Relation of Sound Intensity to Number of Steps

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ABSTRACT
The Covid-19 pandemic affected public health enormously. Research has shown that physical activity increases when people listen to music. This study explores if there is a relationship between sound intensity and the number of steps. Therefore, the research question was 'How does the intensity of sound have an impact on a person's activity levels regarding the number of steps taken. To investigate this research question, data from five participants was gathered. The steps were measured with the Xiaomi Mi Band (version 4,5 or 6) and the sound intensity was measured with a sound detection module LM393. Data was gathered and cleaned after a two-week period. The results in this paper can only be interpreted as suggestive results and answers to the research question and are likely to be reliable. Looking at the results, it was found that there is most likely no relationship between the intensity of sound and the number of steps.

Author Keywords
Physical activity; Walking; Social interaction; Sound intensity; Behaviour.

INTRODUCTION
The Covid-19 pandemic affected public health enormously. The main focus during the pandemic was the number of infections by the virus. However, the behavior of the hospital, government and citizens was crucial for social, economic, and political dynamics [9]. 'To flatten the curve', several restrictions (e.g., self-isolation, physical distancing) were implemented by governments, which had direct consequences on the behavior of the society and decreased the overall well-being [1]. The implemented measurements negatively affected the physical activity possibilities including the social interaction related to this. During the Covid-19 pandemic, the number of obese patients increased significantly [1]. Obesity is generally caused by overeating and a lack of movement [2]. Obesity is dangerous since it causes diseases (e.g., diabetes mellitus, gallbladder disease, osteoarthritis, heart disease, and some forms of cancer [2], and in the most severe cases even death [3]. Obesity is just one of the many examples in which public health is affected by the pandemic. Public health should be taken seriously during pandemics and also during normal situations. The decrease in physical activity level is highly associated with the lack of social support, which was the case during the pandemic [13]. Furthermore, physical activity increases when people listen to music [12].
The perfect number of steps taken per day as a solo topic has been researched often before. However, there has been little research done to the relation between number of steps and sound intensity. The definition of sound intensity is the sound power per unit area in a specific direction commonly expressed in ergs per second per square centimeter or in the scale of decibel [14].
The purpose of this study is to expand knowledge on this topic because this could have possible positive influences towards, for example obesity or other physical health topics. The target group in this study are students. This target group is especially relevant since it is one of the groups most severely affected by the covid measurements [16].
In this study, the sound intensity and the number of steps taken by a person are measured to find if there is a relation between the two. This allows future governments to take social interactions into account and adjust the measurements so that the pandemic becomes less harmful for the public's wellbeing. Therefore, the research question is: "How does the intensity of sound have an impact on a person's activity levels regarding the number of steps taken?"
This report first gives an overview of the related work towards sound intensity and number of steps taken, then the methods used for data gathering will be explained. Afterwards, the outcomes of the collected that will be shown and discussed, from which a conclusion is drawn.

RELATED WORK

The relation between walking and health
Increasing the daily number of steps results in decreasing the amount of obesity within a population, however, it has a relation to many more physical conditions like cardiovascular diseases and type 2 diabetes [4]. Much research has been done on what specific number of steps is related to this healthy lifestyle and this resulted in 10.000 steps per day [10]. This is not a holistic boundary, but it is a good indicator of the ideal activity per day.

Effects of increased sound intensity

Although sound intensity can possibly be related to a more social life there are also negative side effects of increased sound intensity. Research has shown that increased sound intensity can cause nuisance, sleep disturbance, disruption of daily activities and stress. These effects can lead to higher blood pressure and elevated levels of the stress hormone cortisol. Sound can also be directly linked to physiological reactions such as increased blood pressure. For children, an increased sound intensity can also have a negative influence on the learning performance of children [17].

An example of a famous phenomenon related to negative sound intensity is called tinnitus. Tinnitus can heavily influence your social life since interacting can be intense and people with tinnitus cannot have the same social interactions that others would have in the same situation [8].

Relation between mental health and physical health

Physical health and mental health are strongly connected to each other. When the mental health is in a bad state of mind this strongly affects your physical health by for example not coming out of bed, emotional eating and in the end, having a bad physical state. On the other hand, physical health also has a big influence on your mental health. This can be reflected in, for example, insecurity and body shaming by others or feeling that you are not able to do something because your physical health is bothering you [15].

Effects of noise/sound intensity on human behavior and social interactions

Noise in living environments increased over the past years as a direct result of modern civilization. According to studies, there have been extreme examples of noise effects on social behavior like reduction in efficiency of workers and creating nervous breakdown. However, noise and especially music can also have positive effects on human and social behavior. This is because the human body gets excited by musical and certain noisy sounds. This excitement depends on the type of noise and the intensity of noise [5].

Increasing the daily number of steps results in decreasing amount of obesity within a population, however, it has a relation with many more physical conditions like cardiovascular diseases and type 2 diabetes [19]. Much research has been done to what specific number of steps is related with this healthy lifestyle and this resulted in 10.000 steps per day [18]. This is not a holistic boundary, but it is a good indicator of the ideal activity per day.

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METHODOLOGY

A research question was established at the beginning of this study, which was; "How does the intensity of sound have an impact on a person's activity levels regarding the number of steps?" To answer this question, an experiment among five participants was conducted in which quantitative data was collected. The number of steps in a day and the sound level throughout the day was collected as indicated in Table 1. The data was transported into a CSV format which was followed by cleaning the data and visualizing it appropriately. This allowed the researchers to investigate the relation between the number of steps and the sound level throughout the day.

Kind of data	Unity	Interval
Sound intensity	1 unit of resistance equals 0.00489 Volt	Per 10 seconds
Total steps	Number of steps	+/- 1-3 minutes
Time	s, seconds	Per seconds

Table 1. The meta data

Participants

In this study, the participants were five Industrial Design students in Eindhoven aged 19 (1 participant) and 20 (4 participants). These students collected data for a period of two weeks. At the start of the study, the procedure of measuring was deeply discussed in order to have a similar way of measuring and minimizing the internal validity. During this study ethics were considered, meaning the participants in this study were all adults. They all gave their explicit consent on a voluntary basis, using an informed consent form [Appendix A]. The participants were allowed to stop participating in the study at any time without the need to give any explanation. If a participant stopped participating this would not have any negative consequences for the individual.

Procedure

After the consent form was signed by the participants, the procedure of the study was explained. The participants were asked to take the measurement station in the suitably designed box (shown in Figures 1 and 2) and the Xiaomi Mi Band (version 4, 5 or 6) with them all day for a total time period of two weeks. The measurement station contained the sound sensor (sound detection module LM393), data logging shield, power bank, and Arduino [Appendix C]. The data of the number of steps was collected by the Mi Band and saved on the participant's personal Mi Fit account. The data of the sound intensity was directly stored on the SD card of a data logging shield through coding [appendix D]. It was important that while measuring, the participants paid attention that no object blocks the sound sensor of the measurements station, since this could cause a reduced sound intensity. On the sound sensor, there is an adjustable potentiometer which was at the start of the study set to an initial position. The participants checked three times a day if the potentiometer was still in the same position looking at the measured data. Measuring started from the moment the participant woke up and ended when the participant went to sleep. The measurement station was always connected to a power source during daytime (e.g., power bank, laptop) which was charged during nighttime. Additionally, the participants brought a spare power source, and additional wires to make sure the measurements were continued even when (technological) problems occurred.

Figure 1. Measuring station setup front view.

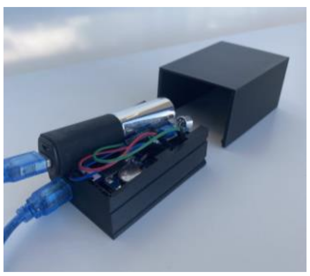

Figure 2. Measuring setup inside the designed box.

Data exportation

After all participants finished measuring, the data from the measuring station was gathered and exported into a CSV file. To export the data containing the number of steps, the data was retrieved from the Mi band using an app called Zepp Life [11] . The Mi band was synchronized with the app, which made the exporting of the data possible. This file was then sent to the users via email in a Zip folder, which they opened with a given password and allowed the researchers to subsequently view the data. This data was delivered in an XML file, however, was converted to a CSV file by using Excel for privacy reasons. Both CSV files needed some change and cleaning up and were then opened in Jupiter Notebook to create clear visualizations.

Data analysis

First, all collected data was cleaned for each user separately. The data was not generalizable for all participants, since they behaved differently depending on the sound intensity, therefore the data was analysed separately as well. The number of steps was measured every 1 to 3 minutes and the sound was measured every 10 seconds. These did not have the same interval which was solved by the function called moving average which is described in the python code [Appendix F]. The moving average sums up an x amount of data points at a specific period of time and divides this total by the number of data points to get an average data point as a result. For steps, the moving average was eight data points and for volume, this was 80 data points. Since there were more data points of volume compared to the number of steps. Different graphs, boxplots and line plots were used to visualize the data. The sound sensor did not measure any values beneath 70 units of resistance even in a silent room, therefore 70 units of resistance was the lowest value possible. From all data points, the value of 70 units of resistance was subtracted to get more valid results.

Risk analysis

Before this study began, several problems, which could occur during the study, were identified. The participants carried the measurement system throughout the day, it was possible that (parts of) the measurement system would break down. As mentioned before, the participants brought an additional power source and wires. However, if the data shield or sound sensor would break there were no measurements, and the participant should order the new element as soon as possible to continue the study. In addition, the participants could forget to wear the Mi band, or it could run out of battery. To prevent this, alarms were set at the beginning of the day to wear the Mi Band and at the end of the day to charge it. The same procedure was applied to carry the measuring system and charge its power bank. If the participant still forgot to measure with one or both needed devices (e.g., Mi band, measuring station), then this data was removed from the data set. The participants would make up for their missed days in the extra week added after the original dates of the study.

Fair principles

In this study, the international FAIR principles and ethics were taken into account. Each specific point of the FAIR principles is applied and discussed in our study [Appendix B]. Our study was based on the guidelines of the FAIR principles and thus provides other researchers to easily find, access our research, to interoperate and reuse the study. During the study ethical problems are considered, such as the privacy of the participants.

Findability

If this study would be published, it would be findable by using a unique identifier (DOI) and the researchers' names. The research will contain keywords, so corresponding search terms will lead to the research. The rich metadata will contain keywords to make it easier to find for researchers.

Accessibility

The study can be easily accessed through Canvas by the researchers, the teacher assistant, and the lecturer of this course. However, an authentication procedure is mandatory before the data can be accessed. Throughout the study participant numbers are used, instead of names, to make sure the data is anonymous. In this way, data cannot be traced back to specific participants. During the study only the necessary data is gathered, so only sound intensity and number of steps are collected.

Interoperability

In the “Methodology” section, the (meta)data is concisely described which allows researchers to reproduce this experiment. A .csv document containing all data will be used, so others are able to work with the document in programs like Python. To reach more people the English language will be used. It is marked when a dataset is derived from another database. These datasets are then clearly linked to the publication using the ACM style reference.

Reusability

The metadata will be clearly described with attributes, interval, and unity, which can be found in table 1. This data will meet the standards of TU/e, which means specifically for this research that the numeric data meets the domain standards. Domain standards such as well-established and sustainable file formats, documentation (metadata) following a common template and using common vocabulary.

DATA CLEANING

After the data was collected [Appendix G] , different visualizations were created to explore if there was a correlation between the number of steps and the sound intensity [Appendix F]. The data of the five participants was analyzed and visualized individually, to look for correlations in the individual datasets. However, for four out of five participants the data had errors. These errors occurred when exporting the data of the Mi Band with the number of steps taken by the participants [Appendix E]. The number of steps taken by the four participants was inaccurate throughout the whole dataset and additionally a lot of data was missing (see Figure 3) Therefore, the data of four participants could not be used for analyzation and visualization. So, the results that will be discussed below will only include the data analyzation and visualization of one participant, participant 4. For participant 4 the six first days were cleaned out, since the sound sensor of the measurement station measured incorrectly these days. Hence, the high value of the sound intensity (see Figure 5). From the 1st of June, the position of resistance on the sound sensor was adjusted to its initial position. Therefore, the results discussed below will only contain the data analyzation and visualization of participant 4 from the 1st of June till the 11th of June. When reading the results below it is good to know that participant 4 was in quarantine from 3 to 6 June because of Covid-19. This explains the lower results on those days.

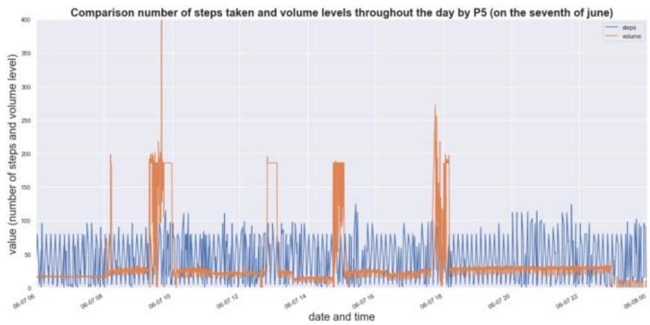

Figure 3. Comparison number of steps taken and volume levels throughout the day by P5

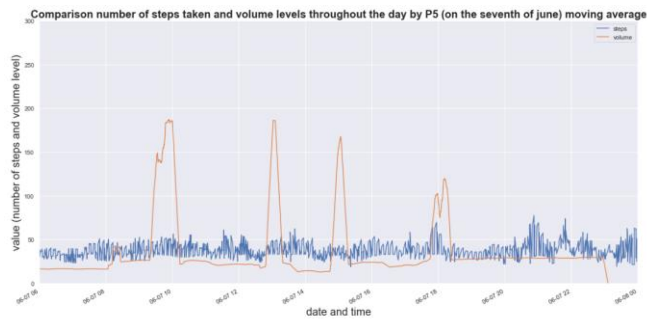

Figure 4. Comparison number of steps taken and volume levels throughout the day by P5

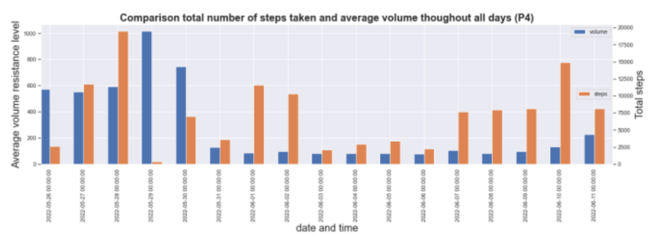

Figure 5. Comparison of total number of steps and average volume throughout all days (P4).

RESULTS

Figure 6 shows a visualization of a line plot of the data from participant 4 on the 8th of June. In this visualization, the number of steps versus the volume level are plotted and the calculation of moving average was utilized to perform this plot. Two peaks are visible for both the steps and volume. The first peak is between 8.30-9.30h and the second peak is from 16-17h. Other days were compared to this specific day and had alike results.

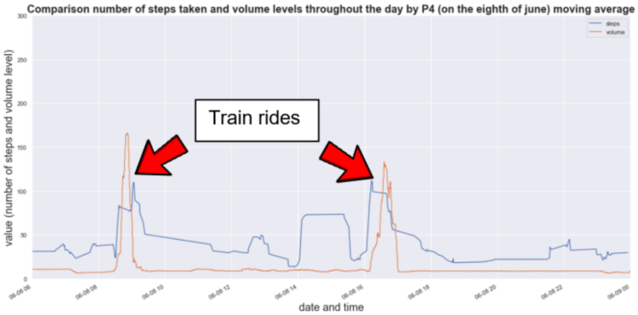

Figure 6. Visualization of the number of steps and the volume levels of one person.

Figure 7 shows the comparison of the total number of steps and the average volume throughout the day. In general, the volume level is between the 70-130 units of resistance. On the last day, the volume is much higher approximately 240 units of resistance, compared to previous days. Looking at the total number of steps taken on each day, the steps vary a lot namely from 2.000 to a maximum of approximately 15.000 steps. On the 2nd of June the volume resistance level is similar to the 9th of June. In contrast, on the 2nd of June the number of steps is around 10.000, whereas on the 9th of June this number is around 8.000. This shows a difference of around 2.000 steps, while the volume resistance level is the same.

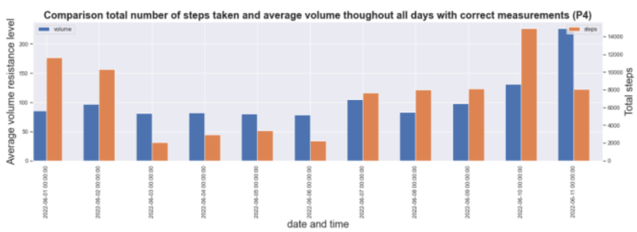

Figure 7. Comparison of total number of steps and average volume throughout all days

Afterwards, the correlation between the volume resistance and the number of steps was calculated using the correlation coefficient. This coefficient is a statistical measure, measuring the strength of a relationship between the relative movements of two variables [6]. The values of this coefficient can range between -1.0 and 1.0, meaning a negative correlation and positive correlation respectively. The correlation coefficient of participant 4 was calculated and resulted in the number of 0.159 (see Figure 8).

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In [30]: corr_coëf_correct_data = np.corrcoef(volume_15m_without_incorrect_measurements, steps_15m_without_incorrect_measurements)
         print("correlation coëfficiënt:", corr_coëf_correct_data[0,1])

         correlation coëfficiënt: 0.15872708186953716
```

Figure 8. Correlation coefficient calculation

DISCUSSION

The data gathered throughout the two weeks has given valuable insights regarding the research. The data helped finding an answer to the research question: "How does the intensity of sound have an impact on a person's activity levels regarding the number of steps?''. From the analysis it was found an increasing sound intensity did not always result in a higher number of steps taken by the participants and did not seem to have a causal relationship. For example, in Figure 6 there seems to be a correlation, however, the participant took the train back and forth which increased the sound intensity level. The participant had to go to the station which increased the number of steps. However, based on the research done by Mendonca [13] and Macone [12], which suggests that the increase in physical activity is highly associated with social interaction, it was assumed that sound intensity would influence the number of steps taken. In this case the sound intensity measured would indicate the social interaction of the participants.

Throughout the study, the SD-card was checked daily to see if all the data was collected by the data logging shield. It was quickly realized that the sound sensor was not able to detect soft sounds, such as conversations. The researchers noticed that the collected data contained the same sound intensity level during a conversation as when working alone in a quiet space. Additionally, the sound sensor measured extremely high values of sound intensity while biking because of the wind, for example, but there was no social interaction. Also, when travelling by train the sound intensity increases a lot, but you are not adding to the number of steps taken. Since this study mainly focused on finding how social interaction, measured by the sound intensity, influences the physical activity, it was sometimes hard to determine whether high sound intensities were related to individualistic or social behavior (e.g., biking, conversations, partying). For similar studies, it is beneficial to have the participants log the activities throughout the day improving the analysis of relations, leading to better conclusions.

When it comes to the validity of our research, some bottlenecks occurred. First of all, the research was done with only five participants. The validity of the results can be disputable, because of the small number of participants incorporated in this study. Besides the fact that all participants followed the same instructions and checked their data throughout the two weeks, correct data was imported for only one participant. Therefore, the results of this study can be arguable on its validity. Increasing the number of participants would directly increase the accuracy of the results of this research. Furthermore, the study took place for only two weeks. This short period of measuring could also be seen as a bottleneck, since it can be questionable if these two weeks accurately resemble a person's activity levels.

As discussed in the methods, the procedure of measuring was extensively explained to the participants. The adjustable potentiometers of the sound sensors were initially set on the same position. However, the participants noticed that due to friction and the movement of carrying the measuring station all day, the potentiometer changed position which influenced the measured sound intensity. The participants were asked to check the position of the potentiometer throughout the day to make sure it was still at the same level. The participants were told to carry the measuring station in the designed case with the specifics of making sure the sound sensor was free of space. This meant that no objects or surface could block the sound sensors, since this could otherwise affect the measurements done. Since the participants were not checked on how they carried their measuring station throughout the study, there is no knowledge whether the participants carried the station with them (in the right way) throughout the two weeks. So, due to the possibility of the changing position of the potentiometer, and the lack of knowledge on how the participants carried the measuring station, the validity of the results can be arguable.

As discussed before, the validity of the results can be questioned. The results of this research can be seen as somewhat reliable, since the research can easily be repeated because of the in-depth explanation of the methodology and study set-up. Therefore, we think repeating the research would result in the same outcomes, meaning the research could be seen as reliable.

During the study, the participants were asked to wear a CE-certified Mi Band to track their data. The data was collected and stored in such a way that personal data could not be traced back to participants. Next to that the participants were not dependent on the researchers and the study did not harm or discomfort the participants. In other words, the participants were not limited in their daily life. The participants did not receive any compensation in exchange for their participation. Throughout the study the TU/e code of conduct rules were followed.

Throughout the study the FAIR principles were consciously considered. It was made sure that the research is easily findable and accessible for other researchers, and they can interoperate and reuse the study. This was done by identifying every participant with a unique number, so all the data is anonymous and cannot be traced back to the participants. The research contains keywords, so that corresponding search terms will lead others to this research. The data will only be accessible to the researchers, the teacher assistant, and the lecturer, via Canvas. In this way an authentication procedure is mandatory before the data can be accessed. Throughout the report an ACM style of reference is used when other sources are consulted. Other than that, the data in the research will only be used for research purposes of the TU/e and is deleted afterwards.

CONCLUSION

In this study, the research question "how does the intensity of sound have an impact on a person's activity levels regarding the number of steps?" has been investigated. After analyzing the data gathered, it was found that there is most likely no relationship between the intensity of sound and the number of steps.

The findings of this research can suggest actions for future research. For instance, redoing the research but having participants log their (social) activities. This could give better insights into when participants were having social interactions, which would make it easier to find relations between the changes in sound intensity and social interactions of the participants. Furthermore, it would also make it easier to clean data. Having participants log their activities, both social interactions and other activities, would make it easier for future research to draw valid conclusions.

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APPENDIX

Appendix A. Consent form

The goal of this research is to gain insights on how sound intensity has an impact on a person's activity levels regarding number of steps. This research is done by Milou van Gompel, Eva Veldhorst, Anne van de Ven, Puck Verbeek and Niels Witlox, all five of us are Industrial Design students of Eindhoven University of Technology.

Your participation in this study is completely voluntary. If you decide to participate in this study, you can withdraw at any time without having to give a reason. If you decide not to participate or if you withdraw from the study at any time, there will be no adverse effect.

The study involves collecting data, sound intensity and amount of steps, for two weeks. Your data will be processed anonymously and cannot be traced back to you. No personal data will be asked, such as name, email, address, etc. During the study you will be asked to wear a Mi-Band for two weeks, to count the number of steps. Next to that you will be asked to bring a YODL-kit with you throughout the day, to measure the sound intensity.

All data from the research is securely stored in a place that others outside our research team cannot access. To protect your privacy, no information is requested that can be traced back to you as a person.

Signing below indicates that:

• You have read and understood the above information.

• You know that participation is completely voluntary and you can stop or withdraw at any time from the interview without adverse effects. You don't have to give a reason for that.

• You are at least 18 years old and agree to participate.

• You agree to the collection, storage and processing of the data as above has been described.

If you decide that you do not want to participate in the study, you can decline participation by not signing and informing the researcher.

Signature: ____________________ Date: ______/ ______/ ______

Appendix B. FAIR principles

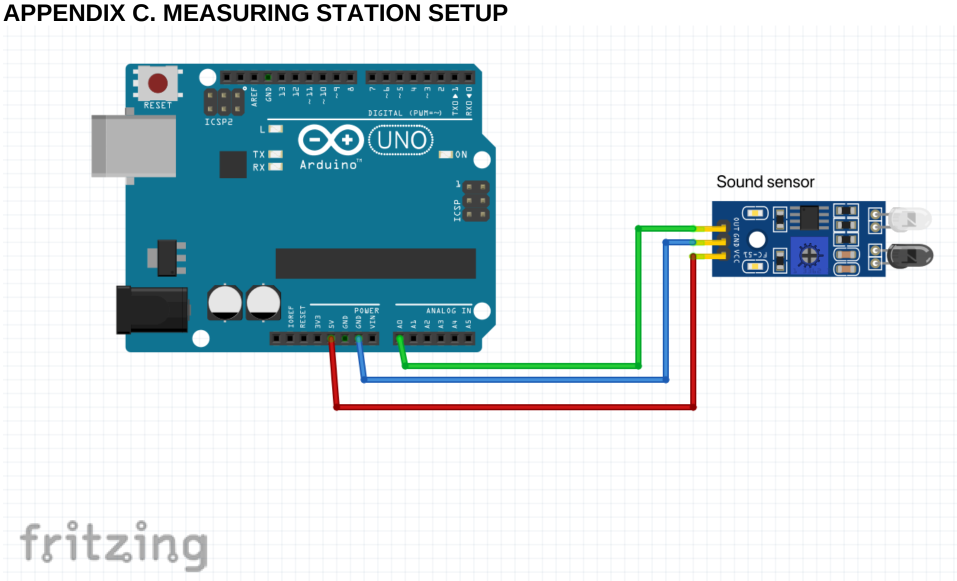
The international FAIR principles are guidelines for the description, storage, and publication of scientific data.

FAIR stands for: Findable, Accessible, Interoperable and Reusable.

Below is a list of the measures taken to comply with the FAIR principles. After each measure, the abbreviation that refers to each principle of the FAIR principles is given.

1. Every participant has a unique identifying number, which is linked to the collected data. This is done by adding the dataset to the appendix of the final report. (F1)
2. There are rich metadata, describing our data. This will be done by using keywords to optimize possibilities for re-use. (F2)
3. The DOI and bibliographic references of the dataset can be found together. (F3)
4. The metadata is recorded in the generalist public repository. (F4)
5. The data will be accessible as it will be linked to an HTTP address. (A1.1)
6. The data will only be accessible to the researchers, the TA, and the lecturer responsible. This data is accessible via an HTTP-link, which needs authentication before the data becomes accessible. (A1.2)
7. The metadata is added in the appendix of the final report, in order to be accessible. This also applies to the consent form. (A.2)
8. The data and metadata are both saved as a .csv file, in this way the data is easily accessible and presentable. (I1)
9. The researchers will use standardized vocabulary that is open and universal, using resolvable global identifiers linking to explanations.
10. It is marked when a dataset is derived from another database. These datasets are then clearly linked to the publication using the ACM style reference. (I3)
11. The metadata will be clearly described with the attributes, interval, and unity, which can be found in table 1. (R1)
12. The data in this research will only be used for research purposes of the TU/e and after this, it will be deleted. (R1.1)
13. The procedure for collecting data, the time of the research, the circumstances of the research, and the goal of the research are described in the methodology of this report. We will appoint the people that collected data the same as for the research unit. (R1.2)
14. The metadata will meet the basic standards of the TU/e including ethics. In this research that means the numeric data is meeting the domain standards. (R1.3)

APPENDIX C. MEASURING STATION SETUP



APPENDIX D. ARDUINO CODE FOR SOUND SENSOR

```
//sources: https://how2electronics.com/decibel-meter-using-sound-module-arduino/#Source_CodeProgram
//declaring values
const int chipSelect = 10; // Important to check; this is Arduino dependent
int num_Measure = 5000000 ; // Set the number of measurements
int pinSignal = A0; // pin connected to pin O module sound sensor
long Sound_signal;    // Store the value read Sound Sensor
long sum = 0 ; // Store the total value of n measurements
long level = 0 ; // Store the average value

//include library's for datashield data saving and real time clock
#include <SPI.h>
#include <SD.h>

#include <Wire.h>
#include <TimeLib.h>
#include <DS1307RTC.h>

File myFile;
//turn on Debug_mode
#define Debug_mode true
// Define pin for signaling activity
#define debugled 8

void setup() {
  pinMode (pinSignal, INPUT); // Set the signal pin as input
  // Open serial communications and wait for port to open:
  blink1();
  if (Debug_mode) {
    Serial.begin(9600);

    while (!Serial) {}
    Serial.println("DS1307RTC Read Test");
    Serial.println("-------------------");
    Serial.print("Initializing SD card...");
  }
```

```
  delay(1000);
  pinMode(chipSelect, OUTPUT); // Set Chip Select pin to "output" otherwise the routine will not work
  delay(1000);

  if (!SD.begin(chipSelect)) {
    if (Debug_mode) {Serial.println("initialization failed!");}
    while (1);
  }
  if (Debug_mode) {Serial.println("initialization done.");}

  // open the file. note that only one file can be open at a time,
  // so you have to close this one before opening another.
  myFile = SD.open("data.csv", FILE_WRITE);

  // if the file opened okay, write to it:
  if (myFile) {
    if (Debug_mode) {Serial.print("Writing to data.csv...");}
    myFile.println("Date/Time, volume resistance level");
    // close the file:
    myFile.close();
    if (Debug_mode) {Serial.println("done.");}
  } else {
    // if the file didn't open, print an error:
    if (Debug_mode) {Serial.println("error opening data.csv");}
  }

  pinMode(LED_BUILTIN, OUTPUT);
  blink1();
}

void blink1() {
  digitalWrite(debugled, HIGH);   // turn the LED on (HIGH is the voltage level)
  delay(500);                       // wait for a second
  digitalWrite(debugled, LOW);    // turn the LED off by making the voltage LOW
  delay(500);                       // wait for a second

}
```

```
void timestamp()
{
 tmElements_t tm;

 if (RTC.read(tm)) {
  // Block 1: write to serial
  if (Debug_mode) {
   Serial.println();
   Serial.print("Date (D-M-Y) = ");
   Serial.print(tm.Day);
   Serial.write('-');
   Serial.print(tm.Month);
   Serial.write('-');
   Serial.print(tmYearToCalendar(tm.Year));
   Serial.print(" , ");
   print2digits(tm.Hour);
   Serial.write(':');
   print2digits(tm.Minute);
   Serial.write(':');
   print2digits(tm.Second);
   Serial.print(" , ");
  }

  //Block 2: write to file
  myFile.println();
  myFile.print(tm.Day);
  myFile.write('-');
  myFile.print(tm.Month);
  myFile.write('-');
  myFile.print(tmYearToCalendar(tm.Year));
  myFile.print(" T "); // special separator required for coupling with data foundry
  print2digitssd(tm.Hour);
  myFile.write(':');
  print2digitssd(tm.Minute);
  myFile.write(':');
  print2digitssd(tm.Second);
```

```
    myFile.print(" , ");

  } else { if (Debug_mode) {
    if (RTC.chipPresent()) {
      Serial.println("The DS1307 is stopped.  Please run the SetTime");
      Serial.println("example to initialize the time and begin running.");
      Serial.println();
    } else {
      Serial.println("DS1307 read error!  Please check the circuitry.");
      Serial.println();
    }}
  }
}

void print2digits(int number) {
  if (number >= 0 && number < 10) {
    Serial.write('0');
  }
  Serial.print(number);
}

void print2digitssd(int number) {
  if (number >= 0 && number < 10) {
    myFile.write('0');
  }
  myFile.print(number);
}
//reading vollume level

void print_volume_level()
{

// Performs 5000000 signal readings (max readings)
  for ( int i = 0 ; i <num_Measure; i ++)
  {
   Sound_signal = analogRead (pinSignal);
    sum =sum + Sound_signal;
```

```
  }

  level = sum / num_Measure; // Calculate the average value
  // Check if any reads failed and exit early (to try again).
  if (Debug_mode) {
    if (isnan(level)) {
    Serial.println(F("Failed to read from volume sensor!"));
    return;
    }
    Serial.print(F("  volume resistance level: "));
    Serial.print(level);
  }
  myFile.print(level);
  myFile.print(F(" , "));
  sum = 0 ; // Reset the sum of the measurement values
}

void loop() {
  // re-open the file for reading:
  myFile = SD.open("data.csv", FILE_WRITE);
  blink1();
  if (myFile) {
    timestamp();
    print_volume_level();
    myFile.close();
    // close the file:
    delay(1000);

  } else {
    // if the file didn't open, print an error:
   if (Debug_mode) { Serial.println("error opening data,csv");}
  }
  blink1();
 delay(5000); // one measurement cycle every 10 seconds (5000 + 500 + 500 + the time it takes the circuit to do 5000000 measurements)
}
```

APPENDIX E

This is a screenshot of one of the CSV files which included the weird data from one Mi Band. As can be seen, a repeating sequence of numbers is in the whole data set.

A4 fx 30/05/2022

	A	B	C	D	E
1	date	time	steps		
2	########	00:01	62		
3	########	00:06	5		
4	########	00:09	62		
5	########	00:14	5		
6	########	00:17	62		
7	########	00:22	5		
8	########	00:25	62		
9	########	00:30	5		
10	########	00:33	62		
11	########	00:38	5		
12	########	00:41	62		
13	########	00:46	5		
14	########	00:49	62		
15	########	00:54	5		
16	########	00:57	62		
17	########	01:02	5		
18	########	01:05	62		

APPENDIX F

Jupyter Notebook with Python code can be found in Zip file in document 'Appendix F'

APPENDIX G

Raw data from participants excel can be found in Zip file in document 'Appendix G'