood is an advantage ensuring the sound is intense enough. I used four battens and fronts for each chordophone and glued them into the shape of a polyhedron, which anatomically adheres to the player's arms and legs. I fastened the strings to the top plates of the chordophones with rivets on one side and tuning pins on the other side. I raised the strings behind the rivets with hard walnut saddles, which are less likely to wear off soon. For this craft production I used: woodworking machines (planing cutter, circular saw, band saw, combi grinder), power tools (cordless drill, vibratory grinder, straight grinder), hand tools (screwdrivers, vices, planers, pliers, hammer, file) and dispersion adhesive.

An experiment, and at the same time also a challenge for me, was to assemble a circuit controlling the rotating arm, which resonates the strings of the chordophones. The player should be able to regulate the speed of the arm and the circuit should be autonomous in a sense that the whole instrument should not have to be connected to an AC socket. I achieved both by assembling the circuit from an Arduino Uno board, an L298N bridge, a 100kΩ potentiometer, two 9V batteries and the 12V motor itself. By rotating the potentiometer's small thumbwheel, the energy driving the motor is regulated so that the motor speeds up or slows down. A program running on the Arduino board controls the flow of energy through the circuit (see Appendix H). I enclosed the whole circuit, including the motor, in a small wooden box that I made from spruce wood to preserve the resemblance to the chordophones. I faced many difficulties when working with electronics, but this part of the thesis was the most beneficial for me in terms of learning new technologies.

The Bodychord's strings could be tuned in many ways. However, experimenting with different tuning physically would require to always retune all 16 strings. To facilitate this process a tuning program was created (see Appendix I) in the programming language Python, in which I can specify individual tones and their frequencies. When running the code in the command line I assign a combination of tones I would like to try to each chordophone. The tones are then played in a loop that corresponds to the rotation of the motor. Once I am satisfied with how the tones match together, I tune the strings according to the found combination.

Idiophones. In the Idiophones, the sound is generated by the hit and subsequent vibration of themselves. They are hollow metal hemispheres of various sizes, which I bought as forged semi-finished products. The hits to the hemispheres are caused by metal spheres, which I drilled through the center on a column drill. I attached the chains to the spheres through the created holes, connecting them with the player's fingers.

Tension. The Tension instrument consists of a single wire, i.e., an unwound string, riveted to a wooden base. The resonant properties of the stand are very damped due to the length of the string, so I used a pickup connected to the amplifier and speaker to achieve the desired increase in volume.

6 Evaluation of Broader Impact

In my work, I follow the principles of the sound art movement and the making of experimental musical instruments (EMIs). I briefly discussed the history of both in Chapter 1. I believe the contribution of my art piece lies primarily in extending the category of EMIs. This category contains many remarkable, original instruments, which have never been seen before. Their unique sounds and shapes are meant to broaden the audience's understanding of sound and enrich their senses.

The main reason why I appreciate sound art so much is because it is open to everyone. Contrary to classical music, sound art does not require traditional musical education [6]. The same also holds for the making of EMIs. The instruments of established artists can thus be compared to the creations of experts in various technological fields or even just music enthusiasts working from their home garages. If my art inspires at least one person to start experimenting with sound, I will find all the work worthwhile. The truth is that in comparison to visual arts, sound art remains in the minority.

Strengths of the artwork. I am convinced that in the context of EMIs, the most significant aspect of my artwork is that it is a profoundly original artwork despite it being built on the well-known and established sound principles. It demonstrates one of the possible approaches towards sound and its topicality in the contemporary world.

Weaknesses of the artwork. I see as limiting that my understanding of sound is based on subjective perceptions and personal experiences. It is thus not generalizable to a larger population, and it remains entirely plausible the artwork will be open to many interpretations. I still stand by my belief that literal interpretability should not be considered essential for art appreciation.

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Appendices

A

Chordophones

Figure A.1: Self-portrait, Photo: Karolína Oliveriusová

Figure A.2: The World of Tomorrow Exhibition, Photo: Alexander Dym

Figure A.3: The World of Tomorrow Exhibition, Photo: Alexander Dym

B

Frequency Drawings

Figure B.1: Frequency drawings, Photo: Karolína Oliveriusová

C

Sketches

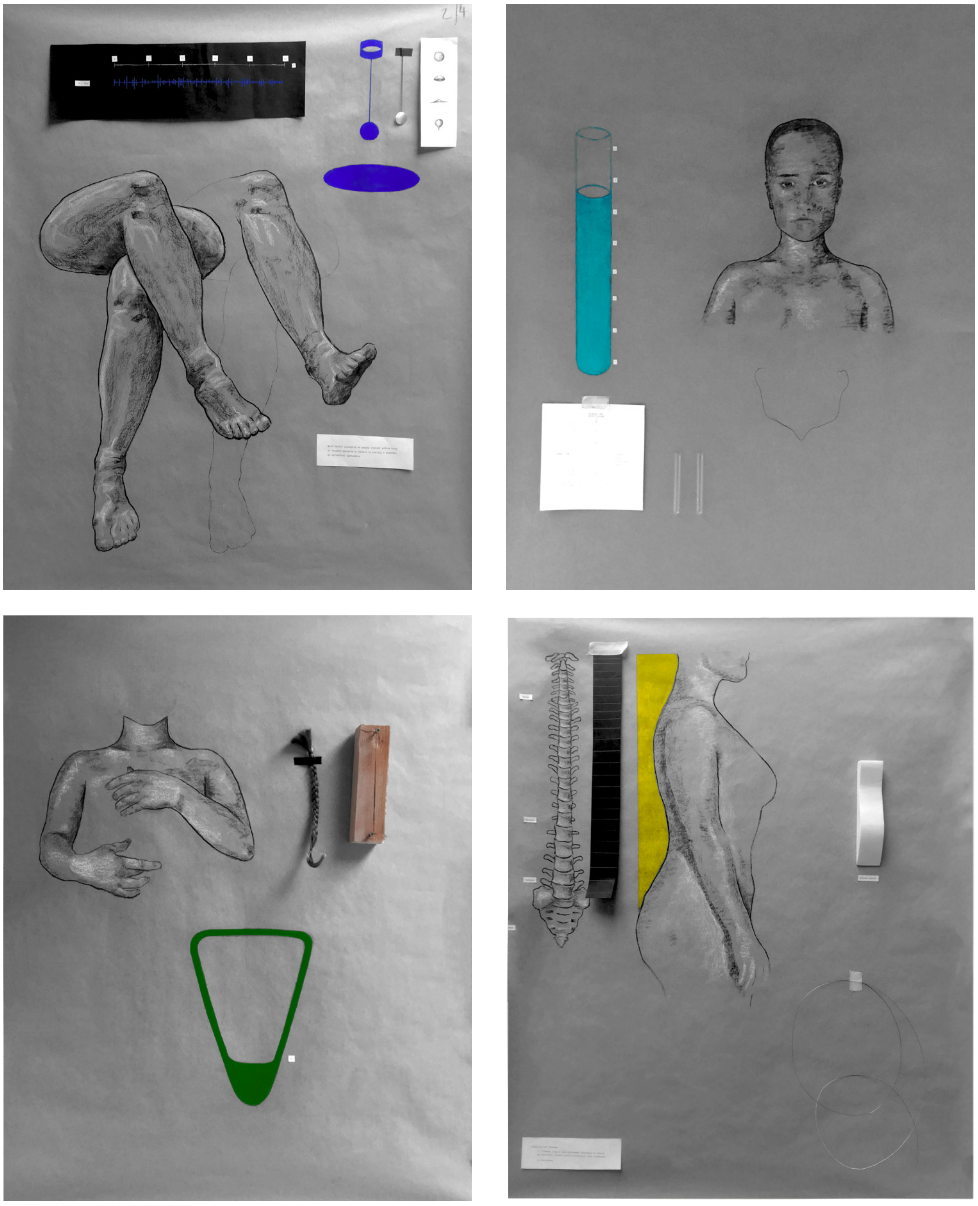

Figure C.1: Sketches, Photo: author

D

Harry Partch

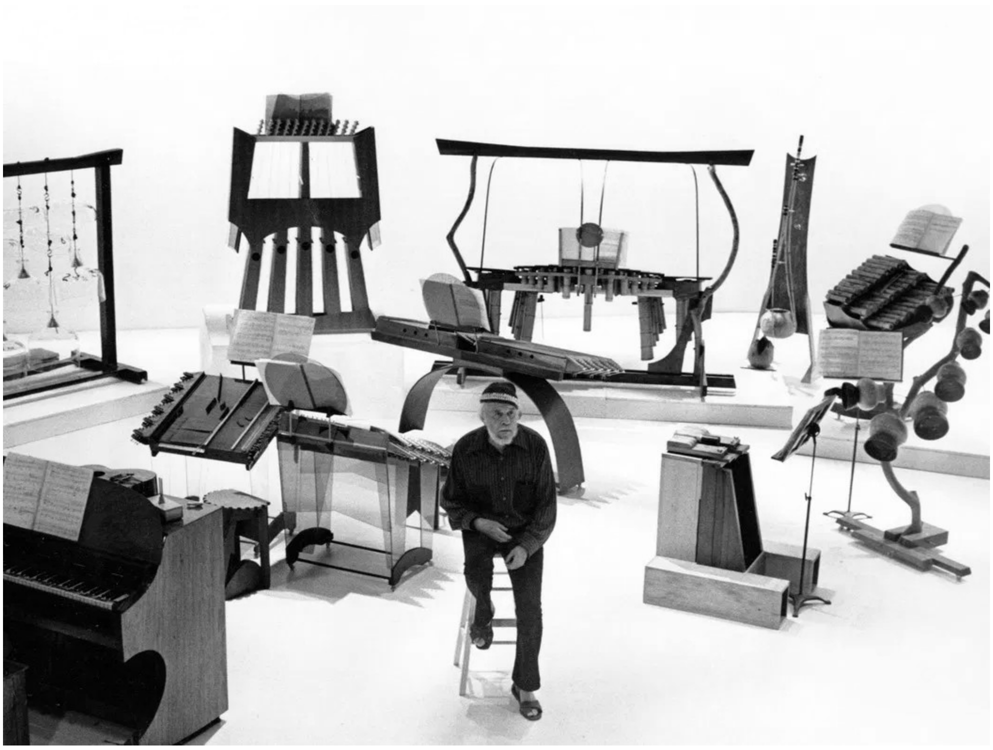

Figure D.1: Harry Partch and his instruments, Photo: Betty Freeman

E

Bodychord

Figure E.1: Bodychord, Photo: author

Figure E.2: Bodychord, Photo: author

F

Idiophones

Figure F.1: Idiophones, Photo: author

Figure F.2: Idiophones, Photo: author

G

Tension

Figure G.1: Tension, Photo: author

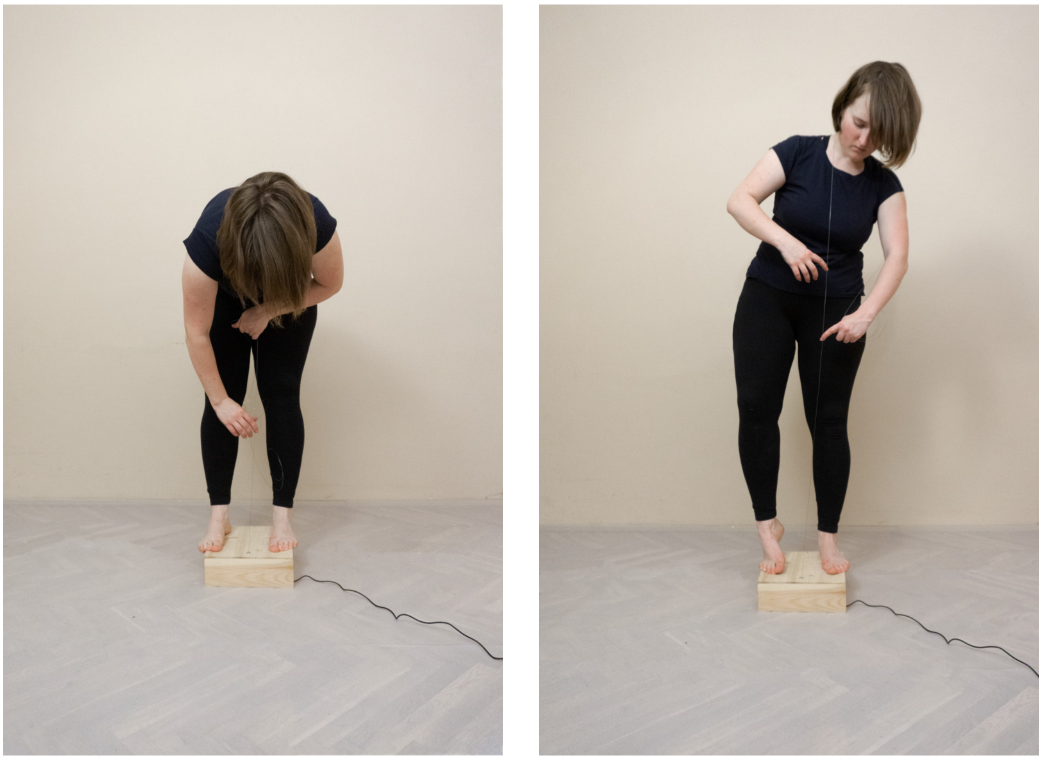

Figure G.2: Tension, Photo: author

H

Motor Code

```
// pin definitions
const int OUT_PIN_01   = 8;
const int OUT_PIN_02   = 9;
const int OUT_PIN_PWM  = 10;
const int LOW_CUTOFF   = 10;
const int MAX_OUTPUT   = 240;    // maximal value is 255

int motor_speed;
int loop_iter = 0;

void setup() {
  pinMode(OUT_PIN_01,  OUTPUT);
  pinMode(OUT_PIN_02,  OUTPUT);
  pinMode(OUT_PIN_PWM, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  loop_iter++;
  digitalWrite(OUT_PIN_01, LOW);
  digitalWrite(OUT_PIN_02, HIGH);

  // reading the potentiometer ... valua in interval [0,1023]
  motor_speed = analogRead(A0);

  // normalize to interval [0,MAX_OUTPUT]
  motor_speed = motor_speed * (MAX_OUTPUT / 1023.0);
  motor_speed = min(motor_speed, MAX_OUTPUT);

  // low speeds cutoff
  if ( motor_speed < LOW_CUTOFF ){
    motor_speed = 0;
  }

  analogWrite(OUT_PIN_PWM, motor_speed);

  if ( loop_iter == 10000 ){
    Serial.println(motor_speed);
    loop_iter = 0;
  }
}
```

I

Bodychord Code

```
import numpy as np
import simpleaudio as sa
from time import sleep
import msvcrt

# tone frequencies definitions
A3   = 220.00;      C4  = 261.63;      E4  = 329.63;      Gis4 = 415.30
A4   = 440.00;      B4  = 493.88;      E5  = 659.25;      Gis5 = 830.61

# assigning tones to chordophones
chord_0 = [A3, C];       chord_0.append(1)     # Chord_0  VP 220 - 329 (A3 - E)
chord_1 = [E, Gis];      chord_1.append(1)     # Chord_1  VL 329 - 440 (E  - A)
chord_2 = [A, B];        chord_2.append(1)     # Chord_2  MP 440 - 587 (A  - D5)
chord_3 = [E5, Gis5];    chord_3.append(1)     # Chord_3  ML 587 - 987 (D5 - B5)

def sound(frequency, seconds):
        fs =  44100          # samples per second
        t = np.linspace(0, seconds, int(seconds * fs), False)
        note = np.sin(frequency * t * 2 * np.pi)
        audio = note * (2**15 - 1) / np.max(np.abs(note))
        audio = audio.astype(np.int16)
        part = int(0.3 * len(audio))
        for i in range(part):
                audio[i] = int((float(i)/part) * audio[i])
                audio[len(audio) - i - 1] = int((float(i)/ part) \
                    * audio[len(audio) - i - 1])
        play_obj = sa.play_buffer(audio, 1, 2, fs)

# setting the tone duration and pi/4 motor rotation speed
tone_duration = 0.5;          motor_speed = 0.3

sides = [0, 0, 0, 0]
print('Playing sides ', [a+1 for a in sides])

l = []
while True:
        if msvcrt.kbhit() > 0: # check if the sides changed
                line = msvcrt.getch().decode('ASCII')
                l.append(line); print(l)
                if (line == 'x'): exit()
                if (line == 'd'): l = []
                if len(l) < 4: continue
                if sum([0 if a.isdigit() else 1 for a in l])  > 0: continue
                if sum([0 if int(a)-1 < 3 else 1 for a in l]) > 0: continue
                sides = [int(a)-1 for a in l]
                print('Playing sides ', [a+1 for a in sides]); l = []
        sound(chord_0[ sides[0] ], tone_duration); sleep(motor_speed)
        sound(chord_1[ sides[1] ], tone_duration); sleep(motor_speed)
        sound(chord_2[ sides[2] ], tone_duration); sleep(motor_speed)
        sound(chord_3[ sides[3] ], tone_duration); sleep(motor_speed)
```