Step to the beat: A musical journey through movement and motivation

Working Dates	Working timeline
Dec-1	Early December to December end:
Dec-2	Figuring out prototype construction.
Dec-8	Early January to mid: Purchasing the
Dec- 16	electronic supplies to build and finished
Dec-25	building.
Jan-3	Late January to February Mid:
Jan 17	Interviewed music therapist and
Jan 18	continued to add information
Jan-24	Late February to Early March:
Feb 2	Conducted experiment and
Feb 12	completed research on the platform.
Feb 13	
Feb 20	
Feb 27	

Feb 28

March 1

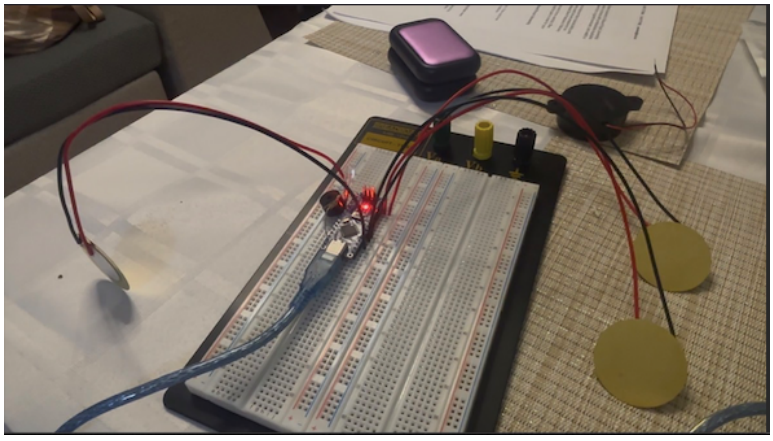
March 2

March 3

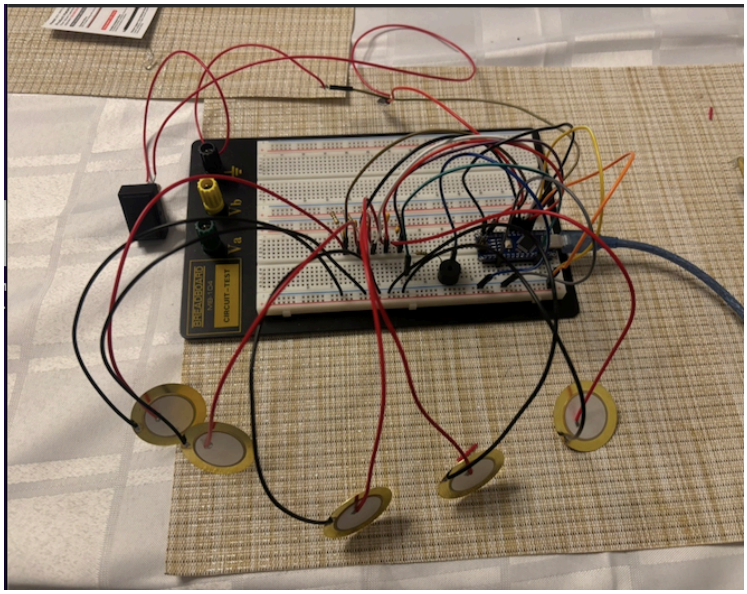
March 4

Materials used for building the staircase

- 1 Arduino Nano microcontroller
- 1 bread board
- 5 Piezoelectric disks
- 5 1MΩ resistors
- 5 0.1μF capacitors
- 1 buzzer
- 5 LEDs
- 5 330Ω resistors
- Jumper wires



This is the first connection I made for the prototype

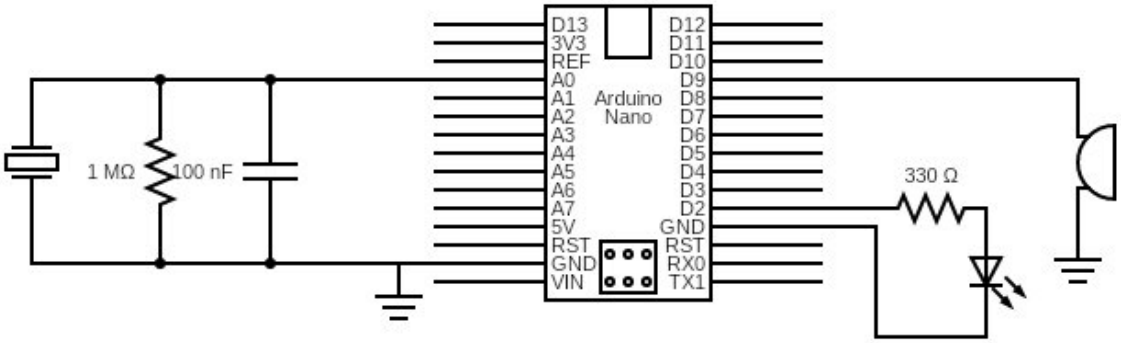


This is with most of the necessary connections needed, LEDs are not connected yet.

Final prototype of the musical staircase, built the Sunalta train station to demonstrate a bigger picture

After doing some research I figured out that I will need a 1M Ohm resistor for the piezo since the 330 Ohms resistor was not working when I tested it first. I connected everything for one step at first and then when it worked I built the remaining and added the code for the remaining 4 steps.

The connection is a piezo disc connected to an arduino through a 1M ohms resistor and a 0.1 microF capacitor, then those are connected to the ground. Then for the LED, it is connected to the arduino through a 330 ohms resistor and another end is connected to ground. For the speaker it is directly connected to the arduino and its other end is connected to the ground.



This is the circuit diagram for one step. My piezo discs are connected in A0, A1 A2 A3 and A4 analog pins. My LEDs are connected to D2, D3, D4, D5 and D6 digital pins. My speaker is connected to the D9 digital pin.

I wanted to measure the amount of electricity generated by my prototype so, I took my multimeter and I held the two ends of the piezo to the nodes of the multimeter and I tapped the piezo multiple times and then I calculated the average voltage I got and it was 0.48 V. Then I converted the value of the capacitor from microF to Fararads. This is the formula I used. (Capacitance in Farards) = Capacitance in micro Farards x 10^-6. The value I got was 0.0000001 F. Then I used this formula Energy= 1/2 x Capacitance x Voltage squared to calculate the energy produced by one step and multiplied that value by 5, then I got 58nJ. To get that value in nano Joules I took the value I got in Joules and used this formula to convert to nano joules
Joules x 10^9.

Then I referred to PAVEGEN's technology which produces 3 to 5 J of energy per step, so a 50 step staircase climbed by one person will produce 150 to 250 J of energy. Then I found the number of train stations in Calgary which is 45. Then I took the average weekday ridership and divided it by 45 and I got 5800 people in one station and lets say 40% of commuters use the stairs. We will get 2320 people using the stairs. Then I took

the number of people and multiplied it by 150J and I got 348,000J. To convert to Watt hour I divided the energy in joules by 3600 and I got 97 Wh. This energy can be used to light up LED signage or it could be stored for later use.

I found a study which did something very similar to the experiment I will be doing. They used stair climbing therapy sessions with music and without music and they compared the results. The results showed a 5.7% ($p=0.007$) increase in a constant and stable stride and a level of participant enjoyment increased significantly ($p=0.031$) and the participants reported feeling more motivated when the audio feedback was provided.

The probability of the stable stride being random was 0.7% and the chance of the increase in participant motivation being random was 3.1%. This means that the effects of music being totally random was almost negligible.

After searching for musical therapists in Calgary whom I could interview to get their insights, I also thought of asking a teacher at school. My teacher said she knew a musical therapist and she would be willing to help me with my project. Jane Proctor, a certified music therapist based in Toronto gave me some insights which I could use in my project. She explained that music therapy can influence heart rate, stimulate cognition and memory, and increase endorphin production. She also stated the ISO principle where the music is matched with the person's mood and it is slowly modified to bring the person's mood to the desired state. In addition, she mentioned the speed or tempo of the beat can influence the walking pace. A faster beat tends to increase the walking speed and a slower beat leads to a slower speed but, in both cases the person's walking will be stable. This information was used in the Psychology analysis part of my project.

I was finally able to conduct my experiment which I was planning on doing.

The participants were asked to climb the staircase in my school first without any music, recorded the time they took and another time with music and recorded that time.I used workout beats to mitigate most of the bias and I did not ask them to walk in time with the music. To begin, I asked them how they felt on a scale 1 to 5, one being tired and 5 being energetic. Then I recorded that data and moved on to the next person. Then I realized that I should also take their energy levels from before testing so that I can

compare it later on. Then for the remaining students I implemented that part as well and recorded my results. I took the numbers I got and turned them into bar graphs and I calculated the mean for all the results and I observed that their energy levels had gone up a little after the experiment and they were a bit faster with music. Using this information I came to the conclusion music can impact our perceived energy levels and walking/ climbing speed.

Participant #	Motivation Before	Motivation After
Participant 1	3	4
Participant 2	2	4
Participant 3	4	3
Participant 4	3	4
Participant 5	4	4
Participant 6	2	4
Participant 7	3	4
Participant 8	3	5
Participant 9	3	3
Participant 10	3	4
Participant 11	3	3

Perceived energy level before average	3.1
Perceived energy level after average	3.8

Participant #	No music time	Music time
Participant 1	7:15	6:00
Participant 2	7:08	7:41
Participant 3	5:12	4:25
Participant 4	6:52	5:00
Participant 5	6:07	5:56
Participant 6	7:23	10:11
Participant 7	6:09	5:36
Participant 8	4:12	4:15
Participant 9	6:19	6:41
Participant 10	4:06	5:36
Participant 11	5:54	10:03
Participant 12	6:00	6:00
Participant 13	6:49	5:00
Participant 14	6:00	6:00
Participant 15	6:00	6:00
Participant 16	7:00	6:00

Climbing speed without music average	6.7
Climbing speed with music average	6.19

Then I thought about some limitations which could come along with the benefits of this staircase. Constant usage of the staircase can lead to the degeneration of the pressure sensors or other elements. Another challenge could be related to the costs of installation. On a large scale at first the installation costs could be high but in the long term it could save energy and money from reduced electricity consumption. Lastly, another potential limitation could be the music distracting some of the commuters or the musical notes could be too loud which ends up causing noise pollution. This could be mitigated with routine checks and testing the staircase multiple times before opening it to the public.

I was thinking about some potential use cases since there are staircases in multiple other places people will use and train stations are not the only one. Implementation in commercial buildings, educational institutions and hospitals are other places where this idea can be installed to bring a positive impact.

Since there are some cases where staircases are not available such as bus stops, there is an alternative. Modifying the design of staircases to a flat platform can be used in places which do not have stairs. The flat platform would have the same pressure sensing and music generation technology so, when a person walks on that path the same output is given but instead of a vertical staircase, it is a pedestrian pathway. If this is implemented next to bus stops, people can walk in that area while waiting for the bus.

These are the sources I used throughout my project.

2024-Q3-Ridership-APTA

- https://www.apta.com/wp-content/uploads/2024-Q3-Ridership-APTA.pdf

How Does Public Transit Affect Mental Health?

- https://lifestyle.sustainability-directory.com/question/how-does-public-transit-affect-mental-
  The Effects of Music Tempo on Arithmetic Cognition Testing, Heart Rate, and Perceived Stress *
  https://spark.bethel.edu/cgi/viewcontent.cgi?article=1010&context=human-kinetics-students

PAVEGEN

- https://www.pavegen.com/how-it-works

City of Calgary newsroom

- https://newsroom.calgary.ca/calgarys-light-rail-transit-system-past-present-and-future/#:\~:text=The%20inaugural%20line%2C%20built%20in,connecting%20Calgarians%20like%20never%20before.&text=Construction%20resumed%20in%20the%20early,make%20travel%20even%20more%20efficient.

Psychology Today

- https://www.psychologytoday.com/ca/blog/urban-survival/201501/commuting-the-stress-that-doesnt-pay

Musical stairs: the impact of audio feedback during stair-climbing physical therapies for children

- https://www.tandfonline.com/doi/full/10.3109/17483107.2014.886085#:\~:text=All%20reports%20(child%2C%20therapist%2C,warrants%20further%20development%20and%20evaluation.

Let's Talk About Iso-Principle: The Introduction

- https://musictherapytime.com/blog/lets-talk-about-iso-principle-the-introduction

Hospital installs 'piano staircase' to boost exercise

- https://www.classicfm.com/music-news/taiwan-hospital-piano-staircase-boost-exercise/

Science Direct

- https://www.sciencedirect.com/topics/engineering/piezoelectric-disk#chapters-articles

Science direct

- https://www.sciencedirect.com/topics/materials-science/capacitance

Stock Cake

- https://stockcake.com/i/musical-stairway-ascending_2038805_1296501

Super Simple psychology book by DK.

```
const byte NUM_STEPS = 5;

// Piezos
const byte piezoPins[NUM_STEPS] = {A0, A1, A2, A3, A4};

// LEDs: step LEDs mapped to D2..D6 (5 LEDs)
const byte ledPins[NUM_STEPS]   = {2, 3, 4, 5, 6};
const byte statusLedPin         = 7;   // optional

// Sound
const byte soundPin = 9;

// Notes (High octave Do Re Mi Fa Sol - louder)
const int notes[NUM_STEPS] = {523, 587, 659, 698, 784};

// ---- Tuning knobs ----
int threshold = 60;                 // adjust 40..150
unsigned int noteDuration = 140;    // ms
unsigned int ledOnTime = 180;       // ms
unsigned int cooldown = 180;        // ms (debounce per piezo)

unsigned long lastHit[NUM_STEPS] = {0, 0, 0, 0, 0};
unsigned long ledOffAt[NUM_STEPS] = {0, 0, 0, 0, 0};
unsigned long statusLedOffAt = 0;

void setup() {
  // LEDs
  for (byte i = 0; i < NUM_STEPS; i++) {
    pinMode(ledPins[i], OUTPUT);
    digitalWrite(ledPins[i], LOW);
  }
  pinMode(statusLedPin, OUTPUT);
  digitalWrite(statusLedPin, LOW);
```

```
  // Sound
  pinMode(soundPin, OUTPUT);

  Serial.begin(9600);

  // Startup beep + flash (optional)
  digitalWrite(statusLedPin, HIGH);
  tone(soundPin, 1000);
  delay(120);
  noTone(soundPin);
  digitalWrite(statusLedPin, LOW);
}

void loop() {
  unsigned long now = millis();

  // Turn off LEDs when their timer expires
  for (byte i = 0; i < NUM_STEPS; i++) {
    if (ledOffAt[i] != 0 && now >= ledOffAt[i]) {
      digitalWrite(ledPins[i], LOW);
      ledOffAt[i] = 0;
    }
  }
  if (statusLedOffAt != 0 && now >= statusLedOffAt) {
    digitalWrite(statusLedPin, LOW);
    statusLedOffAt = 0;
  }

  // Read piezos and trigger actions
  for (byte i = 0; i < NUM_STEPS; i++) {
    int v = analogRead(piezoPins[i]);
```

```
  // Trigger conditions
  if (v > threshold && (now - lastHit[i] > cooldown)) {
    lastHit[i] = now;

    // Light that step LED + status LED
    digitalWrite(ledPins[i], HIGH);
    ledOffAt[i] = now + ledOnTime;

    digitalWrite(statusLedPin, HIGH);
    statusLedOffAt = now + ledOnTime;

    // Play note (brief)
    tone(soundPin, notes[i]);
    delay(noteDuration);
    noTone(soundPin);

    // Debug
    Serial.print("Step ");
    Serial.print(i + 1);
    Serial.print(" hit, value=");
    Serial.println(v);
  }
}
```

This is the code for my prototype